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Advanced Methodologies and Technologies in Medicine and Healthcare



Mehdi Khosrow-Pour, D.B.A.



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Advanced Methodologies and Technologies in Medicine and Healthcare

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Information Resources Management Association, USA

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Preface

Advanced Methodologies and Technologies in Medicine and Healthcare is a single-volume major reference work comprised of 38 unique chapters focusing on some of the most advanced and innovative technologies and methodologies available to scientists, instructors, researchers, and medical professionals worldwide. The concepts presented within these chapters are sure to support operational, clinical, and research initiatives in various branches of medicine and healthcare.

This publication is aimed to serve the needs of libraries, corporations, hospitals, healthcare organizations, and individuals seeking advanced cross-disciplinary knowledge on the conceptual, methodological, and technical aspects of a wide range of subject matter – from gene expression to mobile health.

Attention is also given to emerging topics including but not limited to mental health, electronic health records, medical diagnosis, health literacy, and health information technology. The chapters within this publication are sure to provide readers the tools necessary for further research and discovery in their respective industries and/or fields. Additionally, this publication could be extremely beneficial for use in coursework by instructors of various medical and healthcare programs.

Advanced Methodologies and Technologies in Medicine and Healthcare is organized into seven sections that provide comprehensive coverage of important topics. These sections are 1) Bioinformatics, 2) Biology, 3) Clinical Science and Technologies, 4) Healthcare Administration, 5) Health Information Systems, 6) Medical Education, Ethics, and Law, and 7) Medical Technologies.

The following paragraphs provide a summary of what to expect from this invaluable reference source:

Section 1, “Bioinformatics,” is comprised of four chapters and opens this extensive reference source by highlighting bioinformatics and its innovations that change how we recognize and care for illnesses. The first chapter in this section, “Bioinformatics,” authored by Prof. Mark A. Ragan from The University of Queensland, Australia, presents bioinformatics first from the perspective of computer science and information technology, then from the perspective of bioscience. In practice these perspectives often merge, making bioinformatics a rich, vibrant area of multidisciplinary research and application.

The next chapter in this section, “Bioinspired Solutions for MEMS Tribology,” authored by Profs. R. Arvind Singh and S. Jayalakshmi from Kumaraguru College of Technology (KCT), India, presents the tribological issues in MEMS devices, examples of conventional solutions for the tribological issues, and unique bioinspired solutions that have great capability to mitigate surface forces at micro/nano-scales.

The third chapter in this section, “Building Gene Networks by Analyzing Gene Expression Profiles,” authored by Prof. Crescenzo Gallo from the University of Foggia, Italy, examines various methods for analyzing gene expression data and addresses the important topics of (1) selecting the most differentially expressed genes, (2) grouping them by means of their relationships, and (3) classifying samples based on gene expressions.

The fourth and final chapter in this section, “Concerns and Challenges of Cloud Platforms for Bioinformatics,” authored by Profs. Nicoletta Dessì and Barbara Pes from the Università degli Studi di Cagliari, Italy, investigates the extent to which cloud technology offers a viable platform for developing and deploying applications that support users in searching and integrating information offered by bioinformatics resources. It outlines the basic features that such computing applications should exhibit and the challenging issues they deal with.

Section 2, “Biology,” is comprised of two chapters and explores emerging innovations on the use of genetic advancements in disease treatment. The first chapter in this section, “GWAS as the Detective to Find Genetic Contribution in Diseases,” authored by Profs. Simanti Bhattacharya and Amit Das from the University of Kalyani, India, examines the use of the genome wide association study (GWAS) as a powerful method to understand the complex association of variant in gene and disease phenotype.

The second and final chapter in this section, “RNA Interference Therapeutics and Human Diseases,” authored by Profs. Dolly Sharma, Shailendra Singh, and Trilok Chand from the PEC University of Technology, India, explores various techniques used by RNAi Therapeutics to fight diseases and discusses the future prospects of it.

Section 3, “Clinical Science and Technologies,” is comprised of three chapters on the latest techniques and methods of clinical science. The first chapter in this section, “A Gamification Update to the Taxonomy of Technology and Mental Health,” authored by Profs. Madeline R. Marks, Amanda C. Tan, and Clint Bowers the University of Central Florida, USA, explores the need for mental health providers and software developers to work in concert with each other when developing technology for mental health. It also articulates the importance of the patient and the patient’s role in connecting technology into the equation.

The second chapter in this section, “Heart Sound Analysis for Blood Pressure Estimation,” authored by Prof. Rui Guedes from the Faculdade de Medicina da Universidade do Porto, Portugal, Prof. Henrique Cyrne Carvalho from the Serviço de Cardiologia, Hospital de Santo António, Centro Hospitalar do Porto, Portugal, and Prof. Ana Castro, Universidade do Porto, Portugal, examines how heart sound analysis may be used to estimate blood pressure and which methods are employed to detect pulmonary hypertension.

The third and final chapter in this section, “Sociological Perspectives on Improving Medical Diagnosis Emphasizing CAD,” authored by Dr. Joel Fisher from the Department of State, United States Government, USA, emphasizes diagnosis and the need to collect key patient information (pivotal information) at the earliest possible point in the patient’s disease process and put such pivotal information in physicians’ hands.

Section 4, “Healthcare Administration,” is comprised of five chapters and explores emerging innovations on topics such as hospital management, delivery of patient care, and telemedicine, among others. The first chapter in this section, “Electronic Health Record (EHR) Diffusion and an Examination of Physician Resistance,” authored by Profs. Kristen MacIver and Madison N. Ngafeeson from Northern Michigan University, USA, details several of the benefits of electronic health record systems and uses a systematic review of literature to critically analyze and detail the most common perceived physician barriers to the adoption of electronic health records.

The second chapter in this section, “Internet of Things Applications for Healthcare,” authored by Prof. Ljubica Diković from the Business Technical College, Serbia, provides a comprehensive review of recent solutions as well as possible future implementations from the m-health perspective. It also explores how further developments in wireless communications and configurations will have a huge impact on future healthcare delivery systems.

Preface

The third chapter in this section, “Maintenance Policies Optimization of Medical Equipment in a Health Care Organization,” authored by Profs. Juan Ignacio Roig, Andrés Gómez, and Isabel Romero from the University of Castilla-La Mancha, Spain and Prof. María Carmen Carnero from the University of Castilla-La Mancha, Spain & University of Lisbon, Portugal, examines how to minimize the corrective breakdowns produced in the electromedical equipment of a healthcare organization through the creation of preventive maintenance datasheets in which the activities undertaken, the periodicity, the estimated time to do the activity, etc. are identified.

The fourth chapter in this section, “The Optimal Workforce Staffing Solutions With Random Patient Demand in Healthcare Settings,” authored by Dr. Alexander Kolker from GE Healthcare, USA, provides an overview and examples of application of the data analytics methodology called the “newsvendor” framework. This methodology helps to determine the optimal staffing solutions for the specified time periods for hospital units with randomly fluctuating daily patient census.

The fifth and final chapter in this section, “Using Technology to Reduce a Healthcare Disparity,” authored by Prof. Nilmini Wickramasinghe from Epworth HealthCare, Australia & Deakin University, Australia, examines a technology-mediated solution to address communication barriers that result when delivering healthcare to non-English speakers or limited proficient English-speaking patients.

Section 5, “Health Information Systems,” is comprised of eight chapters on emerging innovations in the development of applications and concepts in clinical, patient, and hospital information systems. The first chapter in this section, “Challenges and Implications of Health Literacy in Global Health Care,” authored by Prof. Kijpokin Kasemsap from the Suan Sunandha Rajabhat University, Thailand, explains perspectives on health literacy, trends and issues with health literacy, and the challenges and implications of health literacy in global healthcare.

The chapter “Information Systems and Technology Projects in Healthcare Organizations,” authored by Profs. Jorge Gomes and Mário José Batista Romão from ISEG, Universidade de Lisboa, Portugal, is also housed within this section. It studies how organizational maturity, enhanced by IS/IT investments and project management best practices, leads to successful projects in healthcare organizations.

Another noteworthy chapter in this section, “Peer-to-Peer Health-Related Online Support Groups,” authored by Prof. Neil S. Coulson from the University of Nottingham, UK, examines the need for randomized controlled trials of pure peer-to-peer online support interventions across both physical and mental health conditions.

One of the closing chapters, “Software Evaluation From the Perspective of Patients and Healthcare Professionals,” authored by Prof. Rui Pedro Charters Lopes Rijo from the Polytechnic Institute of Leiria, Portugal and Prof. Domingos Alves from the University of São Paulo, Brazil, examines the evaluation of the healthcare software from the perspective of the patients, the doctors, the nurses, and/or the supporting staff.

The final chapter in this section, “User Resistance to Health Information Technology,” authored by Prof. Madison N. Ngafeeson from Northern Michigan University, USA, surveys extant theories of the resistance to health information technology and provides a paradigmatic lens for leveraging this knowledge to practical solutions in health IT adoption.

Section 6, “Medical Education, Ethics, and Law,” is comprised of seven chapters on the changes in technological innovations implemented in modern medical education and the ethics and law surrounding it. The first chapter in this section, “Comprehensive E-Learning Appraisal System,” authored by Drs. Jose Luis Monroy Anton, Juan Vicente Izquierdo Soriano, and Maria Isabel Asensio Martinez from the La Ribera University Hospital, Spain and Prof. Felix Buendia Garcia from the Polytechnic University

of Valencia, Spain, provides a small analysis of online training courses for health professionals, and deepens into an appraisal system developed to integrate different complementary variables and how they can be implemented as a method addressed to assess online courses in a more comprehensive way.

This chapter is followed by “Flipping the Medical School Classroom,” authored by Drs. Kristina Kaljo and Laura Jacques from the Medical College of Wisconsin, USA. It identifies tools and strategies on how to incorporate flipped lectures into medical education and addresses the increasingly diverse needs of today’s matriculating medical student.

Another chapter presented early within this section, “Integrating Evidence-Based Practice in Athletic Training Through Online Learning,” authored by Profs. Brittany A. Vorndran and Michelle Lee D’Abundo from Seton Hall University, USA, includes information about how evidence-based practice is currently being used by athletic training clinicians and educators, the perceived barriers of athletic training using evidence-based practice, the importance of using evidence-based practice, and managing the transition needed to successfully adopt the use of evidence-based practice.

One of the closing chapters, “Medical Equipment and Economic Determinants of Its Structure and Regulation in the Slovak Republic,” authored by Profs. Beáta Gavurová, Viliam Kováč, and Michal Šoltés from the Technical University of Košice, Slovakia, analyzes the unsuitable distribution of the medical equipment among the healthcare facilities in the Slovak Republic and explores solutions to this issue.

The final chapter in this section, “Use of Technology in Problem-Based Learning in Health Science,” authored by Profs. Indu Singh, Avinash Reddy Kundur, and Yun-Mi Nguy from Griffith University, Australia, highlights the impact and advantages of moving from a traditional classroom-based teaching model to a more enhanced blended/e-learning approach from the student and teacher-based perspective. It also discusses some of the challenges of implementing this mode of teaching.

Section 7, “Medical Technologies,” is comprised of nine chapters on emerging technologies and applications for the improvement of patient health from the perspectives of doctors, nurses, and patients. The first chapter in this section, “Defining and Characterizing the Landscape of E-Health,” authored by Profs. Yvonne O’Connor and Ciara Heavin from the University College Cork, Ireland, characterizes the landscape of e-health technologies from an information systems (IS) perspective. It also reveals that there is a need to integrate the various features and functions of e-health technologies to ensure the growth of e-health.

This chapter is followed by “Kinect Applications in Healthcare,” authored by Profs. Roanna Lun and Wenbing Zhao from Cleveland State University, USA, which surveys the current applications of using the Kinect technology in healthcare. It also outlines a number of open research issues that could overcome the limitations of the current Kinect technology.

Another noteworthy chapter in this section, “Neuroscience Technology and Interfaces for Speech, Language, and Musical Communication,” authored by Profs. Dionysios Politis and Miltiadis Tsalighopoulos from the Aristotle University of Thessaloniki, Greece and Dr. Georgios Kyriafinis from AHEPA University Hospital, Greece, examines the medical practices and the learning potential for the new world of augmented human computer interaction platforms.

One of the closing chapters in this section, “A Validation Study of Rehabilitation Exercise Monitoring Using Kinect,” authored by Profs. Wenbing Zhao, Deborah D. Espy, and Ann Reinthal from Cleveland State University, USA, presents a validation study using Microsoft Kinect to monitor rehabilitation exercises. It also assesses the feasibility of using Kinect by examining the enforceability of a set of correctness rules defined for each exercise.

Preface

The final chapter in this section, “Virtual Reality as Distraction Technique for Pain Management in Children and Adolescents,” authored by Prof. Barbara Atzori from the University of Florence, Italy, Prof. Hunter G. Hoffman from the University of Washington, USA, Drs. Laura Vagnoli and Andrea Messeri from Meyer Children’s Hospital of Florence, Italy, and Prof. Rosapia Lauro Grotto, University of Florence, Italy, evaluates the effectiveness of virtual reality during several painful procedures in pediatric and adolescent patients, its applicability, and the potential for wider dissemination of virtual reality analgesia in clinical settings.

The comprehensive coverage this publication offers is sure to contribute to an enhanced understanding of all topics, research, and discoveries pertaining to medicine and healthcare. Furthermore, the contributions included in this publication will be instrumental to the expansion of knowledge offerings in this area. This publication will inspire its readers to further contribute to recent discoveries, progressing future innovations.

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Section 1

Bioinformatics

Chapter 1

Bioinformatics

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ABSTRACT

Bioinformatics has emerged as new discipline at the interface of molecular bioscience with mathematics, computer science, and information technology. Bioinformatics is driven by data arising from high-throughput technologies in molecular bioscience. To enable biological discovery, bioinformatics draws on and extends technologies for data capture, management, integration and mining, computing, and communication technology. The rise of genomics has been a key driver for bioinformatics. Genomics, however, was never an end unto itself, but rather was intended to enable the understanding of complex biological systems. Bioinformatics continues to evolve in support of its constituent domains and, increasingly, their integration into genome-scale molecular systems biology. This chapter presents bioinformatics first from the perspective of computer science and information technology, then from the perspective of bioscience. In practice these perspectives often merge, making bioinformatics a rich, vibrant area of multidisciplinary research and application.

INTRODUCTION

Over the past 30 years, bioinformatics has emerged as new discipline at the interface of molecular bioscience with mathematics, computer science and information technology. Bioinformatics is driven by data arising from high-throughput technologies in molecular bioscience including DNA and genome sequencing, gene expression analysis, protein and RNA structure characterisation, and bio-imaging. To enable biological discovery, bioinformatics draws on and extends technologies for data capture, management, integration and mining, computing, and communication technology including the Internet. The rise of genomics, from the first bacterial and model-organism projects to the Human Genome Projects and the thousands of genome projects that have followed, has been a key driver for bioinformatics, and in turn has enabled these projects to be completed and their results applied. Genomics, however, was never an end unto itself, but rather was intended to enable the understanding of complex biological systems. Bioinformatics continues to evolve in support of its constituent domains and, increasingly, their integration into genome-scale molecular systems biology.

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This article presents bioinformatics first from the perspective of computer science and IT, then from the perspective of bioscience. In practice these perspectives often merge, making bioinformatics a rich, vibrant area of multidisciplinary research and application.

BACKGROUND

The term *bioinformatics* was introduced in 1970 in reference to the study of informatic processes in biological systems (Hogeweg, 2011). In this original usage, *bioinformatics* encompassed “how living systems gather, process, store and use information” (Nurse, 2008). Never widely adopted, this usage was superseded in the late 1980s when bioinformatics, as presently understood, emerged as a new field at the interface of molecular bioscience with computer science and information technology (Dickson, 1987). Today bioinformatics builds on mathematics, statistics and algorithmics, and finds applications across the biosciences particularly in genomics, proteomics, structural biology and molecular systems biology. Biology is increasingly an information science, with bioinformatics a key enabling technology.

Other disciplines have developed at the bioscience - computer science - IT interface, and there is little consensus on where boundaries should be drawn among them. Bioinformatics is sometimes said to focus on the development and application of methods and software tools to acquire, manage, analyse and/or visualise biological data, whereas *computational biology* refers more to the application of these methods and tools to theoretical or applied biological questions (Huerta *et al.*, 2000). *Biomathematics* or *mathematical biology* involves the development or use of mathematical modeling or simulation, while *biostatistics* emphasises experimental design and statistical analysis. *Molecular systems biology* focuses on the inference or analysis of networks of genes, proteins and/or other cellular molecules, while *synthetic biology* applies these technologies to design and engineer new biological functions or organisms.

BIOINFORMATICS FROM THE PERSPECTIVE OF COMPUTER SCIENCE AND INFORMATION TECHNOLOGY

One way of exploring the interface between molecular bioscience and IT is to track experimental data from their generation, capture and retrieval, through their aggregation and dissemination *via* international data services, to their subsequent analysis. Here I deconstruct data analysis into data models, algorithms, analytical methods and software, workflows and visualisation. This trajectory is common to scientific data, although bioinformatics is notable for its culture of open data, well-established data formats and standards, and data reuse facilitated by large international repositories with associated data services.

Data Generation, Storage and Retrieval

Instruments and experiments generate diverse data types in molecular bioscience. Capturing these primary data and the associated metadata, and managing their storage and retrieval, are primary activities in bioinformatics. The quantities of data generated by DNA-sequencing platforms, in particular, are such that raw data are no longer archived; rather, bioinformatic methods are used to assess quality and extract summaries. Data formats are specific to experimental technologies and, to some extent, instrument manufacturers. In some areas of molecular bioscience, standards have been developed to ensure

that data can be interpreted unambiguously and, in principle, the experiment can be reproduced. For example, the MIAME (Minimum Information About a Microarray Experiment) standard (Brazma *et al.*, 2001) specifies how experimental design, laboratory protocols, biological samples, microarray platforms, and raw and processed data must be described, and recommends the use of certain data formats and ontologies. The MIBBI project promotes the coherence of minimum-standards checklists across nearly 40 areas of bioscience and biomedicine (Taylor *et al.*, 2008).

Public Data Resources

Newly generated biomolecular data (*e.g.* DNA and protein sequences, protein structures, gene-expression data) are submitted to public data repositories, where they are assigned unique persistent identifiers; all major bioscience journals require new data to be so identified. The main international collection centres are the US National Centre for Biotechnology Information (NCBI), the EMBL European Bioinformatics Institute (EBI), and the DNA Data Bank of Japan (DDBJ). Individually and in collaboration with each other, these centres carry out further quality control on incoming data, conduct research in bioinformatics, promote best practice in bioscience data management and analysis, and provide comprehensive online data services (*e.g.* search, retrieval, integrative analyses over multiple data sources, and links to journal articles and patents) which are cost-free at the “point of use” for the international research community. Other public data resources serve specific areas of molecular bioscience, *e.g.* protein structure. Increasingly, the largest projects in molecular bioscience maintain their own public data resources, *e.g.* The Cancer Genome Atlas and the International Cancer Genome Consortium. Both large and small data sources are reviewed in the annual Database issue of the journal *Nucleic Acids Research*.

Data Formats and Models

The need for data integration and re-use has driven the development of standard data presentation formats, notably the FASTA format (Lipman & Pearson, 1985). However, no single data model has been universally adopted across all bioinformatics applications. Many public data services provide flat (ascii) files, but relational (MySQL), semantic (RDF), Web Services and hybrid approaches are also in use. Third-party tools such as SRS or BioMart are often used to integrate and index multiple related collections for combined use. With public data now in the tens of petabytes and growing rapidly, bioinformatics has entered the era of Big Data.

Algorithms and Computation

The molecular biosciences offer diverse and difficult analytical challenges, against which a wide range of algorithmic approaches are deployed. Gene and protein sequences map naturally to strings, regulatory signals to motifs, phylogenies to trees, lateral genetic transfer to edits on trees, genetic regulatory networks and protein interactions to networks, and so on. Thus operations in bioinformatics can often be recast as known or new problems in *e.g.* string matching, motif discovery, classification or graph theory. Many problems mapped in this way are NP-hard, *e.g.* maximum clique, vertex cover and Steiner tree (Karp, 1972), or are suspected of being so. Increasingly, however, many are fixed-parameter tractable, allowing high-quality solutions even on very large bioscience data. Heuristics are important in bioinformatics as well: the sequence alignment problem drove the early development of dynamic programming,

phylogenetics is an important application domain for Markov chain Monte Carlo in conjunction with Bayesian approaches, and problems in gene regulation, protein localisation and biomolecular networks continue to provide challenges for machine learning. Even so, key problems in bioinformatics continue to pose algorithmic and computational challenges for large data, requiring computational infrastructure with large shared memory and/or high-capacity input/output.

Methods and Software

Innumerable bioinformatic methods and software exist. Many are developed for highly specific applications, and quickly fall out of use or are superseded. Stand-alone tools, available by download from websites, remain popular; other tools are available *via* public servers or webtools, or integrated into online data services. Coordinated sets of tools that share input/output formats and a common user interface are popular in some application areas, *e.g.* DNA sequence analysis (DNASTAR, Sequencher), motif discovery (MEME Suite) and phylogenetics (PAUP*, PHYLIP). The great majority of bioinformatic tools arise from academic research, with the attendant issues of stability, support and sustainability. Although bioinformatics is characterised by a robust open-source ethic and active developer/user communities exist around many toolsets, commercial software is important in some areas, notably structural biology, proteomics and bio-image informatics. Notices of new methods and software may appear in academic journals (*e.g.* the Application Notes section of *Bioinformatics*; the annual Web Server issue of *Nucleic Acids Research*).

Bioinformatic Workflows

An important class of tools supports the composition and execution of bioinformatic *workflows* or “pipelines”, *i.e.* linked series of data-manipulation and analytical steps. For example, software modules that retrieve and reformat sequences, align multiple sequences, and infer trees can be linked to form a phylogenetic workflow. Popular workflow-management frameworks in bioinformatics include BioConductor/R, Galaxy, GenePattern, GMOD, SRS and Taverna. E-research middleware that links data sources, analytical and visualisation tools, computational resources and storage are gaining popularity particularly for large-scale projects.

Data Visualisation

Visualisation of large bioscience data is likewise an important theme in bioinformatics. Challenges include the visual representation of very large, complex, multi-scale data; integration of visualisation with data mining and analysis; integrated display of different data types (*e.g.* pathways and gene-expression levels); standards; and augmented computer interaction (O’Donoghue *et al.*, 2010). Genome browsers (*e.g.* the ENSEMBL, IGV and UCSC Genome browsers) allow simultaneous display of one or more genome sequences together with additional experimental data (*e.g.* expression levels) and computationally based annotation. Stand-alone visualisation tools remain popular for defined tasks, *e.g.* visualisation of molecular structures (PyMol) and display of phylogenetic trees (TreeView).

BIOINFORMATICS FROM THE PERSPECTIVE OF BIOSCIENCE

Comprising the other side of the bio – IT interface are the multiple fields of modern molecular bioscience, arranged here in reference to the primary direction of information flow in biological systems, from DNA (genomics) to RNA (transcriptomics) to protein (proteomics). To a first approximation, DNA/genome bioinformatics focuses on the primary (linear) sequence, whereas protein informatics is equally or more concerned with three-dimensional folded structure. There is increasing appreciation that biological information flow is not unidirectional; the analysis of biomolecular networks and systems is one of the fastest-growing areas of today's bioinformatics.

Individual Molecular Sequences

DNA, RNA and protein sequences represent the largest application area of bioinformatics. Important problems in *sequence bioinformatics* include quality control and management of sequence data; assembly of full-length sequences; discovery and annotation of features (*e.g.* genes, regulatory signals); sequence comparison in functional and evolutionary contexts; and retrieval of similar sequences from databases. Some of the earliest bioinformatic algorithms and software were designed to manage and analyse individual sequences.

Genome Informatics

With progress in automated technologies, it is becoming commonplace to sequence the genetic material of an individual – the coding regions only (*exome sequencing*), or *whole-genome sequencing*. Many earlier methods have been repurposed, and new approaches developed, to assemble, annotate and analyse plant and animal genomes, which are typically 10^8 - 10^{11} basepairs in size and replete with low-complexity regions and repetitive elements. In *metagenomics*, these methods are applied to study DNA extracted directly from environmental samples, without prior isolation of individual species. Continuing innovation in sequencing technologies, including non-hierarchical (“shotgun”) strategies, short-read and single-molecule sequencing, and new types of data encoding, has been made possible by innovative bioinformatics.

Feature Discovery and Annotation

For a sequence to be useful in biological investigation, features represented therein must be discovered and annotated. Early discovery of features involved painstaking laboratory work; today, bioinformatic methods that draw on the body of experimental knowledge are the mainstay of feature annotation. Some features (*e.g.* transcriptional start and stop signals for bacterial genes) are conservative and can be found efficiently by similarity matching and/or rule-based inference, whereas others (*e.g.* transcription factor binding sites) are based on motifs of variable position and low information content, and can be discovered (if at all) only by statistically based approaches including neural networks, hidden Markov models, support vector machines or other machine-learning approaches (Libbrecht & Noble, 2015). The MEME Suite (Bailey *et al.*, 2015) provides important programs for motif discovery and analysis. The annotation process is well-suited to a workflow-based approach.

Sequence Comparison

Many operations in bioinformatics involve the statistical comparison of two or more sequences. Historically, these problems introduced into bioinformatics important concepts from computer science including dynamic programming, hashing, and suffix trees. Comparison problems can be classified as pairwise, one-*versus*-many (*e.g.* finding best matches in a database), and many-*versus*-many (*e.g.* multiple sequence alignment). The heuristic Basic Local Alignment Search Tool (BLAST) is by far the most widely used bioinformatic algorithm for database searching (Altschul *et al.*, 1990); variants are available *e.g.* to match a nucleotide sequence against a nucleotide database, a protein against a protein database or a nucleotide sequence against a protein database, or preferentially to recover weak matches (more distantly related sequences). Software for multiple sequence alignment includes Clustal, MUSCLE, PRANK and T-Coffee, while bacterial genomes can be aligned with Mauve.

Phylogenetics

Although originally developed as subfields within evolutionary biology, *molecular phylogenetics* and its genome-scale counterpart, *phylogenomics*, are widely accorded a place in bioinformatics conferences, journals and texts. Important operations include database matching, clustering, multiple sequence alignment, and the inference and comparison of phylogenetic trees and networks. The main algorithmic frameworks for tree inference include distance (*e.g.* neighbour-joining), parsimony, maximum likelihood and Bayesian inference, the latter using Markov chain Monte Carlo (MCMC) to estimate posterior distributions of model parameters. Important software includes the PHYLIP package, PAUP*, RaxML, BEAST and MrBayes (Yang & Rannala, 2012). As multiple sequence alignment and most methods of tree inference scale poorly with data size, heuristics are widely employed and alternatives that do not require multiple sequence alignment are being actively explored (Chan *et al.*, 2014). TreeBASE and the Ribosomal Database Project (RDP) are important repositories of phylogenetic models and data.

Gene Expression

The development of bioinformatic methods for analysis of gene expression has been driven by technology: the introduction of spotted arrays in the 1980s, microarrays of increasingly high density since 1995, and more recently sequence-based transcriptomics. Operations in *expression bioinformatics* include experimental design, data capture and management, normalisation (statistical correction for variation arising from the array platform rather than from the biological sample), analysis of differential expression (*e.g.* under different experimental conditions), clustering, classification and functional interpretation. Specialised methods continue to be developed for the study of alternative splicing, other types of transcriptional variation, and regulatory RNAs. Both commercial (GeneSpring) and free (LIMMA; programs in BioConductor/R and GenePattern) software is widely used to analyse expression data.

Epigenetics

Epigenetics refers to heritable states in gene expression or phenotype caused by mechanisms other than changes to the sequence of genomic DNA. Large-scale epigenetic data have recently begun to appear with the advent of technologies that probe the methylation status of DNA, chemical modifications of histones, structural conformation of the chromatin and occupancy of control sites in specific cell types

and/or under specified conditions. Bioinformatic operations in epigenetics are not unlike those in genome analysis and annotation, with emphasis on statistically based approaches including machine learning. ENCODE (Encyclopaedia of DNA Coding Elements) is a very large consortium project whose aim is to assess the activity and function of the entire genomic DNA, not only protein-coding genes (Ecker *et al.*, 2012).

Structural Bioinformatics

Structural bioinformatics focuses on the computational analysis of the three-dimensional structures of biomolecules, especially proteins and RNAs. Important activities include the description or prediction of protein structures, surfaces, dynamics and interactions with other molecules including antibodies and drugs (Gu & Bourne, 2009). Important software packages include Amber, Gaussian, GROMACS and NAMD. The Critical Assessment of Techniques for Protein Structure Prediction (CASP) is a biennial community-wide competitive evaluation of methods and software, while Folding@Home is a distributed computing project for protein folding and computational drug design. For RNAs, recurrent themes include the prediction of folded structure and target specificity. Software includes the Vienna package, UNAFold, miRanda, PicTar and TargetScan. Databases include PDB, Swiss-Prot, UniProt (proteins) and Rfam (RNA).

Systems Bioinformatics

Systems bioinformatics aims to understand cells or organisms as integrated molecular systems. Typical operations include management and integration of multiple types of genome-scale data; inference of biomolecular interactions, pathways (*e.g.* of biosynthesis or metabolism) or networks (*e.g.* of genetic regulation or protein-protein interaction); and computational modelling, sometimes at very large scale. Models may be static or dynamic, and may focus on mechanistic details or phenotypic outcomes (Csermely *et al.*, 2013). Important data sources include the Kyoto Encyclopedia of Genes and Genomes (KEGG) and Reactome. The Dialog for Reverse Engineering Assessments and Methods (DREAM project) is a CASP-like competitive evaluation in computational systems biology.

Ontologies

The Gene Ontology models knowledge in molecular and cell biology in three hierarchies: Biological Process, Molecular Function, and Cellular Component (The Gene Ontology Consortium, 2012). Other biological ontologies model knowledge about *e.g.* specific organisms, types of molecules, pathways, phenotypes, diseases and experimental methods. GO and some others follow the Open Biomedical Ontology description format. *Gene set enrichment analysis* provides statistical tests of the over- or under-representation of ontology terms in the results of an experiment, compared with their frequency in a background.

Bio-Image Informatics

Bio-image informatics focuses on the capture, management, annotation, analysis and visualisation of data generated by light and electron microscopy, electronic imaging and related technologies. Image data

can be static or dynamic, and are often large (Walter *et al.*, 2010). Consensus remains to be developed on metadata standards. Application areas range from the molecular scale through cell structure, tissues, organ systems and whole organisms and include informatic methods in support of histopathology, high-throughput screening, medical imaging, particle tracking and single-particle analysis.

Societies and Journals

The scientific journal *Computer Applications in the Biosciences* adopted the title *Bioinformatics* from 1998. Other important journals include *BMC Bioinformatics*, *Briefings in Bioinformatics*, *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, and *PLoS Computational Biology*. The main international scientific society in bioinformatics is the International Society for Computational Biology (ISCB), which sponsors annual conferences including Intelligent Systems in Molecular Biology, the International Conference on Research in Computational Molecular Biology, ISCB Asia, and Pacific Symposium on Biocomputing. Other important conference series include Asia Pacific Bioinformatics Conference, European Conference on Computational Biology, International Conference on Bioinformatics, and International Conference on Genome Informatics. Many other well-regarded societies, conferences and journals now offer a bioinformatics section.

FUTURE RESEARCH DIRECTIONS

The rapidly increasing affordability of genome sequencing is driving new fields of personalized genomic health care and medicine, and opening unprecedented opportunities in areas as diverse as anthropology, forensics, plant and animal breeding, industrial biotechnology, and environmental management. Bioinformatic challenges across these application domains include the management of immense quantities of diverse data, sometimes in secure environments (*e.g.* to protect patients or intellectual property); highly scalable algorithms and tools especially for networks, systems and populations; and the ability to overlay geospatial coordinates and temporal models. Many important datasets are already too large to be moved, and new types of bioinformatic tools and infrastructure are being trialled that take analyses to the data (*e.g.* in the cloud) rather than vice-versa. The most-pressing and difficult challenge continues to be the education and training of personnel who can work across the component disciplines of bioinformatics to solve ever more-complex biological problems, while enriching information science and technology.

CONCLUSION

As foreseen by Nobel Laureate Walter Gilbert (Gilbert, 1991), biology has substantially become an information science. At the same time, the richness of problems and ever-growing deluge of data across modern biology is increasingly transforming information science and technology into a living science in the most literal sense.

Bioinformatics is now an indispensable enabling technology at the interface of bioscience with mathematics, statistics, computer science, and information science and technology. This is seen most dramatically in genomics and the other “omic” sciences, which continue to be driven by ever-larger data

and the need for integrative analysis of complex biological systems. Specialty areas continue to evolve within bioinformatics to support the study of gene regulation, biomolecular and cellular structure, drug discovery, molecular evolution, bio-imaging and other application domains. Standards, policies and a network of large international bioinformatics centres ensure that biomolecular data are well-managed, openly available for re-use, and in many cases integrated into value-added data services.

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KEY TERMS AND DEFINITIONS

Epigenetics: The study of heritable changes in gene expression or phenotype that do not arise from changes in the nucleotide sequence of the genome.

Gene Expression: The process in which information in a gene is transduced to yield one or more gene products (proteins and/or non-protein-coding RNAs).

Genomics: The study of the totality of genetic information in a cell or organism.

Metagenomics: The study of the genetic information in a sample of a mixed community, for example from soil, water, or the intestinal tract of an animal, without prior separation of the constituent organisms.

Omics (or ‘Omics): Genomics, transcriptomics, and other fields of biology characterised by the study of the totality of a class of molecule (*e.g.* proteomics), process (*e.g.* metabolomics) or traits (*e.g.* phenomics) in a cell or organism.

Phylogenetics: The study of genetic relationships among molecules, organisms or taxa over time.

Synthetic Biology: The engineering design and construction of new or modified functions in biological systems.

Systems Biology: The study of networks of interactions among the components of a biological system, emphasising a synthetic, non-reductionist approach and emergent properties.

Transcriptomics: The study of the totality of the RNA molecules arising from the expression of genes under specified conditions.

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Chapter 2

Bioinspired Solutions for MEMS Tribology

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ABSTRACT

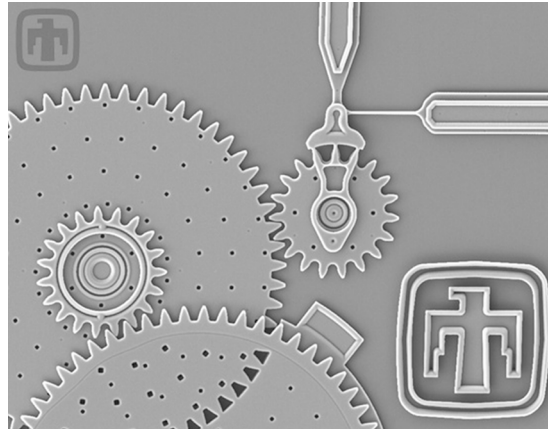
Micro-electro mechanical systems (MEMS) are miniaturized devices that operate at a small scale. Actuators-based MEMS have not been commercially realized yet, owing to the manifestation of high surface forces such as adhesion and friction between their moving elements. In recent years, inspiration from “Lotus Effect” has opened a new direction in the field of micro/nano-tribology to manipulate/control surface forces at small scale. The underlying principle discovered from the super-hydrophobic nature of the leaves of water-repellent plants has led to the design and development of various biomimetic tribological surfaces that exhibit remarkable reduction in surface forces under tribological contact. This chapter presents the tribological issues in MEMS devices, examples of conventional solutions for the tribological issues, and unique bioinspired solutions that have great capability to mitigate surface forces at micro/nano-scales.

INTRODUCTION

Micro-Electro-Mechanical Systems (MEMS) are miniaturized devices that perform intelligent functions. They can be classified as: (i) sensors based, which have sensing elements and (ii) actuators based, which have elements that undergo mechanical motion. Micro-motors/engines, micro-gears and micro-shutters are examples of actuators based devices. Figure 1 shows a micro-gear made from silicon (http://www.sandia.gov/mstc/_assets/images/mems/gallery/gears/1.jpg). In these devices, tribological issues such as adhesion, friction and wear strongly manifest, which undermine the mechanical motion of MEMS elements (Kim, Asay, & Dugger, 2007). Therefore, it is imperative to solve these tribological issues in order to realize smooth operation and increased operating lifetimes of actuators based MEMS. Convention-

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Figure 1. MEMS micro-gear made from silicon. (http://www.sandia.gov/mstc/_assets/images/mems/gallery/gears/1.jpg). In MEMS devices, tribological issues such as adhesion, friction and wear strongly manifest and undermine the mechanical motion



ally, thin films/coatings have been researched for their application to MEMS as solutions to mitigate the tribological issues. Examples include self-assembled monolayers (SAMs), diamond-like carbon (DLC) coatings, polymers and perfluoropolyether films (PFPE) (Bhushan, 2001). In recent years, bioinspired approaches have attracted attention as better alternative solutions for MEMS. This chapter highlights bioinspired approaches that are promising tribological solutions for actuators based MEMS devices.

BACKGROUND

MEMS are built at micro/nano-scale. At these scales, the ratio of surface area to volume is high. Hence, body forces such as inertia and gravity become insignificant. In contrast, surface forces such as capillary, van der Waals, electrostatic, and chemical bonding dominate. These surface forces cause adhesion at the interface of contacting MEMS elements. Amongst these forces, the capillary force that arises due to the condensation of water from the environment is the strongest. Further, adhesion strongly influences friction at micro/nano-scale (Maboudian & Howe, 1997). The magnitude of these surface forces is comparable with those that drive the motion of MEMS elements, thereby rendering the elements completely inoperable. MEMS are traditionally made from silicon due to availability of the process knowledge developed for the material in semiconductor industries. However, silicon does not have good tribological properties (Bhushan, 2001). Silicon due to its inherent hydrophilic nature experiences high surface forces, and because of its brittle nature it undergoes severe wear. Thus, the improvement of tribological performance of silicon is the key to realize the smooth operation of actuators based MEMS. Williams and Le have presented an excellent review on the tribological issues in MEMS devices (Williams & Le, 2006).

Tribological properties of materials at micro/nano-scale are evaluated using atomic force microscopes (AFM) and micro-tribo testers. With these instruments, contact conditions similar to those in MEMS can be easily simulated (loads $\sim$ nN to μ N-mN; area $\sim$ few hundreds of nm²).

CONVENTIONAL SOLUTIONS

The gap between moving elements in MEMS is usually about few microns. Hence, solid lubricants (e.g. graphite, MoS₂, WS₂) or liquid lubricants (e.g. oils, greases) cannot be applied in MEMS devices as their sizes are of the same order as those of MEMS elements. Due to this reason, thin films/coatings with thickness less than few microns have been investigated for their application as ‘boundary lubricants’ for MEMS. Table 1 shows the water contact angle (CA) values, nano-scale adhesion force and nano-scale friction coefficient (μ_n) of silicon (Yoon et al., 2005). The table also shows CA values and nano-tribological properties of thin films/coatings, namely diamond-like carbon (DLC), Z-DOL (commercial name for perfluoropolyether, PFPE), and OTS (octadecyltrichlorosilane) SAM (Yoon et al., 2005; Liu & Bhushan, 2003, Liu, Ahmed, & Scherge, 2001; Singh & Yoon, 2007). The adhesion values given in the table were obtained from force-distance curves measured using AFM. In some cases, the values are taken from the negative intercepts in the friction force versus normal load plots. The nano-scale friction coefficient (μ_n) is estimated as the slope of friction force versus normal load.

Surface energy of a material is indicated by the contact angle between a water droplet and its surface (water contact angle is inversely proportional to surface energy (Bain, Evans & Whitesides, 1989). From Table 1, it is seen that the adhesion values of the test materials are inversely dependent on their CA values. Silicon is hydrophilic in nature and thereby it supports strong capillary force that causes high adhesion. This in turn increases its friction, which retards the motion of actuators. In contrast, DLC, Z-DOL and OTS have higher CA values. This means that they have lower surface energies and sustain lower surface forces. When applied to actuators these materials are capable of promoting smooth motion.

Table 1 shows micro-scale friction coefficient (μ_m) and durability (i.e. the number of cycles for the onset of wear) of the test materials (Yoon et al., 2005; Liu & Bhushan, 2003, Liu, Ahmed, & Scherge, 2001; Singh & Yoon, 2007). At micro-scale, silicon undergoes severe wear within a short duration of

Table 1. Water contact angle (CA) values, nano-scale tribological properties (adhesion force (nN), friction coefficient (μ_n)) and micro-scale tribological properties (micro-scale friction coefficient (μ_m), durability (n)) of silicon and various thin films/coatings, taken from literature

Nano-Scale Tribological Properties			
MaterialSurface	CA(deg)	Nano-scaleAdhesionForce (nN)	Nano-scaleFrictionCoefficient (μ_n)
Silicon	30	50	0.05
DLC	60	40	0.03
Z-DOL	72	35	0.03
OTS	100	5.6	0.04
Micro-Scale Tribological Properties			
MaterialSurface	Micro-ScaleFrictionCoefficient (μ_m)	Durability(Number of Cycles, n)	
Silicon	0.7	< 100	
DLC	0.2	> 500	
Z-DOL	0.17	~ 5000	
OTS	0.18	~ 1600	

Source: Yoon et al., 2005; Liu & Bhushan, 2003, Liu, Ahmed, & Scherge, 2001; Singh & Yoon, 2007

time, i.e. it has low durability (< 100 cycles). Figure 2 shows a worn surface of silicon tested at micro-scale. Wear in the case of DLC, Z-DOL and OTS begins only after hundreds of cycles of sliding, which indicates good durability. These boundary lubricants have distinct mechanisms that promote good tribological properties. By nature they are semi-hydrophobic/hydrophobic, due to which adhesion and friction get reduced to a great extent. In DLC films, in addition to their semi-hydrophobic nature, the formation of transfer layer on the counterface surfaces lowers friction and wear (Erdemir et al., 1996). Z-DOL has fluorine atoms which makes its hydrophobic. Fluorine atoms have larger van der Waals radii that support molecular scale order under shear thereby making Z-DOL a good lubricant (Bhushan, 2001). In OTS, the molecular chains act as molecular springs and reduce friction (Liu & Bhushan, 2003). When these boundary lubricants are applied to silicon MEMS, the tribological performance of the devices can be considerably enhanced.

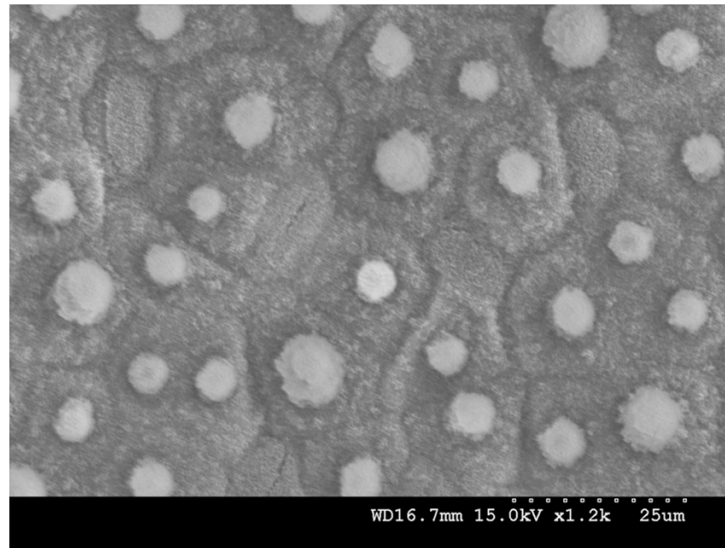
WATER REPELLENT SURFACES

Lotus leaves are superhydrophobic with CA of about 162° (Neinhuis, Barthlott, 1997). This property is an effect of the hierarchical structures on the leaves. Figure 3 shows the surface of a lotus leaf with micro-scale protuberances. The superhydrophobic property is induced by the dual-scale surface roughness from the micro-scale protuberances and waxy nano-crystals. The unique characteristic of lotus leaves to avoid getting wet is popularly known as “Lotus Effect”. Colocasia is another water repellent plant having CA of about 164° (Neinhuis, Barthlott, 1997). Superhydrophobicity of water repellent plants arises due to the heterogeneous/composite wetting of water, wherein water drops sit on top of the protuberances with air trapped in between them, reducing the solid contact area with the water drops.

Figure 2. Worn surface of silicon tested at micro-scale. At micro-scale, silicon undergoes wear within a short duration of time, i.e. it has low durability



Figure 3. Surface of a lotus leaf with micro-scale protuberances. The micro-scale protuberances and waxy nano-crystals on it make the lotus leaf surface superhydrophobic



By mimicking the features present on lotus leaves, scientists have created water repellant surfaces for various applications such as mirrors, car windows, computer/notebook key boards, building structures, fabrics etc., (Gould, 2003).

BIOINSPIRED SOLUTIONS

At micro/nano-scale, friction is in a regime where the contribution from intrinsic/inherent adhesion can outweigh that from asperity deformation (Maboudian & Howe, 1997). Thus, in reducing adhesion, friction also gets reduced, and therefore solutions to reduce adhesion are the key to realize smooth motion between elements of MEMS devices. Further, the effective route to mitigate adhesion is by reducing capillary force at the interface. This can be achieved by learning from 'lotus effect'. Friction at micro/nano-scale depends on real area of contact (Yoon et al., 2005). Therefore, any reduction in real contact area between surfaces directly reduces adhesion and friction. By creating surface features i.e. topography similar to that seen on lotus leaves (which reduces the contact area between water drops and their surfaces) solutions to reduce surface forces in MEMS can be realized.

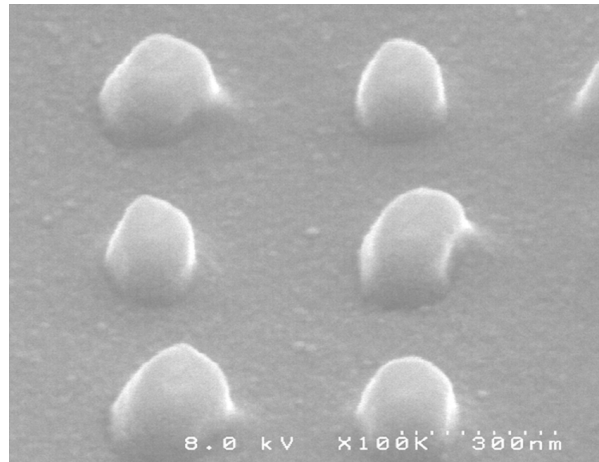
As a pioneering work, nano-scale polymeric patterns on silicon surfaces that mimic the protuberances on lotus leaves were fabricated by capillary force lithography, and investigated for adhesion and friction at micro/nano-scale (Yoon et al., 2006). Figure 4 shows a representative image of polymeric nano-patterns on silicon. CA values indicated that the nano-patterns were hydrophobic (Table 2). AFM measurements showed that the nano-scale adhesion and friction of the patterns was significantly lower than those of silicon and PMMA thin film (Table 2). The superior tribological performance of the patterns is due to hydrophobicity and reduced real area of contact between their surfaces and AFM tips. To note, patterning of surfaces causes a reduction in contact area when the size of the asperities (patterns) is considerably smaller than that of the counterface (AFM tips). An investigation by Burton et al. clearly

Table 2. Water contact angle (CA) values, nano-scale tribological properties (adhesion force (nN), friction force (nN)) and micro-scale tribological property (micro-scale friction coefficient (μ_m), durability (n)) of silicon, PMMA, DLC and various nano/micro-patterned surfaces, taken from literature

MaterialSurface	CA(deg)	Nano-Scale Adhesion Force (nN)	Nano-Scale Friction Force (nN)	Micro-Scale Friction Coefficient (μ_m)
Flat Surfaces				
Silicon	22	984	20-28	0.46
PMMA Thin Film	69	872	5-8	0.66
DLC Thin Film	78	226	5.5-8.3	0.19
Nano/Micro-Patterned Surfaces				
PMMA Nano-Patterns	91-99	30-40	0.51-1.97	0.24-0.33
PMMA Micro-Patterns	91-106	-	-	0.11-0.13
(Replicated Surfaces)	95	67	0.98-1.96	0.13
DLC Nano-Dot Surfaces	59	-	-	0.16
Silicon Micro-Pillars	145	-	-	0.12
Silicon Micro-Pillars coated with DLC	105	-	-	0.08
Silicon Micro-Pillars coated with ZDOL				

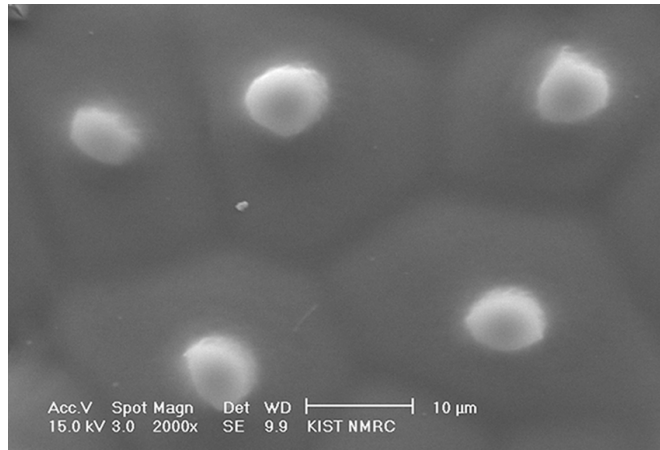
Source: Yoon et al., 2006; Singh et al., 2007; Singh et al., 2011; Singh et al., 2011

Figure 4. A representative image of polymeric nano-patterns on silicon. These patterns mimic the surface topography of a lotus leaf



highlights the influence of pattern size (aspect ratio), counterface tip size and relative humidity on the magnitude of surface forces in polymeric patterns (Burton & Bhushan, 2005). Polymeric nano-patterns have excellent tribological properties at nano-scale, however they do not have good load bearing capability at micro-scale. At micro-scale, under micro-loads (μN - mN) polymeric ‘micro-patterns’ exhibit low friction and good load bearing capability (Table 2) (Singh et al., 2007). Figure 5 shows a representative image of polymeric micro-pattern from the direct replication of the surface of natural lotus (Nelumbo

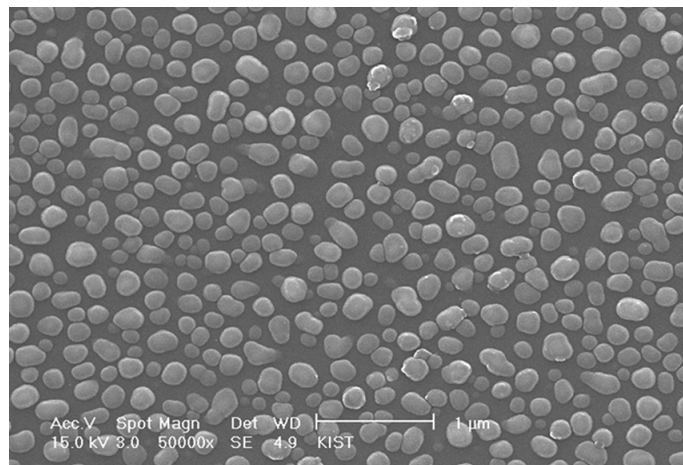
*Figure 5. A representative image of micron-sized polymeric pattern from the direct replication of the surface of natural lotus (*Nelumbo nucifera*). These micropatterns contribute to large reduction in friction under micro-loads*



nucifera). The larger size of the micro-patterns and the increased distance between the micro-patterns together contribute towards reducing the contact area significantly resulting in lower friction.

Polymeric patterns undergo elastic and/or plastic deformation under relatively higher normal loads. Such deformation result in higher contact areas and increase the magnitude of surface forces. An effective way to avoid deformation is to pattern surfaces that are harder and stiffer. Examples of such surfaces include micro/nano-textures produced by UV assisted/aluminum-induced crystallization of amorphous silicon (Zou et al., 2005; Nair & Zou, 2008) and DLC nano-dots surface (Singh et al., 2011). DLC nano-dot surfaces are created by depositing DLC films on nano-sized nickel (Ni) dots fabricated on silicon wafers by annealing Ni thin films. The nano-dot surfaces are hydrophobic and reduce adhesion and friction forces significantly (Table 2). Unlike polymeric nano-patterns that have uniform height and

Figure 6. DLC nano-dots surface. The surface significantly reduces adhesion and friction



are spaced equidistant, the DLC nano-dots are randomly distributed and have un-equal heights. Due to their un-equal heights, only those nano-dots that are taller come in contact with the counterface, thereby resulting in smaller contact areas that lower adhesion and friction. Nano-dots can withstand micro-loads as they are relatively harder and stiffer than polymeric patterns.

Combination of surface patterning and boundary lubrication proves to be more effective in minimizing surface forces. Examples include polymeric patterns with perfluorodecyltriethoxysilane (PFDTES) SAM (Burton & Bhushan, 2005), silicon micro-pillars coated with DLC/ZDOL (Table 2) (Singh et al., 2011) and textured surfaces of Ni films coated with PFPE (Wang et al., 2014). For a detailed discussion, readers are suggested to refer the book (Sinha, Nalam & Lim (eds.), 2013).

COMPARATIVE NOTE

Figures 7 and 8 show the nano-scale friction and micro-scale friction coefficient (μ_m) of polymeric patterns in comparison with those of silicon, DLC and diphenyldichlorosilane (DPDC) SAM (Singh & Yoon, 2007). From these figures, it could be seen that the bioinspired patterns have relatively lower friction property when compared to the rest of the test materials. Bioinspired tribological surfaces have two fold advantages over the conventional solutions i.e. boundary lubricants (DLC, Z-DOL, SAMs) namely:

1. Ease of application and
2. Effectiveness in reducing surface forces.

Figure 7. Nano-scale friction of polymeric patterns in comparison with those of silicon, DLC and diphenyldichlorosilane (DPDC) SAM

Source: Singh & Yoon, 2007

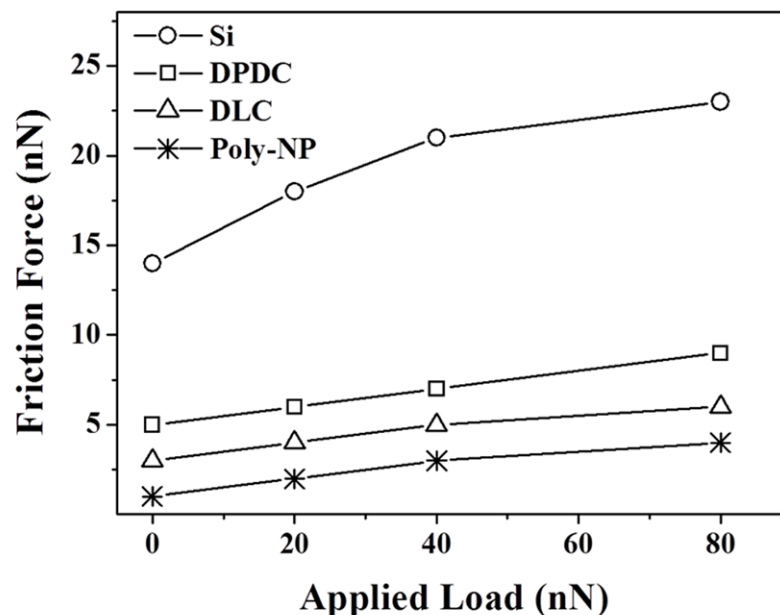
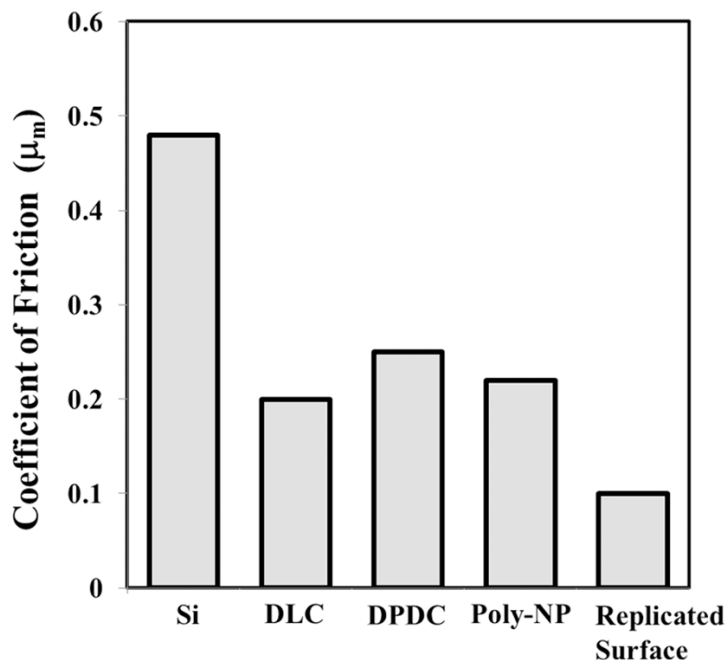


Figure 8. Micro-scale friction coefficient (μ_m) of polymeric patterns in comparison with those of silicon, DLC and diphenyldichlorosilane (DPDC) SAM

Source: Singh & Yoon, 2007



As for the first aspect, boundary lubricants have to be applied to MEMS surfaces externally i.e. via dip coating process, physical/chemical vapor deposition etc. Thus, application of boundary lubricants and ensuring their uniform coating/coverage throughout the surfaces of MEMS elements has remained a major challenge. In contrast, bioinspired patterning of surfaces of MEMS elements can be easily achieved by using the same lithography techniques that are used to fabricate MEMS elements. Moreover, surface patterning can be done verily during the fabrication of the MEMS surfaces. This makes the patterning route more time-effective and cost-effective. Further, in the case of boundary lubricants complex chemistry has to work to make them effective in reducing the surface forces. For example, the tribological performance of SAMs depends on the suitable selections of end groups and chain length. In the case of DLC thin films, the choice of sp^3/sp^2 ratio and the mechanical properties determine their tribological performance. On the other hand, for patterns simple geometric parameters such as height, diameter and pitch (distance between any two adjacent features) define their tribological behavior. By varying these simple geometric parameters, surface forces can be easily controlled.

FUTURE RESEARCH DIRECTIONS

Till date, simple patterns/textures have been investigated for their micro/nano-scale tribological properties for MEMS applications. These surfaces are hydrophobic in nature and reduce surface forces considerably. For more effective reduction in surface forces, patterns with hierarchical structures (2 tier) need to be

investigated. Some examples of hierarchical structures that are of interest are nano-engineered multiscale hierarchical structures with tailored wetting properties (Jeong et al., 2006) and biomimetic, hierarchical structures fabricated on polymer surfaces by sequential imprinting (Zhang, Chan & Low, 2008). Patterns with hierarchical structures give rise to superhydrophobicity, and such topography in combination with boundary lubrication has the potential to greatly reduce surface forces at micro/nano-scale.

CONCLUSION

Bioinspired surfaces have proved to be effective in reducing adhesion and friction at micro/nano-scale and have paved a new way of addressing the tribological issues in MEMS devices. Examples presented in this chapter clearly show that the biomimetic engineering of surfaces is an exciting and practical way to control surface forces. Patterning of surfaces in combination with boundary lubrication can be pursued to control surface forces effectively for the application in miniaturized devices.

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KEY TERMS AND DEFINITIONS

Adhesion: It is the tendency of surfaces to cling/stick to one another. Materials with higher surface energy exhibit higher surface adhesion and vice versa.

Biomimetics: It is the use and implementation of concepts and principles found in nature/natural materials for man-made technology.

DLC (Diamond-Like Carbon): It is a class of amorphous carbon material that has certain properties similar to that of diamond (e.g. hardness). Usually it is applied to surfaces in the form of thin films/coatings by physical/chemical vapor deposition techniques. DLCs are semi-hydrophobic and are good lubricant materials.

Friction: It is the resistance to motion. It is the resistance that one surface encounters when moving over another. Friction causes loss in energy.

Lotus Effect: It is the phenomenon of super hydrophobicity and self-cleaning displayed by the leaves of lotus plant. The unique characteristic of lotus leaves to avoid getting wet is due to the presence of micro-protuberances and waxy nano-crystals on the lotus leaves surfaces.

MEMS (Micro-Electro-Mechanical Systems): They are micro/nano-scale devices that perform sensing and/or actuating functions. They are made using the techniques of microfabrication. Silicon is the most popular MEMS material.

Real Contact Area: It is the real area of contact between two surfaces that are in contact under tribological conditions. The real contact area constitutes the areas where asperities of the contacting surfaces meet. The real area of contact is lower by 3 to 4 orders of magnitude when compared to the apparent area of contact (geometrical area).

SAMs (Self-Assembled Monolayers): They are molecular assemblies of organic molecules, which are formed on surfaces by adsorption or chemical grafting. The thickness of SAMs is typically in the range of few nanometers to tens of nanometers.

Tribology: It is the science and engineering of interacting surfaces in relative motion. It encompasses the study and application of the principles of friction, wear and lubrication.

Wear: It is the unintentional material removal/loss under relative mechanical motion between contacting surfaces.

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Chapter 3

Building Gene Networks by Analyzing Gene Expression Profiles

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ABSTRACT

The possible applications of modeling and simulation in the field of bioinformatics are very extensive, ranging from understanding basic metabolic paths to exploring genetic variability. Experimental results carried out with DNA microarrays allow researchers to measure expression levels for thousands of genes simultaneously, across different conditions and over time. A key step in the analysis of gene expression data is the detection of groups of genes that manifest similar expression patterns. In this chapter, the authors examine various methods for analyzing gene expression data, addressing the important topics of (1) selecting the most differentially expressed genes, (2) grouping them by means of their relationships, and (3) classifying samples based on gene expressions.

INTRODUCTION

Since the detection of the composition of DNA our understanding of biological structures and processes has expanded to a great extent, mostly thanks to computer science which plays a fundamental role in the field of bioinformatics. The main target at present is to analyze and employ the huge amount of accessible data. It is particularly important to distinguish various diseases through useful selection of gene indicators for morbid state and information about the possible correlations between genes.

Data analysis is seen as the largest and possibly the most important area of microarray bioinformatics to obtain the above said targets. Some specific data analysis methods address the fundamental scientific questions about microarray data, that is:

1. Which genes are differentially expressed in one set of samples relative to another,
2. What are the associations between the genes or samples being observed, and
3. Is it possible to group samples based on gene expression values?

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In the next section, we illustrate the basic concepts underlying the previous questions and the bioinformatics research. Then we describe the methods for the first of these questions: the search for differentially (up or down) expressed genes. The following sections address the other two topics of clustering and classifying gene profiles. In the end, we show some concerns and issues of interest for future study and development in the field of (microarray) bioinformatics.

BACKGROUND

Gene expression profiling is an extensively used method in the analysis of microarray data. The leading hypothesis is that genes with similar expression profiles are co-regulated and are probably connected functionally.

Cluster analysis helps reaching these objectives; in particular, gene expression clusters help typify unknown genes assigned to the cluster by those genes that have a known function, and are the support for distinguishing common upstream regulatory sequence elements (Brazma *et al.*, 2000).

Clustering of expression profiles and functional grouping is especially compelling if the complete gene set is known. Hence, we used the large publicly available data set included in the Stanford Yeast Database at <http://genome-www.stanford.edu> for our clustering study.

Many applications aim at the molecular classification of diseases based on gene expression profiling and clustering. See, for example, works on leukemias (Golub *et al.*, 1999) and B-cell lymphomas (Alizadeh *et al.*, 2000). These and other studies confirm the usefulness of microarray bioinformatics for scientific and industrial research.

Gene Expression Profiling

Having M array probes with N samples (time points, patient tissues, *etc.*), you construct an $M \times N$ data matrix (the *gene expression matrix*), where the M rows describe the gene expression values across the experiments and the N columns (samples) describe the experiments across the gene set. Practically, each gene is assigned a set of (possibly normalized) numerical values (the *gene expression profile*) corresponding to the gene's "presence" in each sample.

Then, an $M \times M$ similarity matrix is obtained by calculating the "closeness" between each gene pair with values inversely proportional to the relative (expression profile) distance. Typically Pearson correlation, Spearman's rank correlation, Hamming distance, Euclidean distance and mutual information are employed as similarity measures (Jain & Dubes, 1988; Mirkin, 1996), each having its specific advantages and disadvantages.

The (normalized and possibly log-transformed) expression profiles of thousands of genes are first examined under the typical two-fold comparison (between the same patients in *control vs treatment*, or between two different groups of patients), in order to identify differentially expressed genes. This can be done using an appropriate statistic (t -statistic, Wilcoxon, Mann-Whitney depending on the type of comparison) to compare gene expression variability.

Then selected genes are clustered in order to find groups of co-regulated genes.

The clustering output in the end serves as the basis for typifying the role of undetermined genes by means of information available from known genes, to recognize supposed regulatory elements in the

early regions of the genes in the same clusters and reduce redundancy and generate averaging profiles in the context of regulatory networks.

Cluster Analysis

Cluster analysis (Duda *et al.*, 2001; Jain & Dubes, 1998; Jain *et al.*, 1999) can be summarized as follows. Let n experimental outcomes $x_i \in \mathbb{R}^m$ ($i=1..n$; each point has m components): the objective is to identify the underlying structure of the data, partitioning the n points into k clusters in order to group in the same cluster points “closer” to each other than to points belonging to different clusters.

In the above statement no clear definition exists for “closer” points, and this depends on the resolution at which the data are viewed. The last issue is typically addressed by generating a tree of clusters (a dendrogram), whose number and structure depend on the resolution that is used.

Two of the most common methods of clustering gene expression data are hierarchical clustering and k –means clustering (Geraci *et al.*, 2009; Jain *et al.*, 1999).

Hierarchical clustering is the most used, and produces a representation of the data with the most similar patterns grouped in a hierarchy of subsets. This method, however, suffers from considerable problems when applied to data containing a significant amount of *noise*, revealing itself of low applicability. In this case the solutions may not be unique and be data-order dependent. Mathematically, hierarchical clustering involves computing a matrix of all distances for each expression measurement in the study, merging and averaging the values of the closest nodes, and repeating the process until all nodes are merged into a single node.

K –means clustering involves generating cluster centers in n –dimensions and computing the distance of each data point from each of the cluster centers. The data points are assigned to their closest cluster center. A new cluster position is then computed by averaging the data points assigned to the cluster center. The process is repeated until the positions of the cluster centers stabilize.

UNSUPERVISED NEURAL NETWORKS

Artificial Neural Networks can be used not only for prediction but also for data classification. Unlike regression problems, where the goal is to produce a particular output value for a given input, classification problems require labeling of all data as belonging to one of n known classes. These classification models are typical cases of supervised networks, in which it is a priori possible to associate data to clusters and to train the neural network for the classification of further data.

However, there are cases in which the association is not known before. It is then up to the neural network to independently find the associative structures between data, grouping them in clusters. These neural networks are known as *unsupervised* or *self-organizing* (associative memories).

There is not, therefore, a *correct* output as there is not an *erroneous* output. This involves careful observation and analysis by the researcher. In fact, after an unsupervised network has been trained, it must be tested in many directions as it is important to understand what are the data structures resulting from the neural network itself.

An unsupervised network can be compared to a hypersurface in the n –dimensional space, with m “valleys” or minima corresponding to the desired shape of the outputs. The presentation of an input $X_i = \{x_{i1}, \dots, x_{in}\}$ to the network is equivalent to putting a weight in the corresponding point on the surface,

thus making it fall into the nearest valley, corresponding to $Y_i = \{y_{i1}, \dots, y_{in}\}$. Obviously, an input X_i ’ “similar” to X_i — according to some similarity criterion — should fall into the same depression, drawing by association (hence the term “associative memories”) the same output Y_i (Cammarata, 1990).

Practically, an unsupervised neural network consists of a number of *codebook vectors* Y_i which constitute the center of each cluster. They are the same size of the input space, and their components are the parameters of the unsupervised network. The codebook vectors are the network’s neurons. Some parameters help in training the neural network. The position of the vectors should be adjusted so that the average Euclidean distance between the data points and the corresponding codebook vector should be minimal (Yanai & De Lisi, 2002).

If you also minimize the distance between codebook vectors, the unsupervised network is known as Self-Organizing Map (SOM) or Kohonen network (Herrero *et al.*, 2001).

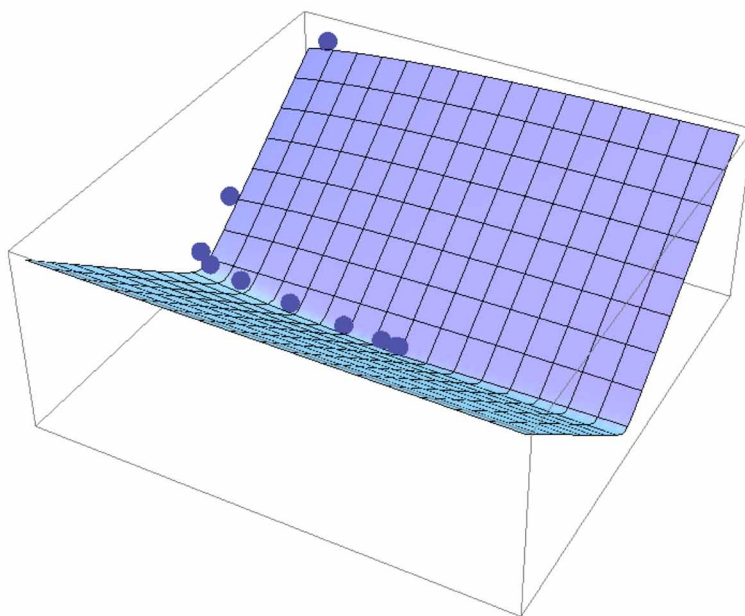
DIFFERENTIAL GENE EXPRESSION

This section illustrates a variety of methods, ranging from classical and more modern statistical theory, to give a detailed path for finding differentially expressed genes in DNA microarray data. Let’s start by illustrating the meaning of “differentially expressed genes”.

DNA microarray data is made of a matrix of numerical values of gene expression levels taken from various patients’ samples. We aim at recognize genes that are differentially (i.e., more or less) expressed under some different experimental conditions (ill and healthy patients, before and after some therapy).

Usually, each gene in the microarray is inspected to decide whether or not it is differentially expressed, typically doing this by studying many individual genes in parallel. This differs from the clustering and

Figure 1. Metaphor oh the hyper-surface for the unsupervised neural network



classification methods of the next sections, which are specifically interested in the interactions between the genes under investigation.

We will now show how expression data can be reshaped and examined for discovering differentially expressed genes.

In paired data there are two measurements from each patient, one before and one after treatment (Figure 2a). To determine whether a gene has been up- or down-regulated after treatment, you may compute the “after/before” fold ratio by considering the log-transformed values. This allows you to simply subtract (and not divide) the “after” from the “before” value, thus obtaining a set of single values whose mean (or median) you want to know if it is different from zero.

In unpaired data (Figure 2b) there are two (independent) groups of patients, and you search for those genes differentially expressed between the two groups. For each patient from each group there is a gene expression value; you want to know whether the mean (or median) of the two groups is different.

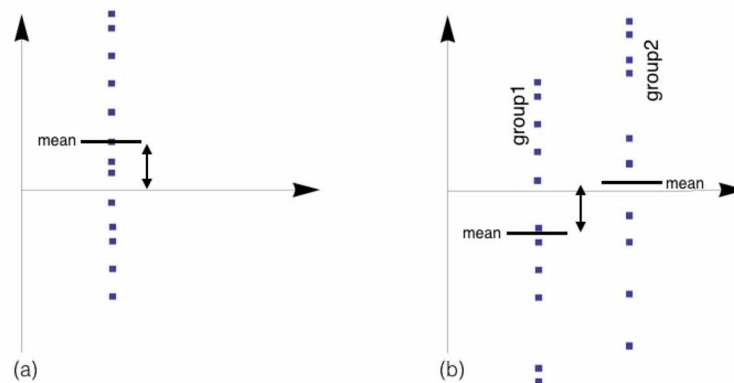
If you have a data set with more than two groups then a more complex approach, typically the analysis of variance (ANOVA), is required.

THE “RELAXED” CLUSTERING ALGORITHM

Preliminaries

The interpretation of the large amounts of data produced by DNA microarray techniques for the analysis of gene expression requires new efficient strategies to reduce the size involved. Clustering algorithms typically group genes (or samples) in clusters of similar expression profiles to identify possible functional relationships between them. Of particular importance are graphical representations of the clusters and their *automatic* annotation from available genome databases (Eisen *et al.*, 1998; Furey *et al.*, 2000; Golub *et al.*, 1999; Pe’er *et al.*, 2002; Wu *et al.*, 2000; Zhou *et al.*, 2002). Similar problems are found in the analysis of large networks, where you try to extract subnets that meet certain criteria (such as the search for web pages on the same subject) (Eckmann & Moses, 2002; Jenssen *et al.*, 2001; Milo *et al.*, 2002; Shen-Orr *et al.*, 2002; Butte *et al.*, 2000; Yanai & De Lisi, 2002).

Figure 2. Example of paired (a) and unpaired (b) data



Here we analyze an algorithm, based on correlation graphs, that combines network analysis with the classical clustering for the study of DNA microarray data. The algorithm depends on two parameters (the *correlation* and *clustering* thresholds), resulting in an effective ability to analyze the sensitivity of the results in response to the particular configuration chosen.

The algorithm is based on the concept of “curvature” (Eckmann & Moses, 2002; Watts & Strogatz, 1998) applied to the network (correlation graph) of co-expressed genes, where the nodes are the genes (or samples) and the edges represent the co-expression between linked genes. Then a certain number of clusters are identified that correspond to connected components of the graph with a high clustering index, defined as the local density of triangular relations (Collet & Eckmann, 2002). The clusters of genes (or samples) are the densest regions of the correlation graph; communities with high clustering index are low-entropy structures, with obvious biological relevance.

The algorithm has been implemented in *Mathematica* (due to its intrinsic computational power and functional paradigm) and applied to some publicly available datasets: *Saccharomyces cerevisiae* (Eisen *et al.*, 1998) and DLBCL lymphoma (Alizadeh *et al.*, 2000). The computational performances obtained are comparable to those required by Hierarchical (Jain *et al.*, 1999) and Markov Clustering (Van Dongen, 2000).

The Clustering Algorithm

A set of DNA microarray data consists of expression levels of N genes in M different experimental conditions (RNA samples). The algorithm (based on the correlation graph approach) is articulated according to the following steps.

1. Read input DNA microarray data X .
2. The $N \times N$ correlation matrix P is defined on all pair of genes $x_{k,l}$ ($k, l = 1..N$) whose elements are computed using the Spearman’s rank correlation coefficient¹:

$$\rho_{k,l} = 1 - \frac{(6 \times \sum_{j=1,M} d_j^2)}{(n^2 - 1)n} \in [-1, 1]$$

where

$$d_j^2 = x_k(j) - x_l(j).$$

Let θ a fixed threshold defining a range of symmetrical comparison $(-\theta, \theta)$. Construct the square adjacency matrix A between genes whose elements $a_{k,l}$ ($k, l = 1..N$) are defined as follows:

$$\begin{cases} a_{k,l} = 0 & \text{if } \rho_{k,l} \in (-\theta, \theta), \\ 1 & \text{otherwise} \end{cases}$$

3. A correlation (undirected) graph G is constructed from the adjacency matrix, with edge weights equal to the correlation coefficients $\rho_{k,l}$.

4. Each node i of the correlation graph has an associated clustering coefficient $c(i)=2\alpha/\beta(\beta-1)$, where α is the number of real and β is the number of possible triangular clusters for node i .
5. Let $\gamma \in [0,1]$ (clustering threshold). From the graph G we induce a subgraph H made of all nodes $i \in G$ (and related edges e) with “relaxed” clustering coefficient $c_r(i)$ greater than or equal to γ .

$$H = \{\text{nodes } i \in G \text{ and related edges } e: c_r(i) \geq \gamma\}$$

The “relaxed” clustering coefficient for a node i is given by the maximum among its clustering coefficient $c(i)$ and those of the nodes directly connected to it: this gives a “tethering” effect by the surrounding nodes, better taking into account the complex structure of the relations between the (correlation) graph nodes than the simple clustering coefficient of each node.

6. From the subgraph H we extract all connected components (made of at least two linked nodes) representing the classes (clusters) identified by the values chosen for thresholds (algorithm’s parameters) θ and γ .

To better understand how the algorithm operates with thresholds θ and γ you may think of the initial graph G as a mountain range. The clustering threshold γ is the fog extending up to a certain height and clusters are emerging mountain peaks. Varying the correlation threshold θ means changing the soil structure, while γ only raises or lowers the fog level and, therefore, modifies the existence and relative size of clusters.

ANALYSIS OF GENE EXPRESSION PROFILES: EXAMPLES

Analysis of Gene Expression Profiles in *Saccharomyces cerevisiae*

Figures 3 and 4 represent the computed results based on the expression profiles of 6,221 *Saccharomyces* genes, crossed with 80 available samples. Even with relatively high values of correlation and clustering we obtain well-defined clusters. Figure 1 represents the final subgraph with correlation $\theta = 0.90$ and clustering $\gamma = 0.70$ derived from an initial graph with 1,917 links. Note that only 237 of 6,221 genes (3.81%) have a nonzero clustering coefficient. Figure 2 shows the subgraph corresponding to $\theta = 0.80$ and $\gamma = 0.64$ starting from 19,026 links, with 1,112 genes (17.87%) showing nonzero clustering coefficient.

Many of the obtained clusters have an acceptable biological basis. For example, Cluster #7 of Figure 3 and Cluster #13 of Figure 4 contain (with obvious differences) almost all the genes for the production of histones: This cluster is quite stable against the variation of threshold parameters. Larger clusters have also been detected, such as the cluster of protein synthesis (Cluster #10 of Figure 3 and #2 of Figure 4). The latter is likely to vary substantially with varying thresholds, and can end up with including hundreds of genes.

Figure 5 shows a visual comparison of a particular cluster belonging to graphs of Figures 3 and 4. This comparison shows how the two-dimensional clustering analysis here implemented with correlation graphs poses a greater resolution detail in carrying out the clustering of the genes involved. This turns out to be an important factor for an adequate biological study, eliminating during analysis those links between genes that appear to be not too strong to resist a greater resolution level.

*Figure 3. Correlation graph of genes in *Saccharomyces cerevisiae* with $\theta = 0.90$ and $\gamma = 0.70$*

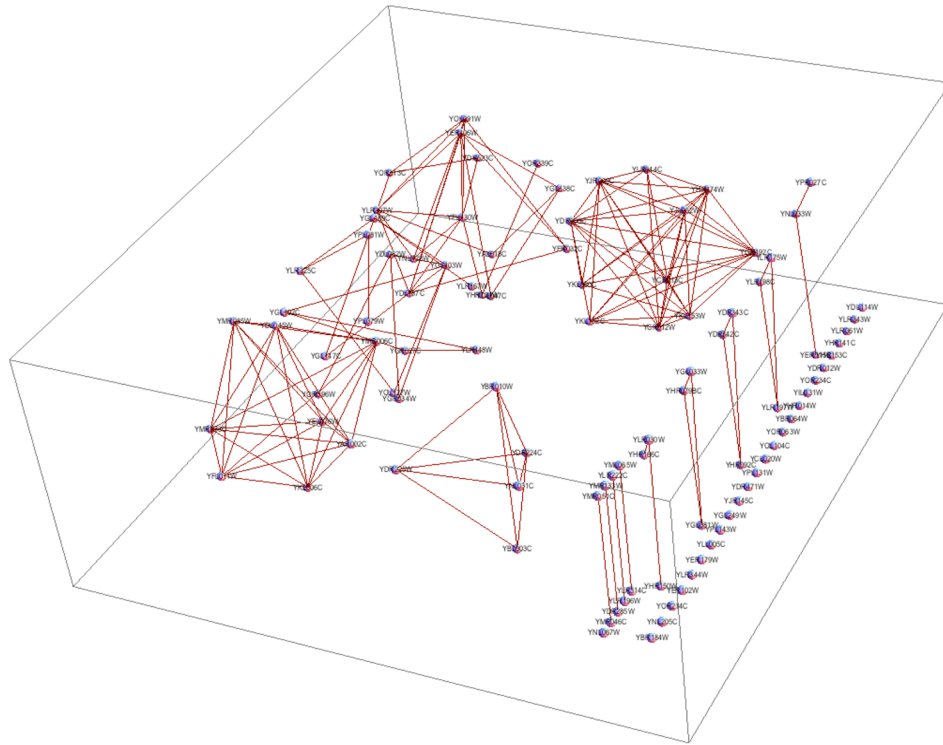


*Figure 4. Correlation graph of genes in *Saccharomyces cerevisiae* with $\theta = 0.80$ and $\gamma = 0.64$*

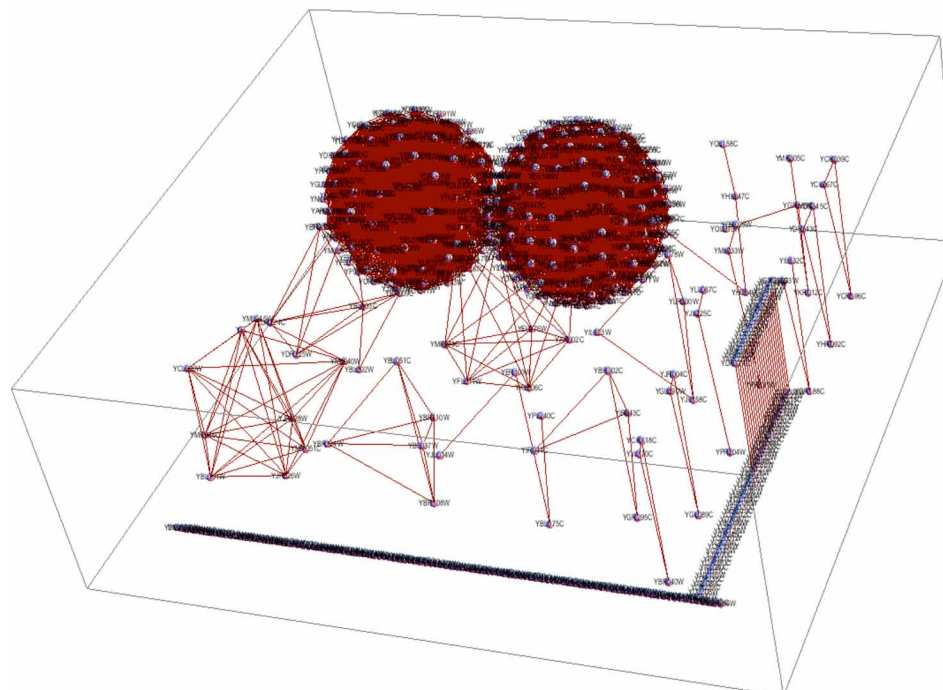
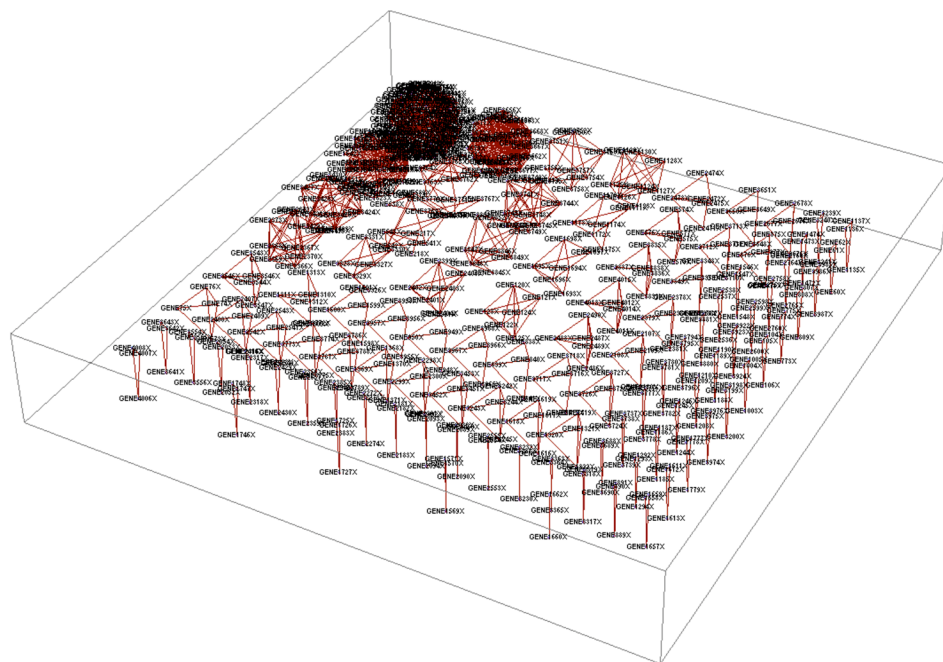


Figure 7. Correlation graph of genes in Lymphoma with $\theta = 0.80$ and $\gamma = 0.24$



Classification obtained with $\gamma = 0.40$ shows in Cluster #75 a group of under-expressed genes in CLL (Chronic Lymphocytic Leukaemia) tumors. With $\gamma = 0.24$ Cluster #76 represents a group of over-expressed genes in DLCL (Diffuse Large B-Cell Lymphoma) tumors.

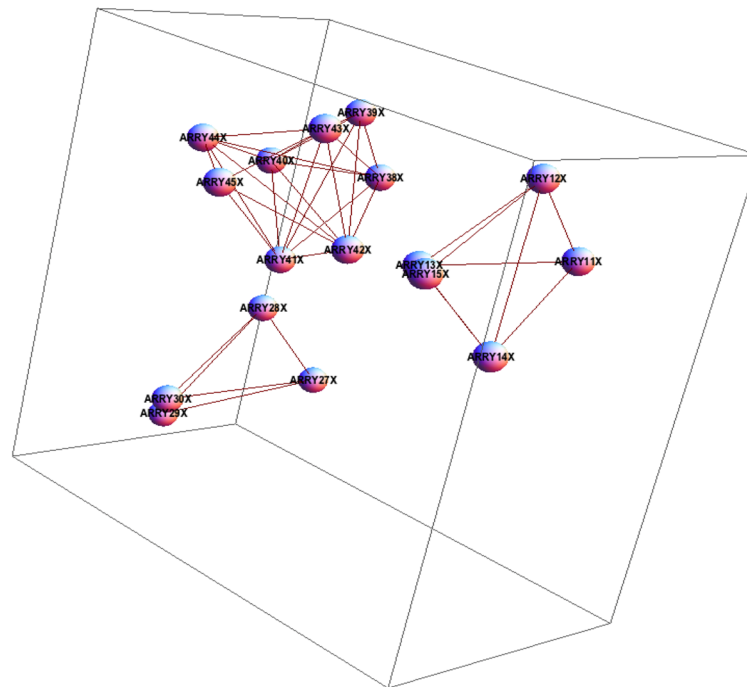
Lymphoma Samples' Analysis of Expression Profiles

Figure 8 shows the classification based on 96 samples of the lymphoma data set (this is the transpose of the gene expression matrix, made of 96 rows and 4,026 columns). The thresholds are $\theta = 0.60$ and $\gamma = 0.30$. There are 17 samples (17.71%) with nonzero clustering coefficient, with 58 initial links. The clusters obtained are clearly identified and are associated with a single sample subtype: Cluster #1 corresponds to T-cells sample, Cluster #2 to FL (Follicular Lymphoma) and Cluster #3 to CLL.

CLUSTERING MICROARRAY DATA WITH NEURAL NETWORKS

The clustering analysis with neural networks has been implemented on the same input data on which the classification was carried out using correlation graphs, that is the gene expressions in *Saccharomyces cerevisiae* (Eisen *et al.*, 1998) and DLBCL lymphoma (Alizadeh *et al.*, 2000).

Figure 8. Correlation graph of Lymphoma with $\theta = 0.60$ and $\gamma = 0.30$



Clustering Gene Expression in *Saccharomyces cerevisiae*

The search for gene expression clusters in *Saccharomyces* fulfilled through unsupervised neural networks provides the basic tool for performing an additional analysis to that of the correlation graphs. Obviously there are some differences.

The analysis carried out with unsupervised neural networks needs to ensure that all possible genes of our original data set are put into predicted clusters. This means classifying 6,221 genes and looking for, in the aggregate source, the biological meaning of that classification.

Figure 9 shows the fitting parameters of the neural network and the average distance obtained. The latter turns out to be 3.8085 and all genes are partitioned into 14 clusters. From this point of view, the correlation graphs' algorithm offers an advantage over the analysis made with neural networks: With the ability to intervene on two thresholds you obtain a greater "filtering" in the analysis of results.

Classification of *Lymphoma* Samples

In this section we focus on analyzing the lymphoma dataset by observing samples with reference to genes. In this context, Figure 10 shows the characteristic elements of the unsupervised neural network in the various clustering iterations, with an average distance equal to 43.1945.

Figure 9. Classification of Saccharomyces cerevisiae: Initialization graph and training of (SOM) unsupervised neural network's parameters

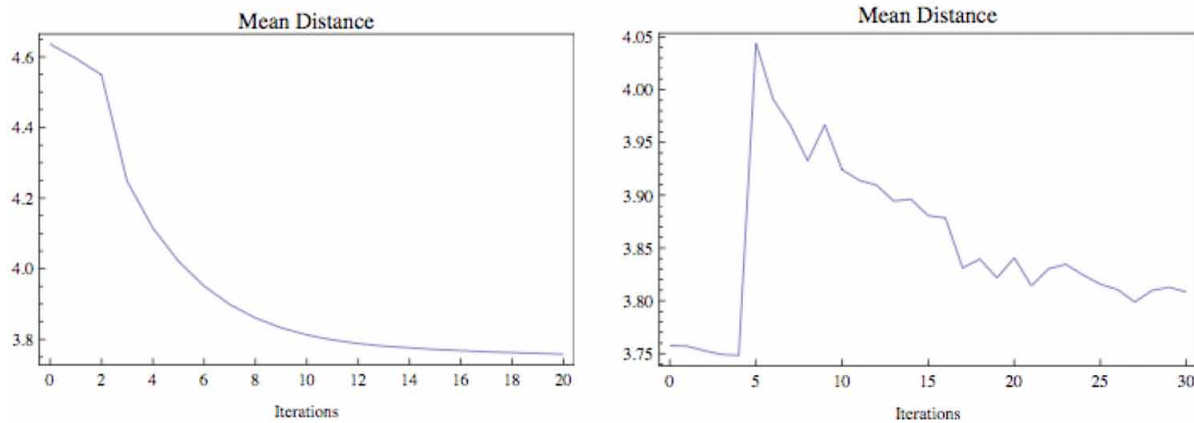
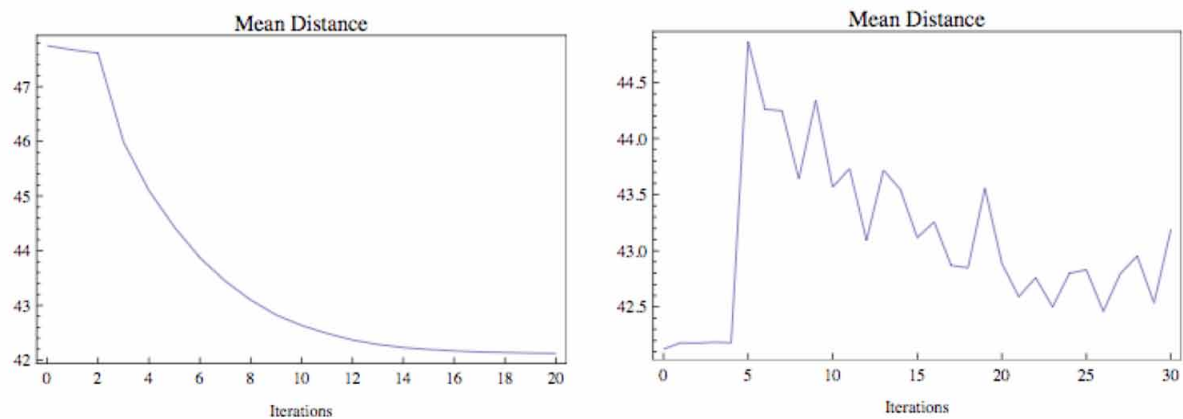


Figure 10. Classification of Lymphoma: Initialization graph and training of (SOM) unsupervised neural network's parameters



FUTURE RESEARCH DIRECTIONS

By identifying combinations of genes that “cooperate” in order to obtain specific bio-logical results, it is possible to identify such genes more attractive for future research and, potentially, specific drug targets to improve the quality of the therapeutic tools available. This can be done by:

1. Filtering those genes that are more up/down-regulated (differentially expressed), and thus possibly responsible for outbreak of disease, and
2. Discovering gene groups possibly associated to different pathological states.

To illustrate the performance of the methodology, we applied it to two independent datasets from patients with various disease subtypes. The results show the validity of the proposed approach and the selection of key deregulated genes recently reported in the literature.

CONCLUSION

It is increasingly accepted the hypothesis that complex diseases are the result of events that occur in various ways. Through the development of computational tools that detect the involvement of multiple genes interacting with each other in specific experimental situations, you can provide solutions that go beyond the capacity offered by those dealing with single genes.

In this chapter we illustrate the analysis of DNA microarray data obtained from the expression of multiple genes, using both special parametric clustering (correlation graphs) and classification techniques with artificial neural networks. The greatest usefulness of the classification procedure described here and its computational approach is that it requires no prior knowledge of the specific functions of genes or interactions between them to produce meaningful results. Instead, it represents an appropriate means of exploring genomic “situations” not yet well investigated, a target within the reach of the individual researcher with the power and flexibility of the computing environments now available.

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KEY TERMS AND DEFINITIONS

Algorithm: An algorithm is a procedure that solves a given problem by a finite number of steps. A problem solved by an algorithm is said *computable*. The term “algorithm” is derived from the Latin transcription of the name of the Persian mathematician al-Khwarizmi, which is considered one of the first authors to have made reference to this concept.

Artificial Neural Network: ANNs are mathematical models that represent the interconnection between elements defined artificial neurons, i.e. mathematical constructs that to some extent mimic the properties of living neurons. These mathematical models can be used both to obtain an understanding of biological neural networks, but even more to solve engineering problems of artificial intelligence such as those that arise in various technological fields (in electronics, computer science, simulation, and other disciplines).

Bioinformatics: Bioinformatics is a scientific discipline devoted to the solution of biological problems at the molecular level with computer methods. It is an attempt to describe, in numerical and statistical terms, biological phenomena with a set of analytical and numerical tools. In addition to information technology, bioinformatics uses applied mathematics, statistics, chemistry, biochemistry and concepts of artificial intelligence. Bioinformatics mainly deals with providing valid statistical models for the interpretation of data from experiments in molecular biology and biochemistry in order to identify trends and numerical laws; generate new models and mathematical tools for the analysis of sequences of DNA, RNA and proteins in order to create a body of knowledge concerning the frequency of relevant sequences, their evolution and possible function; and organize the knowledge acquired at the global level of genome and proteome databases in order to make such data accessible to all, and to optimize the data search algorithms to improve accessibility.

Cluster: Natural subgroup of a population, used for statistical sampling or analysis.

Clustering: Clustering or cluster analysis is a set of techniques of multivariate data analysis aimed at selecting and grouping homogeneous elements in a data set. Clustering techniques are based on measures relating to the similarity between the elements. In many approaches this similarity, or better, dissimilarity, is designed in terms of distance in a multidimensional space. Clustering algorithms group items on the basis of their mutual distance, and then the belonging to a set or not depends on how the element under consideration is distant from the collection itself.

DNA: Deoxyribonucleic acid (DNA) is a nucleic acid that contains the genetic information necessary to the biosynthesis of RNA and protein molecules essential for the development and proper functioning of most living organisms. The order in the sequential arrangement of the nucleotides A, T, C, G represents the genetic information, which is translated with the genetic code in the corresponding amino acids.

DNA Microarray: A DNA microarray (commonly known as gene chip, DNA chip, biochip array or high density) is a collection of microscopic DNA probes attached to a solid surface such as glass, plastic, or silicon chip forming an array (matrix). Such arrays allow to simultaneously examine the presence of many genes within a DNA sample (which often can also represent the entire genome or transcriptome of an organism). A typical use is to compare the gene expression profile of an individual patient with that of a healthy one to identify which genes are involved in the disease.

Gene: The gene is the fundamental hereditary unit of living organisms. Genes correspond to portions of the genetic code localized in specific positions within the sequence (DNA or, more rarely, RNA) and contain all the information necessary for the production of a protein. They are contained and organized within chromosomes, present in all cells of an organism.

Gene Expression: In the field of molecular biology, gene expression profiling is the measure of the activity (expression) of thousands of genes at a time, to create a global picture of cellular function. These profiles can, for example, distinguish between cells that are in proliferation, or show how the cells react to a particular treatment. Many experiments of this type measure an entire genome simultaneously. DNA Microarray technology measures the relative activity of target genes previously identified.

Pattern: In biology with pattern (sometimes “profile”) one refers to different types of regularity, such as the regularity of the biological sequences of DNA or proteins that allow the recognition and specific binding between molecules, or the regularity in the level of expression of the genes of cells which allow the recognition of different experimental cell types including tumor cell types, or the regularity in the events that occur during processes such as the development of an organism, or even the regularities in the behavior of animals.

ENDNOTE

- ¹ Spearman’s rank is more robust than Pearson’s correlation coefficient if there is a non linear correlation between data when data are not normally distributed.

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Chapter 4

Concerns and Challenges of Cloud Platforms for Bioinformatics

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ABSTRACT

Bioinformatics traditionally concerns applying computational approaches for the management and the exploitation of large volumes of biomedical data that continues to expand in size and in distribution. Although the application of cloud computing in biomedical areas is still preliminary, an increasing number of biomedical applications rely on the Cloud for processing large datasets. This chapter investigates the extent to which cloud technology offers a viable platform for developing and deploying applications that support users in searching and integrating information offered by bioinformatics resources. The chapter outlines the basic features that such computing applications should exhibit and the challenging issues they deal with. The architecture and the functionality of the cloud-based environments are presented to stress how cloud platforms could offer added-value service components and flexibility that make their adoption attractive for bioinformatics.

INTRODUCTION

In recent years, computer advances have played an important role in promoting scientific research in biological areas such as genomics, proteomics and other “-omic” subfields which rely heavily on suitable computational infrastructures for managing large-scale data. In particular, the flood of data from genome sequences has given rise to “bioinformatics”, an interdisciplinary research domain which employs a wide range of computational techniques derived from scientific disciplines (such as statistics, machine learning, applied mathematics etc..) for managing biological data. To get to understand the current application fields of bioinformatics, it is necessary to consider the following aspects.

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A first aspect is about the massive production and spread of biological data around the web. Generated within a short period of time and stored in a growing number of web resources, the increasing amount of biological data has introduced new challenges about its management and exploitation.

For example, thanks to next generation sequencing instruments and ICT advances, areas of life sciences that were previously distant from each other (in the ideology, analysis practices, toolkits etc.) are now able to share and analyze data in transparent and reproducible fashion. This interdisciplinary research task calls for the integration of information with multiple levels of granularities from several web resources that often represent information and data in different ways.

In this respect, bioinformatics increasingly deals with providing technical approaches to support interdisciplinary scientific knowledge which relies on working with concepts from different areas in constant evolution and more and more requires experimental techniques, scientific approaches and collaborative management of data (Bosin, Dessì, & Pes, 2007).

A second aspect is about recent advances in computer science that significantly influence the development of computational tools in bioinformatics. Specifically, the service-oriented paradigm has provided a new way of thinking biological resources in terms of computational infrastructures by positioning services as primary functional elements for data integration. Several biomedical organizations (such as the National Center for Biotechnology Information (NCBI) and The National Center for Biomedical Ontology (NCBO)) provide web portals that expose Web services for searching data. Existing techniques for web content classification, search, and visualization seem to be actually inadequate to satisfy the biologist's needs because accessing these heterogeneous systems from the Internet is not straightforward without the availability of standard and common interfaces.

In this respect, bioinformatics research is devoted to search explicit and automatic ways of joining information to improve the usability of web resources.

Finally, the rapid development of the Internet has provided an opportunity to investigate about the use of state-of-the-art technology for the construction of a new generation of tools that integrate plain data sources, public programmable APIs and any kind of available services. Usually referred to as Web2.0 applications, these tools rely on open APIs or reusable services. The availability of biomedical ontologies dramatically increases the range of benefits and the usages derived from these applications that often support a deeper analysis of data by taking into account the semantic information (Dessì, Pascariello, & Pes, 2014).

Considering the aforementioned aspects, it is clear that bioinformatics research addresses three main challenges namely:

1. Storing and analyzing large amount of heterogeneous data.
2. Enabling knowledge extraction from several web resources and collaboration through user-friendly interfaces.
3. Promoting solutions for offering different categories of services to end-users.

Nowadays, the cloud computing paradigm represents a primary solution to these challenges as it extends the role of the Internet to enable a new form of distributed system for large-scale data processing.

As significant component of the Web 2.0 world, Cloud computing expresses a service-based architecture where computing services are delivered on-demand to customers over a network in a self-service fashion that is independent of device and its location. This innovative technology enables the introduction of new computational paradigms that could have a great influence on facing the above challenges. The

application of cloud computing in bioinformatics is still preliminary, although an increasing number of biological applications is relying on the Cloud for processing large datasets (Calabrese & Cannataro, 2016; Schadt, Linderman, Sorenson, Lee, & Nolan, 2011). Conversely, few works have been done to explore the use of architectural cloud-based solutions (Mrozek, 2015).

This chapter aims at investigating the extent to which cloud technology offers a viable platform for developing and deploying applications that support users in searching and integrating information offered by bioinformatics resources. The chapter outlines the basic features that such computing applications should exhibit and the challenging issues they deal with. The architecture and the functionality of the cloud-based environments are presented to stress how cloud platforms could offer added-value service components and flexibility that make their adoption attractive for bioinformatics.

The chapter also sketches some application scenarios that illustrate the potential of cloud-based environments for integrating information from multiple web resources, including biomedical portals.

BACKGROUND ON CLOUD COMPUTING

Cloud technology endows users with a service-based environment that provides hardware and system components and refers to software applications delivered as services over the Internet (Lin, Fu, Zhu, & Dasmalchi, 2009).

Cloud resources are usually organized into bottom-up layers, depending on the type of service:

- **Infrastructure-as-a-Service (IaaS):** Provides suitable hardware, including physical servers and network bandwidth services directly to end users which do not own enough processing power, storage capacity, applications to meet their needs. These resources can be ‘rented’ from a cloud provider on an as-needed basis and accessed from anywhere via an Internet connection. Cloud services employ a metering system that divides the computing resources in appropriate blocks and users pay for the service as an operating expense without incurring any significant initial capital costs.
- **Platform-as-a-Service (PaaS):** Provides a hosting platform in which users are allowed to develop applications without dealing with software issues such as operating system upgrades, implementation of compilers, installation and maintenance of databases etc.
- **Software-as-a-Service (SaaS):** It basically means that the software is available on demand, most of which is browser-based and devoted to a specific function. SaaS applications are often priced by a rental fee, which includes the application software license fees, software maintenance, and technical support costs.

Although provided at different levels, Cloud Services communicate with each other and are self-contained i.e. each service provides the same functionality, independently of other services. The global infrastructure offered by a Cloud environment is made possible by abstracting the physical resources (i.e. storage, memory, network etc.) so that multiple operating systems can run on a single hardware platform concurrently. Commonly referred to as virtualization, this abstraction is based on technologies that greatly improve resource utilization and offer several key advantages, such as a low entry cost to use compute-intensive resources, a pay-per-use model, a high scalability that is dynamically adjusted according to user demand.

The cloud computing platform composes of thousands or even tens of thousands nodes, which provide mass data storage, management and processing. Because these dynamically scalable and virtualized cloud resources are provided as services, users are not required to have expertise nor knowledge or control over the technological structure that supports their tasks.

THE DRIVING FORCES OF CLOUD COMPUTING IN BIOINFORMATICS

Cloud Computing could offer many *added-value services* that previous solutions do not have. In fact, the primary difference is that offerings and services are not located in house, but outside the bioinformatics organization. As reported by Chae, Lee, Marru, Lee, & Kim (2013), a significant number of research institutions are experiencing the capacity limits of their computing facilities. Additionally, collecting and configuring suitable tools and resources for certain research purposes is non-trivial job, even for expert developers. By adopting cloud technology, bioinformatics organizations could avoid the installation and management of software on their own computers and benefit from centralized and automatic software updates. The ease of access, to and from cloud-based resources, promotes the use of cloud-based strategies such as MapReduce a run time system which automatically partitions input data and schedules the executions of programs for large datasets in a large cluster of commodity machines (Taylor, 2010).

As well, its open-source implementation Hadoop has a widespread adoption in bioinformatics. Moreover, cloud paradigm promotes the development of biomedical applications specifically designed to take advantage of cloud infrastructure. Meanwhile, new functionality could be provided, the usage of cloud-based services can be scaled up and down smoothly without the need for upfront cost. Finally, cloud technology helps break the barriers between different web applications.

Recent work in bioinformatics addresses the *flexibility* of the services provided at IaaS layer for the deployment of data intensive applications such as processing high throughput sequencing data or executing intensive analysis algorithms (Zhang, Gu, Liu, Wang, & Azuaje, 2012; Hung & Lin, 2013). These applications get as many machines as the analysis of data needs and automatically scale up and down the hardware resources based on dynamic workloads. Conversely, in distributed processing environments, it is difficult to distribute and co-ordinate a large-scale job on different machines, run processes on them and install additional machines to recover if one machine fails. Cloud technologies remove such technological concerns from the users.

A less explored level of cloud services is PaaS which focuses on building applications such that:

1. Draw the necessary resources on-demand (like compute servers or storage),
2. Perform their tasks, and
3. Relinquish the unneeded resources after a task is done.

Everything is automated and operates without any human intervention by taking advantage of simple APIs of Internet-accessible services that scale on-demand.

A relatively few number of bioinformatics applications exists which has been developed at PaaS layer, although PaaS based solutions should be an added value for the biological community. In particular PaaS applications are attractive for small bioinformatics organizations and research groups that are allowed to benefit from the most advanced technology available today at lower costs and lower risk. Indeed, the

Concerns and Challenges of Cloud Platforms for Bioinformatics

upfront investment is low, they don't need to invest in software / hardware, licenses and renewal costs are kept to a minimum and they only pay for what they use.

As such, PaaS based solutions can offer a powerful and flexible alternative for bioinformatics applications.

Two significant concerns must be addressed before moving data and bioinformatics applications to a cloud environment: the security of information and the bottlenecks of data transferring.

- **Information Security and Privacy:** The scalability and the easy access to cloud resources increases the risk of security of data that have security requirements out of the ordinary such as medical records, clinical data from human studies etc. The storage of such data on publicly accessible servers requires the definition of security rules to protect data security and privacy. For example, mechanisms such as encryption measures and role-based access control models should be deployed on the Cloud respecting both the typicality of biological data and the requirements of scientists in sharing such a data. Differently from conventional web-based environments, the use of the Cloud for storing data and applications improves physical security as it enables the creation of separate virtual machines and firewalls for each independent application environment. Security professionals traditionally recommend partitioning a system as a means of protection. The ease of creating new virtual machines provides ways to improve the security of hosted data by partitioning resources into separate areas, conferring protections against attacks.
- **Bottlenecks of Data Transferring:** Cloud vendors store the backups of users' applications and data in multiple geographical locations. Although, cloud can provide extra processing resources during the peaks (within limits), transferring vast amounts of biological data to the cloud is a significant bottleneck in cloud computing (Grossman & White, 2012). Networking bandwidth limitation causes delays in data transfer and incurs high bandwidth costs from service providers. This cost is an important issue for biomedical institutions that require substantial data movement (on the order of terabytes and petabytes) on a regular basis. As a consequence, the use of cloud infrastructure currently does not make economic sense for applications that need to continuously export or import large volumes of data to and from the cloud.

APPLICATION SCENARIOS

Cloud computing has been applied successfully to deal with tasks that require substantial computational power. Some initiatives have already successfully incorporated the cloud to expedite data processing in next-generation sequencing, comparative genomics and proteomics (Krampis et al., 2012; Sudha Sadasivam, & Baktavatchalam, 2010).

With the emergence of readily available cloud platforms, software developers have the opportunity to move one step closer towards the search and integration of information from the wide range of biomedical web resources.

In exploring these resources, biologists are not interested in the large amount of their content. Conversely, they distill a huge amount of data from multiple web sources in order to obtain key information that focuses on a single class of concepts (e.g., only gene products). Because biological information encompasses many domains of knowledge, the success of the user's depends on his ability in browsing information that is stored in several web sites that exhibit diverse organization, terminology, data formats.

For example, consider a user who investigates about the role of thyroid hormones administration in the treatment of the heart failure. He has to translate his problem in a set of concepts that meet the taxonomy of terms defined by the curators of the web resource he navigates. Often, the concepts of interest don't belong to a single taxonomy. Often, the concepts of interest don't belong to a taxonomy exploited by a single web site. In this case, unearthing specialized information from different web resources can be complex, time consuming and daunting. Moreover, the user must learn and remember the navigation paths of each specific web site he visited. Finally, different biomedical web portals implement the same basic functionality and are often concerned with overlapping information.

The design of applications for effectively support the users in searching biomedical resources must consider three fundamental questions. First, how to integrate structured, semi-structured and unstructured available data with diverse and sparse schemas? Second, how to retrieve meaningful information in an easy and efficient way? Finally, how to implement a searching infrastructure which has to scale, hence change, to meet new requirements stemming from the growth of its searching domain?

The adoption of the Cloud computing makes it easy to exchanging and integrating data amongst multiple service providers via high quality, interoperable services offered in a "neutral" territory by the cloud infrastructure. As it happens for web engines, these services act as specialists which search for data exposed by biomedical organizations via public programmable APIs and return real-time information.

These circumstances can be addressed by implementing PaaS applications that broaden the spectrum of use of the cloud paradigm and encloses the adequate environment for building applications that harvest the full potential of this technology. Typically, this programming environment includes components such as programming languages, web servers, and databases that are not lightweight for most biologists or people with no or limited programming experience. A recent major development is Google App Engine (GAE), a PaaS environment that allows users to quickly develop and run any web application on Google's infrastructure while benefiting from Google services, such as search, e-mail, geographic maps and social networking (Google App Engine. Documentation). GAE applications scale as the traffic and the data storage vary. The use of the basic services is free and users pay only for increased level of services that are delivered over network connection. Within GAE, the data management relies on Datastore a NoSQL database which supports data storage service distribution. Unlike a traditional relational database, a NoSQL database supports operations (i.e. create, read, update, delete) to manage structured objects by means of an SQL-like language (Stonebraker, 2010). Typically, PaaS delivers a software environment to deploy and run applications where cloud resources scale automatically and developers do not need to know how many resources are required nor to assign resources manually in advance. As well, the PaaS environment eases the rapid development of new software components and the introduction of new functionality in existing PaaS applications. Indeed, the PaaS applications promote the event-driven integration of data from heterogeneous and distributed resources by providing convenient and on-demand access to web resources via Web Application Programming Interfaces (API) without the necessity to know where the services are hosted or how they are delivered.

The development of PaaS applications involves substantial changes in the current styles of software development. Specifically, instead of being conceived as a set of procedural tasks, a PaaS application needs to be thought in terms of a framework which undertakes the responsibility of coordinating and organizing the search across different web resources by combining high level services offered by the cloud infrastructure and APIs that satisfy the application requirements.

As an example, BioCloud Search EnGene (BSE) is a PaaS application that facilitates searching and integrating biological information from public and large-scale genomic repositories (Dessì, Pascariello,

Milia, & Pes 2014) using web services provided by the National Center for Biotechnology Information (NCBI). Using BSE, users find their information of interest by means of a simple “Google-like” query interface that accepts the standard name of genes as keywords. The design of BSE is centered on the concept of dataspace, a new paradigm for the integration of heterogeneous data coming from a diverse set of sources, without an a priori schema and regardless their format and location (Dong & Halevy, 2007). A dataspace consists of a set of resources, namely the participants, and a set of relationships between them (Argiolas, Atzori, Dessì, & Pes, 2012). A fundamental part of a dataspace is the catalogue that contains information about the URL of the participants. Using suitable services exposed by participants, BSE provides integrated views of data over web resources by following the pay-as-you-go principle: data from participants are accessed as metered resources without the need to store them locally. Conceived as a multi-level index, the catalogue stores identifiers and annotations about genes, acquires and combines information from participants. The BSE’s user interface supports special templates, namely contexts, that hide the complexity of data searching by means of accordions i.e. a vertically stacked list of items. Each item represents a context and can be “expanded” or “stretched” in order to reveal additional contexts associated with it. Contexts are nested: the user who clicks on a gene’s identifier is redirected to a new accordion to explore new information about the searched gene.

FUTURE RESEARCH DIRECTIONS

Currently, the bioinformatics community mainly adopts the Cloud technology for storing and analyzing large sets of biological data. Hadoop (Taylor, 2010) is the most popular tool for organizing data-intensive analysis into cloud-based pipelines that are executed over multiple nodes. However, this approach remains difficult for biologists with limited programming skills. Therefore, future efforts should be devoted to building lightweight cloud environments that do not require extensive coding by keyboard and allow biologists to organize their work easily by drag and drop operations. In recent years, there has been much activity on the development of biomedical portals i.e. on specially designed web sites that bring information together from diverse sources in a uniform way. For example, BioPortal, is a popular web portal that provides access to a library of biomedical ontologies and RESTful Web Services that enable the incorporation of ontology content into software applications. Although the benefits of such portals are well documented, this explosion of biomedical resources generates impediments for researchers and clinicians when they try to discover the most appropriate information for the realization of their goals.

Perhaps, one of the major obstacles is the difference in the structure of portals: each portal has its own organization, terminology and data formats and the users have to expend an amount of cognitive effort in remembering navigation paths. Moreover, many biomedical portals implement the same basic functionality and are often concerned with overlapping information.

Because cloud technologies ease the access to diverse types of web resources via interoperable services, future research directions should face the problem of setting up a system of standards for data exchanges in order to facilitate the implementation of lightweight cloud applications that support data integration.

Over the past few years, WEB 2.0 technologies tried to enhance user interaction by promoting the use of flexible organizational systems (i.e. social networks, blogs and wikis) that have been introduced into current research practices. As well, recent technologies have evolved and new cloud environments are appearing that allow to reformulate the common investigation practices so that they can profit from a paradigm where domain experts (rather than programmers) organize the domain knowledge in an intuitive and

collaborative way (Dessì, Milia, Pascariello, & Pes, 2014) . From the medical or biological perspective, collaboration is attractive for many circumstances and consists well with the e-Science paradigm that envisions the scientific research carried out via internet (Bosin, Dessì, & Pes, 2011; Bauzer Medeiros & Katz, 2016) . So, future research efforts should be directed to build distributed research environments that support autonomy and intelligent coordination of researchers in creating and managing shared data and knowledge.

In recent years the technological world has grown thanks to the incorporation of sensors, microcontrollers and transceivers for collecting and sharing real-world information. Internet of Things (IoT) is an information acquisition paradigm that defines such computer-based environments where each physical object is equipped with devices for interacting with each other and communicating with the users (Chaâri et al., 2016). By enabling continuous and ubiquitous access to information from any connected device over the Internet, IoT is leading to collect large amount of data from scientific experiments in life sciences and bioinformatics without an uniform way to share, process and understand context information. It is evident that IoT will only achieve its full potential when all the devices will work and learn together without human interaction. Without dedicated functionalities and organizational data structures there is a risk of creating the illusion that scientific advances can be supported by simply making available a greater amount of data. In this respect, it is crucial that bioinformatics starts devoting more attention to cloud technology as a technical structure enabling the organization and the knowledge extraction from these new information sources.

CONCLUSION

Cloud environments contrast sharply with traditional centralized computing platforms that are not only costly, but risk to become increasingly inadequate to meet the requirements of modern biologists. In particular, PaaS level can offer a powerful alternative for building applications that can be re-designed to take advantage of cloud infrastructure. Finally, cloud technology is not only an alternative to the traditional computing environments but occupies an its own niche: it transparently provides the biologists with pragmatic solutions to some open research issues such as big data storing and analytics, knowledge and data sharing, extracting and integrating information from different web resources etc. The above solutions are increasingly being suitable for many biologists and cloud computing is becoming a significant technology for developing a large variety of services which, most important, are exerting revolutionary influences on the whole scientific community.

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KEY TERMS AND DEFINITIONS

Application Programming Interface (API): An API specifies how software components interact in terms of its operations, inputs, outputs, and underlying types in a way that is independent of their respective implementations. APIs allows software developers to build programs as a set of building blocks whose functionality is provided by their corresponding APIs.

Biomedical Ontology: A structured representation of the knowledge by means of formal naming and definition of the types, properties, and interrelationships of the entities that really exist for biological research.

Computer Platform: The computer hardware and the operating system that conforms a set of standards enabling software developers to deploy software applications for the platform.

NoSQL Database: Modern databases conceived for web applications. Unlike a relational database, a NoSQL database does not store data and relationships in tables. Conversely, NoSQL databases are schema-free, distributed and horizontally scalable to clusters of machines i.e. the database is partitioned in a cluster of distributed database servers (each maintaining its own data and a self-contained schema) and it makes easy to add or remove, namely to scale, a single database server.

RESTful Services: In a distributed computing environment, the Representational State Transfer (REST) architecture allows clients and servers to interoperate by using a standardized interface and protocol using a uniform set of simple and well-defined operations. Resources are manipulated using a fixed set of four create, read, update, delete operations: RESTful web service exposes a set of resources identified by URIs and manipulated using a fixed set of four operations (i.e. create, read, update, delete).

Web 2.0: A recent new vision of the Web that enhances collaboration and interaction of users with each other. Unlike traditional Web sites where users had a passive role in viewing information, Web 2.0 environments (such as social networks sites, blogs, wikis etc.) are grounded on user-generated content and foster people to social media dialogue.

Web Service: A Web Service allows two resources to communicating each other over a network Internet for transferring machine readable file formats such as XML and JSON in a manner prescribed by its interface.

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Section 2

Biology

Chapter 5

GWAS as the Detective to Find Genetic Contribution in Diseases

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ABSTRACT

Genome-wide association study (GWAS) is a powerful method to understand the complex association of variant in gene and disease phenotype. With the approach of GWAS, the traditional “one gene to one disease” belief has been taken to another dimension where a rather complex scenario of many possible causal agent (polymorphisms) behind disease onset is explicitly explored. It also gives the liberty to monitor the difference at each point of DNA for each individual in the sample. GWAS is powered with genome mapping projects and depends on stringent statistical analysis that detects the association of polymorphisms to disease phenotype after comparing the samples collected from afflicted and un-afflicted population. However, this method also has its own limitations. But with careful experiment design and unbiased analysis this GWAS, in near future, will become a new edge technology to decipher the disease mechanism so that effective therapeutics, tailored for specific cases can be developed.

INTRODUCTION

In the era of unprecedented advancement in medical and technological sciences, Garrod A.E., a physician to the Hospital of Sick Children, in the year of 1902, reported a case of alkaptonuria that he described as “not the manifestation of disease but is rather of the nature of an alternative course of metabolism...”. That was the first report where the possibility of underlying “molecular evidence” behind human disease came in the lime light. Human diseases and their genetic contribution share a complex and intricate relationship, yet to be explored fully. For few cases, phenotypes (diseased condition) could directly be

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associated with gene, experimentally, whereas a large number of genetic associations behind disease state remained hidden.

That called for a situation where mapping of gene knowledge between afflicted and un-afflicted individuals can be mapped to find out the difference at each point (each nucleotide position or *allele* or *variant*) and the number of occurrences of the mismatched alleles in the diseased individuals (*allelic frequency*) with an assumption that if any allele has higher frequency to appear in the diseased individual then that is associated with the diseased trait. That can be translated as ‘scan through entire gene’ for gene to disease relation mapping or rather, as genetic language, *Genome Wide Association Study* (GWA or GWAS).

These GWAS data not only provide us with the information on the disease association with the gene level knowledge but also enable a deeper understanding of the entire scenario generating a landscape of gene with its minute changes that can be extrapolated to genes coding (impact on protein production) or non-coding regions (impact on protein production regulation), the transcription factor binding sites (regulating transcription), epigenetic modification probabilities (regulation in genetic coding), pathways involved (visualizing the upstream or downstream possible effects) extending to heritability of the diseases. These all impose final impact on the phenotype which is nothing but the diseased state to us. Thus, insight generated with GWAS leads us to understand the actual reason or mechanism behind disease onset that, in turn, guides scientists to find novel druggable targets for more efficient medications or some times, to look for personalized medications (Bush & Moore, 2012).

With the completion of Human Genome Project (human DNA sequence) in 2003 (International Hap-Map Consortium, 2003) and the International Hapmap project (haplotype map of the human genome) in 2005, scientists are well-equipped with resources to correlate genetic contribution to disease onset. Success of the GWAS reflects in identifying the genetic factor contributing to Parkinson’s disease, Crohn’s disease, type 2 diabetes and obesity to name a few. These GWAS data can also be accessed through various repositories. However, its smaller variant size, unavailability of replicated reports, smaller population size under study stand as limiting factors to uncover a larger portion of genetic information to understand properly. With the rapid advancement in research, these limitations will be overcome to generate a better understanding of the entire scenario of disease with GWAS concept.

BACKGROUND

Life material nucleus i.e. DNA is composed of four basic entities and they are: the purines: Adenine (A), Guanine (G) and the pyrimidines: Cytosine and Thymine (T) arranged in a specific pattern that carries information of life. DNA is double helical element where these purines and pyrimidines pair up with each other (A with T and C with G). The complex of different DNA stabilizing and regulatory molecules (protein, RNA etc) along with DNA is collectively known as Genome. Since not only the presence of these basic entities but also their relative position is crucial to maintain the information for life and its sustainability, small variation of these elements (mutation or polymorphism or SNPs) at any of the otherwise conserved position on DNA has been found to bring change in the system. In Pre-GWAS (Ertekin-Taner, 2010) era researchers managed to characterize the genetic association behind disease that followed a Mendelian pattern of inheritance that largely depended on generation wise co-segregation of causal variants with marker alleles that simply followed Hardy-Weinberg Equilibrium. Cause to genetic variation was thought to be chromosomal cross over at chiasmata during meiosis. To explain, suppose,

a family or rather a pedigree of a population was studied for a disease that was found to be occurring due to certain enzyme mutation. This, at that time, was considered to be the candidate gene and was followed by characterization, identification of mutated allele as well as developing therapeutics against it. But there could be number of possible reasons behind genetic variation within or among the population, random mutations being the ultimate source of genetic variations. Along with that not only inheritance but also other effects including environment, living style, age etc contribute significantly to genetic changes. And these also can contribute to disease state if the changed allele gets a higher frequency in diseased population than in healthy population. But during GWAS era scientists actually received the scanned report of entire genome that helps understanding the complex relation of DNA level mutation and disease phenotypes. As for human cases, each disease may require looking at hundreds or thousands of positions to identify SNPs and associated genes that may contribute to risk of developing a certain disease. Increasing evidences show that GWAS represents a really powerful technique to identify these marker alleles at relatively higher speed and precision. GWAS is based on linkage disequilibrium (LD) principle where loci that are physically close together show stronger LD than the loci that are far apart (Visscher, Brown, McCarthy, & Yang, 2012). The strength of LD for an effective population size also decides the number of genetic markers required to specify the haplotype. GWAS also hypothesizes the 'allelic frequency' of a rare variant will be in low LD with nearby common variant. As time advanced, GWAS started exploring different types of variations and linkage to disease for example rare variant identification through evolutionary model, copy number variation (CNV) that include deletion and/or duplication of DNA segments of diverse size and frequency.

WORKFLOW FOR GWAS METHODS

For any experiment to be successful, a well-structured experimental design is essential. GWAS is not exceptional in this case. It systematically follows basic steps (Figure 1), given below:

- **Sample Collection:** A large cohort collection (>1000) for case and control is essential for initial set up. Chip based microarray technology that assays 1 million or more SNPs from population under study are the crude source for GWAS sample size for measuring SNP variation. The technology, briefly, explores the hybridization property of DNA with the collection of microscopic DNA spots attached to a solid surface. It is also important to know the sample in details. Primarily there are two types of phenotypes: case/control pair (dichotomous; where the genetic variation has to be deciphered by comparing, like schizophrenia related SNPs) and quantitative traits (where the phenotype is measurable like blood group). Based on the sample type the source platform is selected and derived data is further taken for analysis. In this regard, quality control step for the data is very crucial to start with a good set of samples. GWAS files contain vast amount of data and thus are prone to error. Again different methods are adopted while generating the data by different cohorts which increase noise to signal ratio. To improve the quality of data and compatibility among cohorts it is necessary to have quality check for the sample that removes false positive cases (Psychiatric GWAS Consortium Coordinating Committee et al., 2009). Table 1 provides a short description of different technologies used for collecting data for GWAS. Advantages and limitations of each technique are also discussed.

GWAS as the Detective to Find Genetic Contribution in Diseases

Figure 1. Overview of GWAS experiment design. This is a schematic representation of GWAS data collection and further downstream analyses. The initial sample cohort should be at equal state ideally. Test set may contain heterozygous allele (shown in yellow). SNP are collected and deviated markers are statistically validated and functionally mapped.

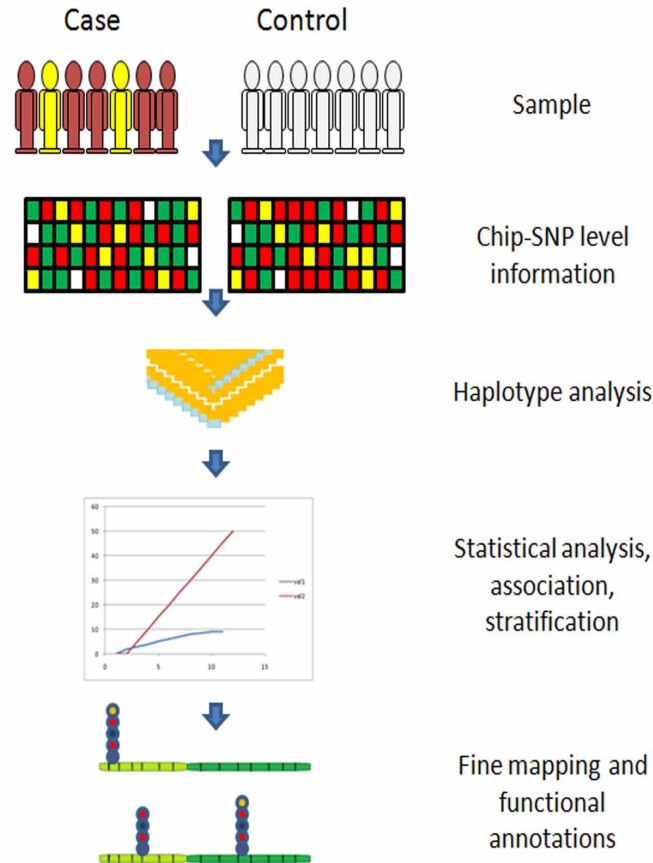


Table 1. Overview of technologies (including their respective advantages and disadvantages) used for GWAS

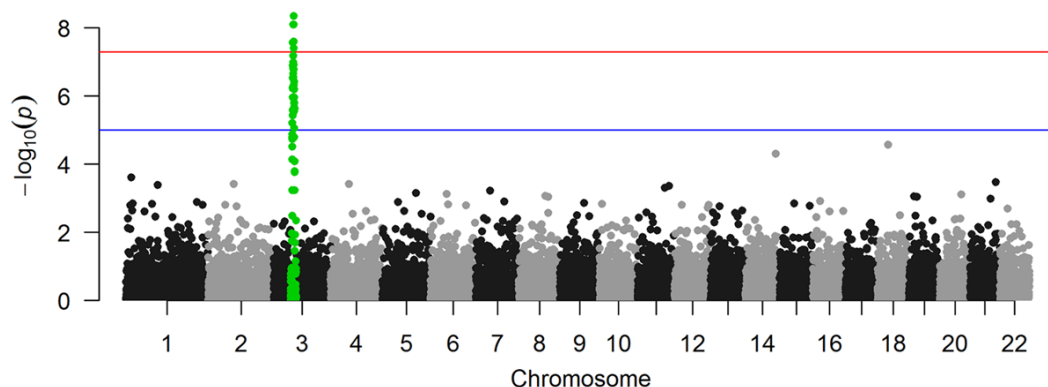
Sl. No.	Technology	Detectable No. of Markers	Advantages	Disadvantages
1	Whole Genome Sequencing	Around 35million or EXOME sequencing; around 3 billion for whole genome sequencing	Individual sampling data, better comprehensive information including non-coding (even intronic) SNPs	Selective applications, high cost and analytically challenging
2	Hap-Map genotyping	Hundreds of Thousands	High quality, cost effective, strong statistical association with diseases/ phenotypes	Chance of missing uncommon variants
3	RNASeq	Varies with samples and study designs	Detection RNA specific SNPs (both coding and non-coding), variations across expression levels can also be co-related	Dominance of common RNAs.
4	1000 genomes based platforms	Millions	Systemic assessment of all variants including uncommon ones	Require multiple testing, accuracy of genotypic and sensitivity of statistical tests are often compromised to some extent

GWAS as the Detective to Find Genetic Contribution in Diseases

- **Find Deviating SNP:** From expecting haplotypes visualize SNP-SNP interaction with HapMap: Chip derived hybridized sample DNA then is extracted and the haploid is taken for sequencing. The result of sequencing experiment is then mapped to the known or control DNA sequence. Thereby the mismatched portion, considered as variant, is obtained. The SNP to SNP interaction is further identified with HapMap result. Other than HapMap, global view of all SNPs signals can also be represented via Manhattan plots. Advantage of this plot is that the strengths and location of each SNP can be directly derived (Figure2). However unlike HapMap, correlation between two or more SNPs and associated phenotype cannot be derived from such plot.
- **Detection of Potential Association Signals:** Once the deviating SNPs are gathered, statistical analysis is carried out to detect the association of the variant to the disease phenotype and majorly done by examining single SNP for its association, done with a series of single locus statistics test. Generalized linear model (GLM) is generally approached to test for qualitative traits and GLM is linear regression model that broadly applies Analysis of Variance (ANOVA)(Hong & Park, 2012). The assumptions are: 1) normal distribution of variance, 2) the trait variances within each group are same and 3) the groups are independent. On the contrary, case/control traits are analyzed with contingency table or logistic regression followed by chi-squared test or related Fisher's exact test. The statistical power derived from these will direct the strength of true association in each case. This is further then stratified based on allelic association or Genotype association followed by further grouping into dominant, recessive, additive or multiplicative type.
- **Fine Mapping:** This step requires all variants in the associated region to have been imputed in genotype or associated version through quality check with stringent conditions and large sample size that is sufficient to resolve among highly correlated signals. The methods employed here broadly calculate posterior probability that tells whether the variant in that locus is causal. Suppose an allele A in the SNP is found to be changed to G through GWAS experiment and found to have

Figure 2. Sample of Manhattan plot based visualization of GWAS data. In a Manhattan plot, x-axis denotes to location of a SNP while the y-axis denotes the strengths of association ($-\log_{10}$ of pvalue). Highly probable SNPs often have strong values associated in the y-axis (marked in green). One major limitation of such visualization is that such plots do not provide any correlations among SNPs and phenotype of interest. The plot is created with the R qqman package.

Source: Turner, 2014



high LD with nearby SNP. Now it also requires the SNP location (whether intergenic, within the gene or at nearby location of genes), gene information, allelic change position, consequences etc to know in details about the SNP.

- **Replication of Detected Association in New Cohort or Subset for Validation Purpose:** Once an associated and finely mapped variant with correlated data comes up, the study is replicated through the new cohort keeping the condition same or through the subset of the sample taken. This step essentially examines the robustness of the experiment design and its outcome.
- **Biological or Clinical Validation:** However, statistical power calculations or significance analyses will only predict the effect of variant (whether risk or protective). To make the findings be free from doubts these findings are validated with biological experiments or clinical validations.
- **Downstream Analysis and Functional Annotations:** The association is further expanded with meta analysis to understand the integrated knowledge of SNP-disease association and consequences (Evangelou & Ioannidis, 2013) for instances, quantitative trait loci analysis, gene ontology or pathway enrichment etc.

IMPORTANCE OF GWAS

In the pre-GWAS era, studies required to go from phenotype (i.e. understand the disease/trait first) to biological processes (with which the disease/trait is mostly associate) so that the causing agents (mostly the genes in the pathway) could be identified. Further molecular dissection, mutagenesis studies and other analyses were carried out to characterize the identified gene and the marker. If the assumption would have been 'one gene one disease' then it would have one shot identification process but could not be held true for complex gene-phenotype relationships. GWAS has this selective advantage for which prior knowledge on biological pathway of the trait does not have to be known as it approaches SNP level to gene to phenotype direction. Since GWAS does an in depth study at allelic level often it comes up with novel candidate genes. The independent statistical analysis and power driven association result often eliminates the chance of biased specific association of SNP to phenotype. Its efficacy in finding SNP and CNV provides more robust data as well as gives information on heritability or ancestry of each subject. Furthermore, GWAS generated huge data to analysis and not only association or fine mapping the post GWAS requires a string meta analysis where more information on SNP/gene correlated data like amino acid change, protein motif change, alteration in biological processes/pathways etc. To access these information effective collaboration are formed with strong consortium of expertise and finally an integrated answer to disease mechanism is solved.

GWAS FOR NEW TARGET IDENTIFICATION IN DISEASES

With GWAS personalized medicine (Thrall J.H., 2004) has achieved a new edge. Personalized medicine is referred to tailoring of medical treatment to the individual characteristics of each patient. In pre-GWAS era the most acclaimed belief was for the association of 'one gene one disease' and identifying the causal gene required 'trial-and-error' kind of studies. But with the advancement in understanding disease complexity a new insight has been revealed showing multiple genetic association and SNP variation behind disease onset. Even within a population under study, there exists SNP level differentiation

in closest relatives. This triggers the importance of understanding the disease prospective for each and every individual taken as case and identifying the causal agent behind the disease in order to develop personalized medicine. Personalized medicine relies on traditional as well as newly developed concepts of genetic association with disease and environmental factors regulating it in order to individualize prevention, diagnosis and treatment. GWAS provides insight to this modern age understanding of multiple gene to disease association by performing entire genome wide scanning at each point, thereby scrapping variant information for individuals (more often called ‘personalized genome’) along with cohort sample. A classic example is study of medicine trastuzumab which is prescribed for only 30% of the breast cancer patient who carry a rare mutation that causes over-expression of protein HER2.

Not only to find out rare events for personalized medicine, GWAS is an intricate study in different fields of diseases like cancer, autoimmune diseases, central nervous system related disorder and many more to name. GWAS have been implemented in five of the commonest cancer types: breast, prostate, colorectal, lung and melanoma and have successfully identified 20 novel disease loci (Easton & Eeles, 2008). With GWAS the genetic architectures of multiple sclerosis (Bashinskaya, Kulakova, Boyko, Favorov, & Favorova, 2015), schizophrenia, bipolar disorder etc have been investigated and GWAS has successfully identified disease susceptibility, clinical phenotypes and treatment responses. Autoimmune diseases like celiac disease, crohn’s disease, rheumatoid arthritis etc occur when own immune cells of an individual attack and destroy body’s cells. With GWAS analysis, the number of genetic risk loci associated with different autoimmune diseases has remarkably increased. Similarly GWAS has encroached different disease section and have identified more associated variant for the given disease/trait than was known before.

GWAS AND ITS SPECIFICITY

First GWAS Discovery

The first report that included prominent GWAS involvement came into light in 2005 when Klein R.J. *et al.* were studying Age Related Macular Degeneration (AMD), a major cause of blindness in elderly. They performed genome wide screening of 96 cases and 50 controls for identifying polymorphisms associated with AMD. Their statistical analysis showed, among 116,204 SNPs that were screened one variant in the complement factor H (CFH) gene showed strangest correlation (p value $<10^{-7}$) with the diseased state. Further resequencing revealed a variant in linkage disequilibrium with the risk allele representing a tyrosine to histidine change at amino acid 402 which is interestingly at the binding site for C-reactive protein (CRP) and heparin. Moreover, CFH is located in a region of chromosome 1 that is repeatedly linked to AMD in family based studies. Previous studies on the conservation of tyrosine at 402 for the functionality of CFH were reported along with the report for elevated serum CRP during AMD. These previous reports and Klein group’s finding established a mechanism of AMD onset through GWAS (Klein, Zeiss, Chew, & Tsai, 2005).

One Article Retraction Due to Statistical Anomaly

Statistical analysis plays a crucial and strong role in GWAS data analysis. Anomaly in this aspect can cause severe case of false positive data as inference. Such a case happened when Sebastiani et al. pre-

sented their work on identifying sets of markers responsible for aging (Sebastiani et al., 2011). Although they collected samples from more than 1000 centenarians, they employed a statistical analysis that was different from the canonical process and led to controversy in scientist community regarding data discrepancies. Ultimately they had to retract their article, one year after its publication.

LIMITATIONS

GWAS is critically dependent on the samples and control taken for studies. Thus GWAS involves different limitations associated with proper quality control and study setup. Common problems that usually occur during GWAS involve case-control groups with less defined demarcations, smaller and less diversified population under study, erroneous sample stratification and proper control size that is comparable to test set for multiple testing. GWAS depends on the statistical relevance that an SNP is linked with disease/trait for a population compared to control population. An error in sample collection, study design and proper quality control will definitely fall into results with faulty statistical report. This will then give rise to a situation of false positive or false negative data and thereby over or under representation of SNP-gene relation. Furthermore, most of the time scientists falsely assume that GWAS SNP gives the hint for the causation of the associated disease but the real scenario is GWAS states the possibility of correlation between an SNP and disease. A sample size with proper statistical power is essential for success of GWA study. Sometimes improper statistical analysis may give false negative result. However, the above mentioned issues can be taken care of and can be corrected. But there are certain fundamental problems associated with GWAS like the common belief of heritability of SNPs for specific disease/traits. To avoid such cases the experiment needs proper information of sample as well as linkage analysis with relevant statistical measures. GWAS detects only those variants that are common (>5%) in a population. Validation of results requires replication in independent samples from different population to avoid any falsified data. Furthermore stringent statistical power calculation may give rise to over or under representation of association. Most of the time the SNPs do not fall in the protein coding region or at least at the nearby region of protein coding gene with known functionality. These sets of SNPs are often under analyzed though they may have significant effect on phenotype.

FUTURE DIRECTIONS

The pre-GWAS era thought of one gene - one disease but with the intervention of GWAS, scientific community has been forced to reprocess their thoughts towards complexities of SNP to disease relation. This has huge impact on human genetics. This view has been further strengthened due to the parallel increase in Whole Genome Sequencing data. With the rapid progress of associated technologies, new and cheap sequencing techniques will continue to evolve further and that will generate huge sample set for careful and thorough fine-mapping. A major concern regarding GWAS is complex dependence-structure for SNPs as well as for individual sample. Mixed model approaches are now being adopted that provide a general and flexible attempt to carry out GWAS of correlated phenotypes.

In the near future, following areas of research or healthcare could benefit significantly from the technical and translational development of GWAS or its associated techniques:

GWAS as the Detective to Find Genetic Contribution in Diseases

- **Personalized Medicine:** This is going to be area where GWAS will probably have maximum impact. Armed with only gene sequence information, GWAS plots (hap-map and Manhattan plots) provide some sort of systemic view of a person's overall genetic architecture. This type of information will help researchers and physicians in finding effective medicines for each and every patient. Drug like trastuzumab already has already shown the way.
- **Phenotype Refinement or Re-Classifications:** What gene signatures differentiate Crohn's disease from ulcerative colitis or psoriasis from lupus? While there are several genes and signaling pathways that are significantly overlapping across such diseases, GWAS has the potential to provide a clear set of gene signatures that would help in proper classification of phenotypes (re-classification in some cases).
- **Understanding the Impact of SNPs in the Non-Coding DNA:** Majority of human DNA is non-coding. However GWAS has found several SNPs which are strongly associated with several diseases are located in non-coding region. Understanding the impact of these non-coding SNPs and finding ways to translate that information to advancement of healthcare should be major focus of GWAS studies.
- **Predictive Analysis Based on Genome Profiling:** Similar to personalized medicine, GWAS helps in identifying potential disease threats for a particular individual. The advantages of hap-map and Manhattan plots (Figure 2) are that they help in weighing the potential impact of known disease causing mutations by directly comparing each person's co-occurring mutations with that of a population data.
- **Policy-Making:** This could be a little distant reality but definitely a very important one in the long run. Similar to many scientific discoveries, GWAS information can also be used for un-explained exploitation of potential threats. While a person may be predicted to be susceptible to certain diseases based on the genetic makeup but there also lies a chance that the person might never develop those diseases at all. To stop healthcare providers from unnecessarily punishing a person due to predicted threats, proper guidelines have to be brought in place.

WEBLINKS

There are several tools/web-servers and statistical packages available for GWAS analysis and further fine mapping. For each of the type of experimental design and analysis selected set of examples are given in Table 2.

CONCLUSION

Today GWAS, along with HapMap project data, other sequencing data, various statistical analysis and further annotations has become a powerful tool to analyze variant association with diseases/traits with the extension in gaining deeper knowledge in disease mechanism for producing personalized medicines. A careful selection of samples and clever experimental design would make it a powerful tool to identify new targets for better understanding of complex diseases. Its efficacy in pedigree wise and expression dependent analysis of genetic association with diseased phenotype has made it an essential tool for de-

Table 2. List of Web-tools used in GWAS

Name	Web Link	Type	Remark
Database for Genotypes and Phenotypes (dbGaP)	http://www.ncbi.nlm.nih.gov/gap	R package	For GWAS data
Disease-ANCEstry Networks (DANCE)	http://gilderlanio.pythonanywhere.com/	Web tool	For GWAS data/ visualization
Bayesian hierarchical generalized linear model (BhGLM)	http://www.ssg.uab.edu/bhglm/	R package	For Haplotype association
Diplotyper	https://code.google.com/archive/p/diplotyper/	Automated tool	For Haplotype association
EasyQC	http://www.uni-regensburg.de/medizin/epidemiologie-praeventivmedizin/genetische-epidemiologie/software/index.html	R package	For Quality Control
GWASTools	https://bioconductor.org/packages/release/bioc/html/GWASTools.html	R package	For Quality Control
DIST	http://dleeelab.github.io/dist/	Software (C++)	For Summary statistics
SNPStats	http://bioinfo.iconcologia.net/SNPstats	Software	For statistical analysis
Sherlock	http://sherlock.ucsf.edu/	Web tool	For statistical analysis
PLINK	http://pngu.mgh.harvard.edu/~purcell/plink/	Open source tool set	For statistical analysis
Comprehensive Meta Analysis (CMA)	https://www.meta-analysis.com/index.php	Paid software	For GWAS Meta-analysis, takes excel input
Meta Analysis Helper (Metal)	http://csg.sph.umich.edu/abecasis/metal/	Free Software	For GWAS Meta-analysis
MetaSKAT	https://www.hsph.harvard.edu/skat/metaskat/	R package	For GWAS Meta-analysis
FunciSNP	http://www.bioconductor.org/packages/release/bioc/html/FunciSNP.html	R package	For SNP prioritization

coding developmental abnormalities across several generations of a population. However, GWAS gives least information for SNPs situated in the non-coding portion (intergenic, distant from known protein coding gene region) of DNA and thereby GWAS loses a large amount of data for downstream analysis. With the advancement in science in near future this problem will definitely get its solution and GWAS will be fully explored to get answers for disease complexity.

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KEY TERMS AND DEFINITIONS

Chromosome: A chromosome is a packaged and organized structure containing most of the DNA of a living organism.

Gene: Gene has different definitions depending on the way it is studied in biology. As per classical (Mendelian) genetics a gene is the basic physical and functional unit of heredity. According to molecular biology a gene is a locus (or region) of DNA which is made up of nucleotides and is the molecular unit of heredity.

Genome: Genome refers to the complete set of genes or genetic material present in a cell or organism.

Linkage Disequilibrium: Linkage disequilibrium is the non-random association of alleles at different loci in chromosome.

Locus: A locus (plural loci), in genetics, is the specific location or position of a gene's DNA sequence, on a chromosome.

Nucleus: A nucleus is a membrane bound cellular organelle that contains genetic material in eukaryotes.

Regression Analysis: A regression analysis is a statistical process for estimating the relationships among variables.

SNPs: Single nucleotide polymorphism (SNP)s are single base pair changes in the DNA sequence that occurs with high frequency in human genome.

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Chapter 6

RNA Interference Therapeutics and Human Diseases

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ABSTRACT

Defective protein synthesis leads to diseases. If protein synthesis can be controlled, disease causing molecules can be tailored in some way. This is the perception behind RNA interference. RNA interference (RNAi) therapeutics is branch of medicine which deals with the treatment of diseases while controlling the gene expression at RNA level. The motive of this chapter is to discover the state-of-the-art of RNAi therapeutics, to explore various techniques used by RNAi therapeutics to fight from diseases, and discuss the future prospects of it.

INTRODUCTION

Humans have more than 20 thousand genes that are protein coding. Proteins are essential building blocks of our body as they perform a variety of functions in human body (Pines, 2007). They produce hormones, enzymes and hemoglobin (Hoffman & Falvo, 2004). As proteins are important, their accurate production is also essential. Diseases are caused either by formation of defective protein or by over production of protein or less production of protein (Shenoy, & Jayaram, 2010; Selkoe, 2003). Diseases like Alzheimer's and Parkinson's disease, Huntington's disease, Creutzfeldt–Jakob disease, cystic fibrosis, Gaucher's disease, Uremia as well as other neurodegenerative disorders, heart disease, some cancers, stroke (Chaudhuri & Paul, 2006) are caused by inappropriate synthesis of protein. Proteins in association with RNA form Ribonucleoprotein (RNP) which relates to diseases like influenza A virus, inherited motor neuron disease spinal muscular atrophy (SMA) (Pellizzoni, 2007), premature aging, cancer (Blasco,

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2005), aplastic anemia (Yamaguchi, Calado, Ly, Kajigaya, Baerlocher & Chanock, 2005), Alzheimer (Diner, Hales, Rabenold, Bishof & Duong, 2004) etc. In short, RNA and protein is linked with an out-sized figure of diseases.

As gene expression (Alberts et al., 2007) is the process of formation of proteins, wherein DNA acts as a template for mRNA which further gets converted into proteins. So, altering the gene expression process may prevent from some disease to occur. More precisely, it is altering gene coding at mRNA level. This is the concept adapted by RNA Interference Therapeutics. RNAi Therapeutics (Aagaard & Rossi, 2007) is the branch of science that focuses on control of gene activity at RNA level to cure diseases.

This chapter is organized as follows: RNA, DNA and gene expression are discussed in Introduction and Background section followed by RNA types, RNA interference process and RNA Therapeutics. Table 1 mentions some of the RNA Therapeutics companies. Further RNAi Therapeutics techniques PMO, LUNAR, RNA upregulation and Gene Silencing are discussed. It is concluded by RNAi Therapeutics' challenges and issues and lastly its future research directions.

BACKGROUND

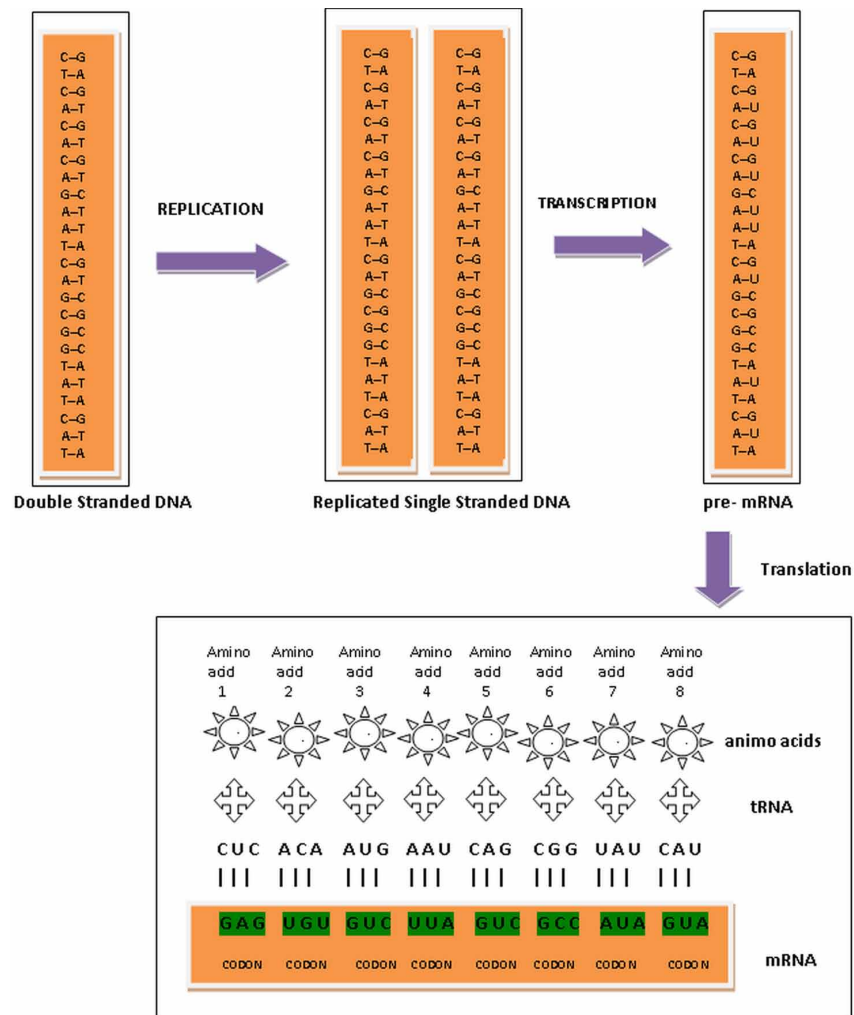
Cells are the building blocks of life. Inside nucleus of a cell, DNA and RNA molecules reside. Ribonucleic Acid (RNA) molecule is a single stranded sequence consisting of four bases Adenine (A), Guanine (G), Cytosine (C) and Uracil (U). This single stranded sequence is known as the primary structure of RNA (Tinoco & Bustamante, 1999). The backbone of RNA contains ribose as sugar. Phosphate groups are also attached to ribose. RNA can be synthesized from DNA. DNA is another molecule which is double stranded molecule. DNA consists of nucleotides that contain a phosphate group, a sugar group and a nitrogen base. Nitrogen bases are Adenine (A), Guanine (G), Cytosine (C) and Thymine (T).

DNA molecule contains a number of genes. Some genes code for protein and others do not. The process of production of protein is called gene expression. Precisely, Gene Expression process involves two sub processes- Transcription and Translation. Gene expression process is initiated by making a copy of DNA to produce a complementary strand called messenger RNA (mRNA) (Anfinsen, 1972) as shown in Figure 1. mRNA is one of the types of RNA. Thymine of DNA is replaced by Uracil of RNA. This step is called Transcription. Proteins are made up of sequence of amino acids. 20 amino acids exist. The bases of mRNA in sets of three, code for a specific amino acid and forms a codon as shown in Figure 1. As the number of bases is four, so 64 ($4 \times 4 \times 4$) possible codons are there. Consequently, more than one codon may code for a specific amino acid. The amino acid is meshed together with codon by another type of RNA which is transfer RNA (tRNA). tRNA contains a complementary sequence of bases on the other side called anti codon as shown in Figure 1. A sequence of amino acids is called a protein. This process is called Translation. Together these processes transcription and translation are termed as gene expression. Each protein consists of a unique sequence of amino acids. Ribosomal RNA (rRNA) links the amino acids so that specific protein is formed.

TYPES OF RNA

Gene Expression is catalyzed by majorly three types of RNAs, namely, messenger RNA, transfer RNA and ribosomal RNA.

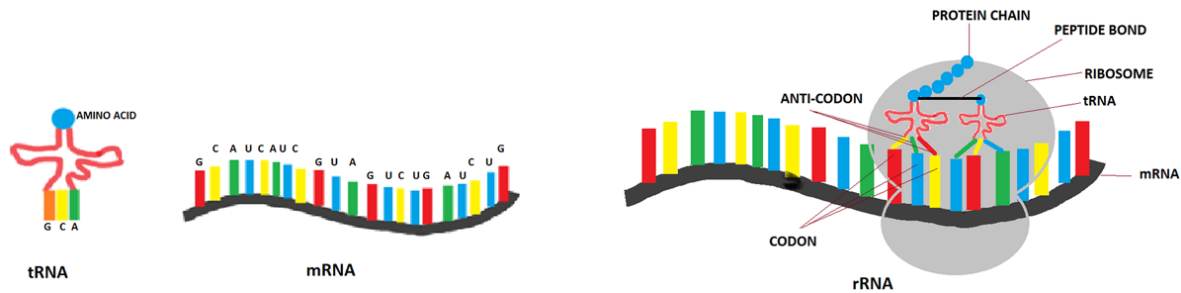
Figure 1. Gene expression process



- **Messenger RNA (mRNA):** mRNA is responsible for transfer of genetic information from DNA to the ribosome and is the biggest family of RNA molecules. The structure of mRNA is shown in Figure 2.
- **Transfer RNA (tRNA):** Suppose we need to bake a cake. We need a kitchen, a recipe and raw materials. In the gene expression process, kitchen correlates to the cell, recipe is with mRNA and raw materials are supplied by tRNA. It brings together RNA nucleotides and amino acids.
- **Ribosomal RNA (rRNA):** rRNA links the amino acids into specific sequence for translation into particular protein.

Other types of RNA are non-coding RNA, transfer-messenger RNA, small-nuclear RNA, micro RNA, small interfering RNA, small nucleolar RNA, antisense RNA and Signal recognition particle RNA. The details of these types are out of the scope of this chapter. Additional readings section can be referred for the same.

Figure 2. tRNA, mRNA and rRNA

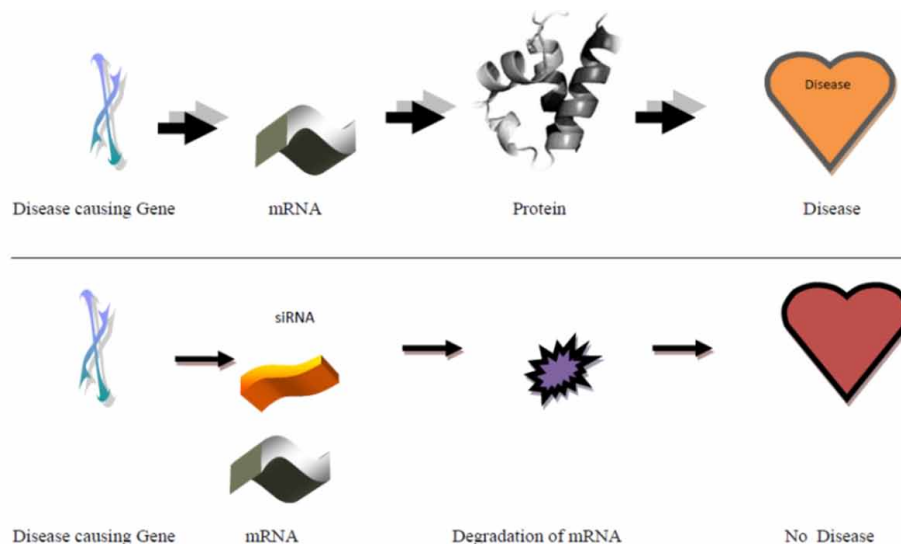


RNA INTERFERENCE

Decades ago, an experiment was conducted to increase the color of petunias flower wherein color producing gene was injected to the flower. Instead of increase in color, it was observed that color was lightened and even white petunias were produced in generations of flower (Jorgensen, Cluster, English, Que & Napoli, 1996). This was how the concept of gene expression suppression was coined. Further experiments revealed that introduction of sense and antisense RNA together forming double stranded RNA (dsRNA) leads to gene silencing (Fire et al., 1998).

The mechanism of RNA Interference (RNAi) involves treating the disease causing gene with specific small interfering RNA (siRNA) that targets the specific messenger RNA (mRNA). This mRNA is involved in production of protein that leads to the disease in question. The motive of treating this mRNA with siRNA is to degrade the mRNA and thus prevent the formation of protein causing disease (Figure 3). Alteration in protein production refers to impeding the gene expression process. This concept of RNAi leads to Gene silencing that means switching off the target gene. It prevents the expression of a certain

Figure 3. RNAi process



gene. One of the applications of Gene Silencing technique was to cure Huntington disease which was caused by the production of protein called Huntington (Sah & Aronin, 2011).

RNA based medicines have been in focus since many years. RNA Therapeutics drug are designed to increase or decrease the production of a protein involved in a disease. It is a mechanism to regulate normal gene expression in order to eradicate several disorders like cancer, Hepatitis C, Huntington's Disease, HIV, malaria etc. (Abdolhamid et al.,2010). Some of the Therapeutics companies have been discussed in Table 1.

PMOs Based RNA Therapeutics

PMO stands for phosphorodiamidate morpholino oligomer. These are synthetic RNA's consisting of same bases as of RNA (A, C, G and T). They are molecular structures that are binded to RNA at specific position in order to change the function of RNA. As they have reasonable RNA binding affinity and low protein binding affinity, they bind RNA wholly without off- target effects. Their prime function is to retard the gene expression in order to prevent cells from making a targeted protein and thus preventing the disease to occur.

PMO's are especially stable, highly soluble and non-toxic. They have the following functions: (Moulton, 2013) blocking translation of mRNA (Hudziak, Summerton, Weller & Iversen, 2000), modifying of splicing of pre-mRNA (Alter et al.,2006), blocking miRNA maturation and activity (Kloosterman, Lagendijk, Ketting, Moulton, & Plasterk, 2007), and blocking other RNA sites – splice regulation sequences (Bruno, Jin & Cote,2004) and ribozymes (Yen et al., 2004).

The manufacture of medicine using PMO technology drives through a number of steps. After examining the target RNA, subunits of PMOs are created by converting 5 sided RNA rings to 6 sided PMO

Table 1. RNA therapeutics companies

S.No	Company	Technology	Targetted RNA	Pipeline	Diseases	Web Address
1	Sarepta Therapeutics	PMO's	mRNA	Exon Skipping	Duchenne muscular dystrophy (DMD)	http://www.sarepta.com/
2	Arcturus Therapeutics	LUNAR UNA	siRNA, mRNA	ornithine transcarbamylase deficiency, Iron disorders	TTR-mediated amyloidosis	www.arcturusrx.com/
3	RaNA	RNA upregulation	long nc RNA	musculoskeletal diseases, and inflammatory diseases	Hematologic disease	ranarx.com
4	Alnylam	Gene Silencing	dsRNA	Cardio-Metabolic Disease, dyslipidemia, hypertension, diabetes, and non-alcoholic steatohepatitis (NASH); and Hepatic Infectious Disease	RSV infection/ hypercholesterolemia	www.alnylam.com/
5	SMaRT	Antisense Technology	asRNA	Myotonic Dystrophy Type 1	breast cancer, prostate cancer, viral infections, deafness	smart-therapeutics.com/
6	Mina Therapeutics	Transcriptional gene activation	saran	development and commercialization of small activating RNA (saRNA) based therapeutics	Liver function, diabetes	http://minatx.com/

subunits. Then these are linked to form the final structure. This structure corresponds to the targeted RNA. Figure 4 has been adapted from Sarepta Therapeutics.

Duchenne muscular dystrophy (DMD) was treated with PMO's Technology. This disease is caused by mutations that disrupt the reading frame of the human DMD gene. Selective removal of exons flanking an out-of-frame DMD mutation can result in an in-frame mRNA transcript that may be translated into an internally deleted, Becker muscular dystrophy (BMD)-like, but functionally active dystrophin protein with therapeutic activity (Poppellwell, Graham, Malerba & Dickson, 2011).

PMO are RNA based molecules in which morpholine ring replaces the ribose. PMOs are also used for restoration of dystrophin in humans which protects from muscle fiber injury (Kinali et al., 2009) as strengthening of muscles depends on it.

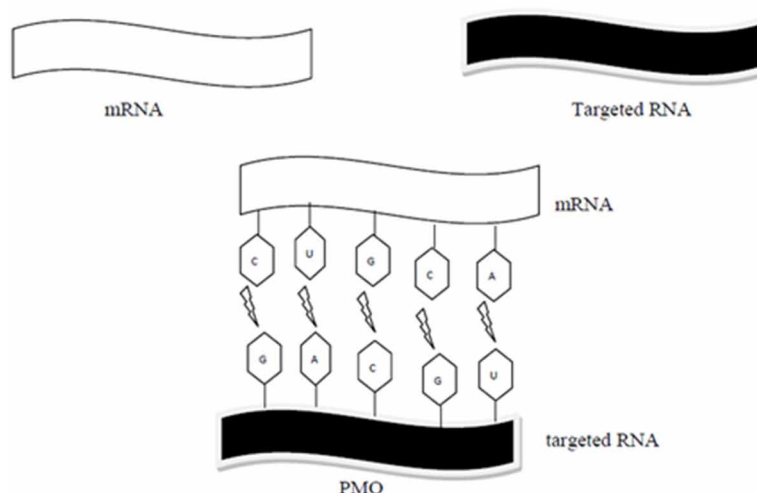
Huntington's disease (HD) is a progressive brain disorder genetically transferred disease that hits a person's cognitive, emotional behavior and leads to uncontrolled jerky movements in body. Mutations in HTT gene cause HD. A trinucleotide sequence CAG of DNA sequence repeats itself 20-30% times leading to HD. PMO's have been used to suppress mutant huntingtin expression (Sun et al., 2014; Burgess, 2014).

Behavior of Flavivirus has also been studied using PMO's. Flavivirus is a genus of viruses in the family Flaviviridae. This genus includes the West Nile virus, dengue virus, tick-borne encephalitis virus and yellow fever virus (Brinton & Disputo, 1988). Viruses like West Nile virus (Deas et al., 2007), Marburg virus, Ebola virus (Warfield et al., 2006), etc are under test while treating them with PMO's. PMO's whose sequences were complementary to RNA elements located in the WNV genome included various sub structures like stem loops, Pseudoknot (Sharma, Singh & Chand, 2014; Sharma, Singh & Chand, 2015; Jiwan & Singh, 2012a; Jiwan & Singh, 2012b; Mann, & Singh, 2011) etc.

LUNAR Technology Based RNA Therapeutics

LUNAR stands for Lipid-enabled and Unlocked Nucleic Acid modified RNA delivery technology. In this technique, lipid particle is fused into the cell membrane that leads to biodegradation process and delivers

Figure 4. PMO's technology



the required RNA. Arcturus Therapeutics, Inc. (“Arcturus Therapeutics”, 2015), a leading company in RNA therapies for rare diseases works on this technology.

Cystic Fibrosis (Hegarty et al, 2009) is a genetic disease that affects the lungs and digestive system. Cystic Fibrosis is being treated with the help of LUNAR technology. Researchers at Arcturus Therapeutics tried injecting human erythropoietin messenger RNA (mRNA) into non-human primates using LUNAR technology. The results were outstanding. The chemically modified RNA was well absorbed by the primate and protein expression proceeded as expected. Most important there were no off target effects of the activity.

Both siRNA and mRNA are used with LUNAR technology. Similar to LUNAR-formulated cystic fibrosis transmembrane conductance regulator (CFTR) mRNA, LUNAR-formulated thrombopoietin (TPO) mRNA, LUNAR-formulated ornithine transcarbamylase (OTC) mRNA and LUNAR-formulated hepcidin (HPN) mRNA have been geared up. LUNAR-formulated TPO mRNA is used for the treatment of thrombocytopenia which is a blood related disorder that leads to low platelet count. LUNAR-formulated ornithine transcarbamylase (OTC) mRNA is used for the treatment of ornithine transcarbamylase deficiency, which leads to accumulation of ammonia in blood. LUNAR-formulated hepcidin mRNA is used for the treatment of iron disorders.

Arcturus Therapeutics (“Arcturus Therapeutics”, 2015) has rightly proved that mRNA medicines have brought a revolution. It has become possible to target any gene in the human genome (Nassa, Singh & Goel, 2013). Various gene prioritization techniques (Gill, Singh, & Aseri, 2014), gene prediction techniques (Goel, Singh & Aseri, 2013a; Goel, Singh & Aseri, 2013b) and gene regulatory networks (Singh, 2013a; Singh, 2013b) are used to identify candidate genes for a particular disease. Not only in humans, genetic testing can be conducted even in unborn babies to detect diseases (Singh, & Singh, 2011).

Therapeutics for RNA Upregulation Using Long Non-Coding RNA

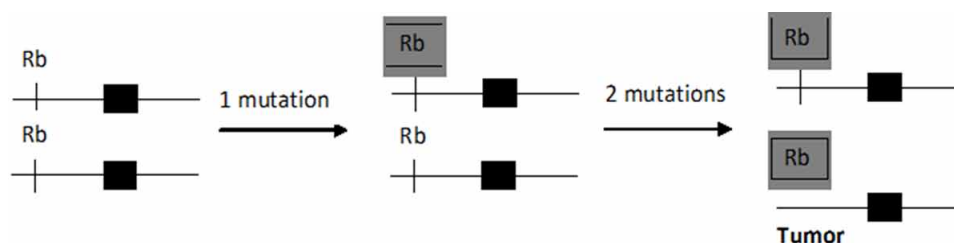
Few years back non-coding RNA was recognized as responsible for several regulatory functions in body. Long non-coding RNA has a specific effect on gene regulation. Using this concept, RNA can be targeted to selectively ‘activate’ therapeutic protein expression (Lee, 2012). Till now in this chapter, we have discussed the evolution of RNA therapeutics for controlling gene expression, but now we would discuss the same for up-regulating the gene expression (Donner, 2014). Some genes including tumor suppressors, growth factors, transcription factors and genes that are deficient in various genetic diseases require upregulation (Wahlestedt, 2013).

During cancer, some tumor suppressor genes are inhibited. These genes encode protein that hinders the formation of tumors. Mutations in the said gene inhibit the function of tumor suppressor gene, thereby leading to growth of infected tissues. A two-hit mutation process (Hyland, 2008) is shown in Figure 5 that results in tumor.

In cardiovascular diseases, therapeutic genes are upregulated using Long non-coding RNA like APOA1-AS and human mimics of Bvht (Fatemi, Velmeshev & Faghihi, 2014). Similarly neurological disorders occur due to downregulation of a protein called Brain-derived neurotrophic factor (BDNF). BDNF is a therapeutic target for neurological disorders. As lncRNA has the potential to target specific set of genes, it has been a major therapeutic target for upregulation.

Not only lncRNA but short activating RNA has also been used for upregulation. Mina Therapeutics proposed a novel approach for treating diabetes (Reebye et al., 2013). Diabetic patients who are bound

Figure 5. Two hit mutation for retinoblastoma



to inject insulin supplements in their body may be treated with the said approach. In this approach, short activating RNA is used to produce insulin in body using surrogate cells by upregulating several pancreatic endodermal genes.

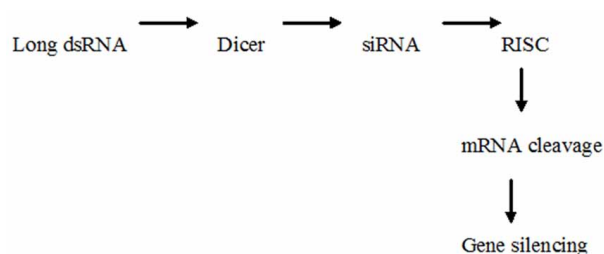
Antisense RNA Based Gene Silencing

Antisense RNA (asRNA) is RNA having molecular sequence which is complimentary to a specific mRNA. Thus asRNA can be binded to mRNA thus forming a double stranded RNA just like DNA. This double stranded RNA can inhibit gene expression. There are various sources of asRNA including induction by doctors. Gene silencing component is produced using asRNA which then interacts with mRNA for its degradation. This process finally alters the gene expression thereby curing the disease. Such small molecules (gene silencing components) have been synthesized to cure many diseases like Myotonic Dystrophy Type 1 and Myotonic Dystrophy Type 2.

Neuromuscular diseases like DMD, myotonic dystrophy and spinal muscular atrophy (SMA) are also treated using antisense oligonucleotides (Muntoni, & Wood, 2011). Myotonic Dystrophy occurs due to repetition of some units in non coding elements of mRNA. More the number of repetitions, severe is the disease. Spinal muscular atrophy (SMA) is another genetic disease affecting nervous system that controls muscle movement. SMA occurs due to deficiency of SMN, a motor neuron protein. Antisense oligonucleotides have been designed to modulate pre-mRNA splicing for restoration of functional proteins in body.

Not only antisense oligonucleotides, but double stranded RNA (dsRNA) that is homologous to the target gene is also used for gene silencing. In this technique dsRNA is diced to produce siRNA (Wood, Trülzsch, Abdelgany, & Beeson, 2003). The antisense strand of siRNA, being complementary to mRNA, leads to mRNA cleavage, degradation and hence gene silencing as shown in Figure 6.

Figure 6. Antisense RNAi based gene silencing



RNAi THERAPEUTICS: CHALLENGES AND ISSUES

RNAi Therapeutics is not easy to implement. Also there are certain issues (Ebbesen, Jensen, Andersen & Pedersen, 2008; Burnett & Rossi, 2012) involved such as:

- Induction of drug into the specific body part,
- Distribution of drug into cells,
- Successful silencing of gene,
- Side Effects of drug on other genes,
- Generate natural immune response,
- Instability under physiological conditions.

Biodistribution of RNAi drugs includes technical and scientific challenges including extended blood circulation times, vascular escape, tissue penetration, cellular uptake, and escape into the cytoplasm (Haussecker, 2014). First and foremost question is how to deliver the drug to the body. Some of the techniques are nanoparticles, cationic lipids, antibodies, cholesterol, aptamers, viral vectors GalNAc-siRNA conjugates and Dynamic PolyConjugates/DPCs (Aagaard, & Rossi, 2007). Two strategies may be adopted- in vivo delivery or ex vivo delivery. In vivo delivery refers to concept of delivering the said drug to the body itself through inhaler or direct injection. On the contrary, ex vivo is a concept of extracting cell from patients, modify them in environment external of body and re-inject the modified cell back to the body. Both the techniques have their own challenges (Tiemann & Rossi, 2009).

Another issue of RNAi delivery is that RNA molecule has to reach cytoplasm of cell in order to interact with protein and hence carry forward the process of gene silencing. For example, in case of cancer therapy, when siRNA routes through the blood, it is easily digested by nucleases in the serum thereby leading to its degradation instead of following its targeted action.

Off target effect is another problem. A gene which is closely related to the targeted gene is also damaged. This leads to unwanted action in body. The literature shows masses of consequences of experiments conducted so far for off-target effects of RNAi delivery. In some cases physiological effects have lead to non-targeted gene expression (Jackson et al., 2003) and even alteration of gene expression of many non-targeted transcripts.

Another growing concern while inducing RNAi in vivo is the activation of immune response. This even sometimes leads to interferon effect. Interferons (Andrea, Gariglio, Gioia, Gariglio & Landolf, 2002) are actually signaling proteins that are sent by cells to other cells signaling them to increase their immune effect. So, the immunostimulatory “side effects” must be taken in account when inducing RNAi.

FUTURE RESEARCH DIRECTIONS

RNAi Therapeutics has been improving incessantly since a decade. Although there are some hurdles to be able to traverse clinical barrier easily, particularly RNA delivery. Lots of lessons have been learnt from previous trials. These lessons are unquestionably going to aid researchers and scientists to accomplish their goal to conquer fatal diseases. With awareness of the topics of gene expression, artificial RNA, techniques for RNA Therapeutics like PMO, Lunar based approach, antisense RNA etc, a number of

researchers can bring revolution in disease control. Firstly, research can be carried out on structures of RNA that cause a particular disease. Further research can be done on preparation of synthetic RNA to control that disease. Delivery of drug to cells is another area.

CONCLUSION

As RNA is associated with a large number of human diseases, treatment of these diseases are also related to RNA. The process of Gene expression is the foundation of functionality of human body. Gene expression includes RNA. Controlling the gene expression leads to control of formation of diseases causing structures in nucleotide sequence. Synthetic RNA controls the gene expression and thus there is no doubt regarding the potential of RNAi Therapeutics in treatment of diseases. Novel techniques and delivery systems are expected to be investigated to perk up RNAi delivery. RNAi Therapeutics should be able to treat more number of diseases in near future. It is going to bring revolution in human disease therapy.

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KEY TERMS AND DEFINITIONS

dsRNA: dsRNA stands for double stranded RNA. Sense and antisense RNA together form dsRNA.

Gene Expression: It is the process of formation of protein, intermediate steps being conversion from DNA to mRNA.

Gene Silencing: The process of prevention of gene expression process during translation or transcription process is called gene silencing.

LUNAR Technology: LUNAR stands for Lipid-enabled and Unlocked Nucleic Acid modified RNA delivery technology. In this technique, lipid particle is fused into the cell membrane that leads to biodegradation process and delivers the required RNA.

PMO: PMO (phosphorodiamidate morpholino oligomer) are synthetic RNA who retards the gene expression in order to prevent cells from making a targeted protein. They are molecular structures that are binded to RNA at specific position.

RNA Interference: The mechanism of RNA Interference (RNAi) involves treating the disease causing gene with specific small interfering RNA (siRNA) that targets the specific messenger RNA (mRNA).

RNAi Therapeutics: Altering gene coding at mRNA level is called RNAi Therapeutics. RNA Therapeutics drug are designed to increase or decrease the production of a protein involved in a disease.

siRNA: Small interfering RNA is also known as silencing RNA or short interfering RNA. siRNA is formed from double-stranded RNA molecular sequence of length 20-25 base pairs and is used for knockdown of long noncoding RNAs genes.

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Section 3

Clinical Science and Technologies

Chapter 7

A Gamification Update to the Taxonomy of Technology and Mental Health

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ABSTRACT

Mental health providers cannot ignore the importance of utilizing technology in this era of the internet of things. This chapter reaffirms the need for mental health providers and software developers to work in concert with each other when developing technology for mental health. The authors also articulate the importance of the patient and the patient's role in connecting technology to the equation. As researchers and practitioners, the goal should be to create technology that will encourage repeated and continuous use of said technology and not just technology acceptance in order to move the field forward toward the provision of low-cost, effective mental health services.

INTRODUCTION

Mental health providers cannot ignore the importance of utilizing technology in this era of the “Internet of Things.” This chapter reaffirms the need for mental health providers and software developers to work in concert with each other when developing technology for mental health. We also articulate the importance of the patient and the patient's role in connecting technology into the equation.

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BACKGROUND

The Problem

Marks and Bowers (2014) developed a taxonomy that allowed mental health providers to understand how technology, can benefit patients as well as direct the provider to the proper platform depending on the aspect of the patient's mental health requirements. A taxonomy was developed that included classifications of disorders with specific disorders from the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (*DSM-5*), delivery platform i.e., mobile device, personal computer, and video game console, and the four classifications of mental health services (e.g., Training, Therapy, Assessment, and Prevention). This taxonomy guided developers to focus on building mental health technology (mHealth) that revolve around a particular sector. Further, the taxonomy capitalized on the similarities between providers and developers in achieving the end-goal of repeated and continued use of their respective product (therapeutic services and software). However, the previous taxonomy did not account for the different motivational strategies employed to reach the end-goal; in the design and development of mHealth providers and developers focus on two different factors. Providers focus on delivering evidenced-based treatments driven by underlying mechanisms of action (MOA); whereas, developers focus on delivering usable and entertaining technology. Compounding this disparate approach between providers and developers is the failure to take into account the patient perspective. The present chapter presents a revised taxonomy that represents the integration of MOA, usability and entertainment, engagement to create gamified technology for the purpose of increasing, repeated and continued engagement with the technology, by the end-user. The taxonomy has been revised to reflect the change of including the end-user and integration of gamification. Additional changes have been made to the taxonomy to better represent this new focus. These include changes to the component of Training, which is now called Psychoeducation; Assessment, which has been removed from the taxonomy because the focus of technology for assessment is not for the end-user. All changes have been made in an effort to better synthesize the newly added information afforded by considering the end-user, in pursuit of creating repeated and continuous engagement with mHealth.

To better understand the disparate approaches between providers and developers and how the end-user will be incorporated, an explanation of each motivational target of the triad is warranted.

Provider

The mental health provider's goal is clear: it is to help a patient improve upon a targeted domain that is interfering with the patient's quality of life. Mental health providers agree that motivation is a key component to attendance and participation in treatment. Without motivation, therapeutic processes cannot take place nor be effective. At each step of the therapeutic process the mental health provider guides the patient through the therapeutic process, and works with the patient to determine the pace of progression to end goals. It is through clinical experience that is informed by research, that the provider makes these crucial decisions.

The therapeutic process involves the general components of 1) establishing a therapeutic alliance, 2) establishing what is the patient's commitment to change, conducting a behavioral analysis, coordinating treatment objectives, 3) executing treatment and maintaining motivation, monitoring progress, and 4) planning for treatment termination by generalizing skills (Rosenbaum & Horowitz, 1983). These steps

create a tailored versus standardized treatment structure, and encourages the patient to be an active participant in the progression toward change (Kanfer & Grimm, 1980). It creates a therapeutic alliance between the mental health provider and the patient. The therapeutic alliance refers to the patient's experience as to the mental health provider's empathy; it refers to the patient's belief as to the provider's credibility as an expert; it refers to the patient's perceived rapport with the provider; it refers to the patient's perception that he or she is receiving the help needed from the provider; it is the patient's perspective that the provider is engaged; it refers to the patient's perception that the treatment is a process working toward specified goals (Elvins & Green, 2008). This therapeutic alliance, while not a specific strategy for motivating patients, encompasses all domains of influencing motivation to adhere to treatment (Barrett, Chua, Crits-Christoph, Gibbons, & Thompson, 2008; Bordin, 1994). The best form of treatment requires practitioners to focus on evidence that supports effective intervention using evidence-based treatments. Evidence-based treatment involves the integration of best available research, clinical expertise, and consideration of individual patient characteristics (Anderson, 2006). In essence, each treatment has an underlying MOA. Considering that mental health providers should be delivering evidence-based treatment in a traditional face-to-face format, providers should continue to provide the best possible treatment regardless of the platform. The focus of the mental health provider is on mHealth's ability to support treatment rationale and adherence to clinical practice.

Developer

Adams (2014) describes the developer's job as brainstorming designs, creating meaning, distinguishing content, and testing the technology. Adams organizes the developer's software designing job into a three-part system:

1. **Concept Stage:** Deciding the kind of technology to develop.
2. **Elaboration Stage:** Creating and developing the software, then conducting usability testing.
3. **Tuning Stage:** Preparing the software for release, including fixing errors in code.

The second and third steps are particularly important because developers desire for users to spend time playing the software and do so on a repeated basis, which, as an aside, is consistent with the desires of mental health providers (Von Ahn & Dabbish, 2008). In fact, there is evidence noting that evaluating usability is crucial in motivating people to engage in the use of mHealth technology. Poor usability and user experience has demonstrated to de-motivate people from using the technology (Spillers & Asimakopoulous, 2014). When issues of usability are resolved, elements that facilitate great technology can be implemented.

Gamification, while not a specific strategy for motivating players, summarizes the integration of elements that compose great games. Successful mHealth games have goals, rewards that people are excited to obtain and, thus, play in order to achieve. Developers elicit excitement by integrating elements that capture attention, relevance, confidence, and satisfaction (Keller, 1983; Paras, 2005). The excitement is palpable and fosters motivation to continue playing. Players work hard to advance in game play by completing levels, collect badges, earn coins, and receive points, in other words, positive reinforcement. The aforementioned rewards are direct reflections of the link between the player's effort and achievement (Malone, 1982). The visual representation of effort and outcome is highly rooted in the competi-

tive nature of a player, which when combined synchronizes and increases the desire to continue playing (Vorderer, Hartmann, & Klimmt, 2003).

This visual representation is a form of feedback, which leans on our innate desire for immediate feedback regarding performance. This desire for immediate feedback is present regardless of context, which in this case, happens to be within a game environment (Ciampa, 2014). While typically viewed as positive, immediate feedback received within the game environment can serve as a potential source of frustration - frustration stemming from game elements being too demanding (Tauer & Harackiewicz, 1999).

Establishing an equilibrium of a game's goals between simplicity, which can be boring, and difficulty, which can be aggravating is essential when considering motivational target of repeated, continuous, use (Malone & Lepper, 1987). This balance is imperative to keep the player interested and motivated in advancing towards the end goal (Richards & Caldwell, 2015). The balance starts with developing a game progression embedded with appropriate challenges and sufficient rewards (Richards & Caldwell, 2015). The in-game rewards of advancing thru the game and earning the aforementioned reinforcement is intrinsically motivating as it captures the notion of progress (Klosowski, 2014).

Another aspect that motivates individuals to advance towards the end goal is the incorporation of narratives, or stories (McDaniel, Fiore, & Nicholson, 2010). Strong storytelling stimulates the users draw to the game, in turn, providing motivation to play. The strength of the story is enhanced when relatable avatars are leveraged. Relatable avatars provide players the feeling of personal connection to the game (Doyle, 2004). The opportunity to customize avatars deepens the player's personal connection to the game leading to enjoyment, and therefore, increased time spent within the game environment (Doyle, 2004; Schmierbach, Limperos, & Woolley, 2012).

The emphasis of the developers' motivational targets, however, is on whether or not the technology is usable and entertaining for the target audience, not that it will actually be used. Just because a technology is *usable* and *entertaining* by definition, does not ensure that the technology serves its' purpose in regards to the providers' MOA. This implies that there is a third variable in the equation, and that is the end-user, patient.

End-User, Patient

End-users validate technology. The End-user must be taken into account at the design phase in order to ensure usability that fosters prolonged and repeated use and engagement. Specifically, the inclusion of an entertaining, usable, mechanism of action driven mHealth will not predict actual use of said technology. Only 35% of adults who own phones have downloaded at least one app, but only two-thirds of those actually use these apps (Purcell, 2011). A mental health technology simply for the sake of creation is not sufficient; no matter the appeal of health technology, it will not be used by the patient unless (i) it helps address with her or his specific problem and (ii) avoids technical failures, i.e., crashes, freezes, error messages (Perez, 2013; Scher, 2013). Perez (2013) demonstrated that only 16% of people would try to use an app more than twice if it fails.

In addition, mHealth design and functionality needs to provide flexibility by taking into account a patient's motivation to use the technology. Motivation to engage with the technology is rooted in the need to reduce symptoms of psychopathology, willingness to seek help, and improve quality of life (Wilson, 2007).

Mental health technology cannot consider each individual when designing technology. That is, symptoms that the technology is designed to mitigate may not line up perfectly with what the patient experiences. Yee (2006) hypothesized and defined three end-user, player, and motivational components as follows.

1. **Achievement:** A Player yearns to make progress within the game, which includes gaining power, wealth, and knowledge of the rules to “better” her or his character, avatar, as well as the inclination to compete against others in the game.
2. **Social:** A Player desires to form relationships and help others in the game, and enjoy being part of a group.
3. **Immersion:** A Player wishes to know what others players do not know and enjoys being able to customize her or his own story and character in the game.

The challenge, therefore, is integrating the benefits of face-to-face therapy into a game construct for mental health in order for the application of the Triad to the taxonomy to be effective.

APPLICATION TO THE TAXONOMY

Good user engagement offers insights into development of more effective implementation of MOA and incorporation of usability and entertainment. As illustrated, each component of the Triad contributes unique motivational targets. Similarly, each component of the taxonomy is different. In psychoeducation, the goal is to gain knowledge and apply that knowledge to the world outside. In therapy, the goal is to deliver a type of treatment that may address and help the patient cope with impairments to activities of daily living. Finally, in prevention, the main goal is preventing individuals (regardless of their risk level) from developing a disorder (Marks & Bowers, 2014). The challenge becomes creating a balance amongst each component to satisfy the MOA, entertainment, and engagement needs of each entity. The following recommendations about gamification guided by the motivational targets of provider, developer, and end-user.

Psychoeducation

Mini-Games

The goal of psychoeducation is to gain and apply knowledge to novel environments. Mini-games can serve as the mechanism for testing knowledge and assessing knowledge transfer. Mini-games are small games, play lasts under an hour, embody one learning goal, easy to learn, and difficult to master.. Mini-games can be employed within several contexts and are best suited towards acquisition of conceptual and procedural knowledge (Smith & Sanchez, 2010).

Mini-games provide the opportunity for fun and engagement while simultaneously accomplishing the goal of providing the user with psychoeducation. New information is processed as stimuli, which is encoded during gameplay interaction. In order to complete the game, players are required to memorize content and be able to recall for completion of the game (Smith & Sanchez, 2010). The advantages of mini-games are two-fold: one, in an environment where the provider is not able to directly observe the

user's understanding, mini-games allow for the quantitative assessment of the users understanding; two, understanding, engagement is imperative in order for the user to gain the conveyed knowledge and retain the newly learned cognitive skills (Andrews, Joyce, & Bowers, 2010).

Therapy

Narratives, Avatars, and Alternate Reality Games

Narratives are powerful tools that embed learning content within the game to create a coherent story that motivates the user to continue their engagement in the game (McDaniel, Fiore, & Nicholson, 2010). In other words, narratives can be used for improving immersion by drawing the player into the world of the game. One type of narrative congruent with the face-to-face therapy format is the interactive story archetype. An interactive story is an experience in which the simulated world responds to the player's movements, decisions, and actions within the game-space (Bates, 1992; McDaniel, Fiore, & Nicholson, 2010; Thue, Bulitko, Spetch, & Wasylishen, 2007). The parallels between face-to-face therapy and the interactive story are seen by the emphasis that the player rather than that of the game structure dictates movements, decisions, and actions. The game structure is synonymous with the therapist, who provides the content and environment and the player is synonymous with the patient, who dictates the simulated world's response. This structure can assist with the creation of a therapeutic alliance between the user and the mHealth technology.

Further strengthening the therapeutic alliance, avatars should be considered during development of the interactive narrative. By placing empathic characters that are, perceived to instill hope; perceived to be competent; and perceived to be committed, creates motivation for continued play. One example of translating the perception of commitment to the novel environment is the utilization of "push-notifications." Outside of the virtual environment, Avatars can be programmed to send "push-notifications" direct to the users cell-phone. Translating the narrative and the avatars presence from the virtual environment, which is housed within the technology platform, to interacting with the user outside of the platform is reminiscent of alternate reality games. Alternate reality games (ARG) are a narrative that extends to the players real world (Johnston, Sheldon, & Massey, 2010).

The integration of an interactive story, empathic avatars, and ARG is an example of combining the motivational targets of the triad and addressing the problem of translation of gameplay to the generalizable, novel, everyday environment.

Prevention

Progression and Positive Reinforcement

Games are typically designed so that complexity and degree of difficulty increases as game-play progresses. Similar to games, users of mHealth technology will have a wide range of abilities and knowledge regarding the target of prevention. In a traditional face-to-face setting, a mental health provider will assess the current skill level, needs, and targets for improvement of the population targeted for prevention. A congruent assessment must take place within the game environment so that the difficulty of the game can be presented accordingly.

Increasing challenge can be designed by way of levels. Levels and degree of difficulty can be implemented by completing an earlier less challenging level, by increasing difficulty as time spent in game increases, or by an adaptive system. The adaptive system, as the name suggests, adapts by adjusting degree of difficulty to the user based on their performance in game. The advantages of the adaptive system are evident considering that users become bored with games that are too easy or frustrated with games that are too challenging, which leads to discontinued play (Klosowski, 2014; Tauer & Harackiewicz, 1999). A user who has the skills and knowledge will be able to progress more quickly while another user will be provided the content in a more judicious manner.

This adaptive approach also lends well to the capturing and analyzing performance in real time. Two types of data can be generated using the adaptive approach. The first is what we would call performance “meta-data.” This data is derived from the capabilities embedded in smartphones and other software to track time spent engaging with content, length of time spent within a module/level, and the location of use. The performance meta-data can provide a mental health provider, as well as the user, with worthwhile information regarding level of engagement for the practice of skills. The performance meta-data can be synced with in-game performance reinforcement (i.e., amount of time spent practicing skills and engaging in content results in collection of badges, coins, points).

FUTURE RESEARCH DIRECTIONS

The aforementioned suggestions are not mutually exclusive, rather the goal was to demonstrate how taxonomy for mHealth can be leveraged to synthesize information and best practices. Future research should look to understand the specific motivational targets that underlie each component of the taxonomy. Specific attention should be given to mental health technology that focuses on prevention. Primary prevention seeks to stop or stall the development of disorder. Primary prevention takes place prior to the expression of symptoms by intervening with all those who share characteristics that place them at risk for development of disorder (Cowen, 2000).

The very definition of primary prevention is that intervention takes place *prior* to the manifestation of symptoms. Whereas in training, therapy, and assessment, the patient has identified that there is interference in their quality of life that warrants attention. In prevention, there is a need to understand how to motivate people to use mHealth technology to promote resilience, and intervene prior to a problem developing. Targeting the motivational aspects unique to prevention would result in the increase of effectiveness of the primary prevention. The challenge is motivating a user to take the time to engage in technology that is perceived as a worthwhile investment of time.

Prevention technology is going to need to have more salient entertainment functions, but will also need to have strong therapeutic MOA. It is important, however, to understand that you cannot simply interpolate a game-like interface onto the MOA that is desired; rather, you must merge the MOA into the game (Von Ahn & Dabbish, 2008).

The original taxonomy, updated taxonomy, as well as the updated component of the taxonomy, has been included (see Figure 1, Figure 2, and Figure 3, respectively)

Figure 1. Expanding the taxonomy of technology and mental health
 Source: Marks & Bowers, 2015

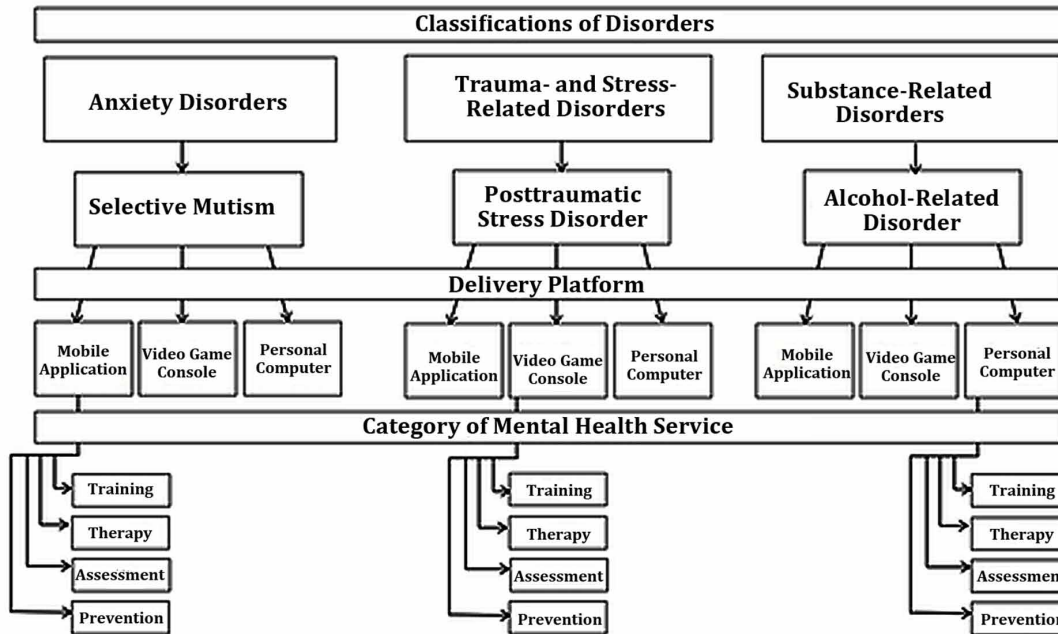


Figure 2. A Gamification, End-User incorporated taxonomy of technology and mental health

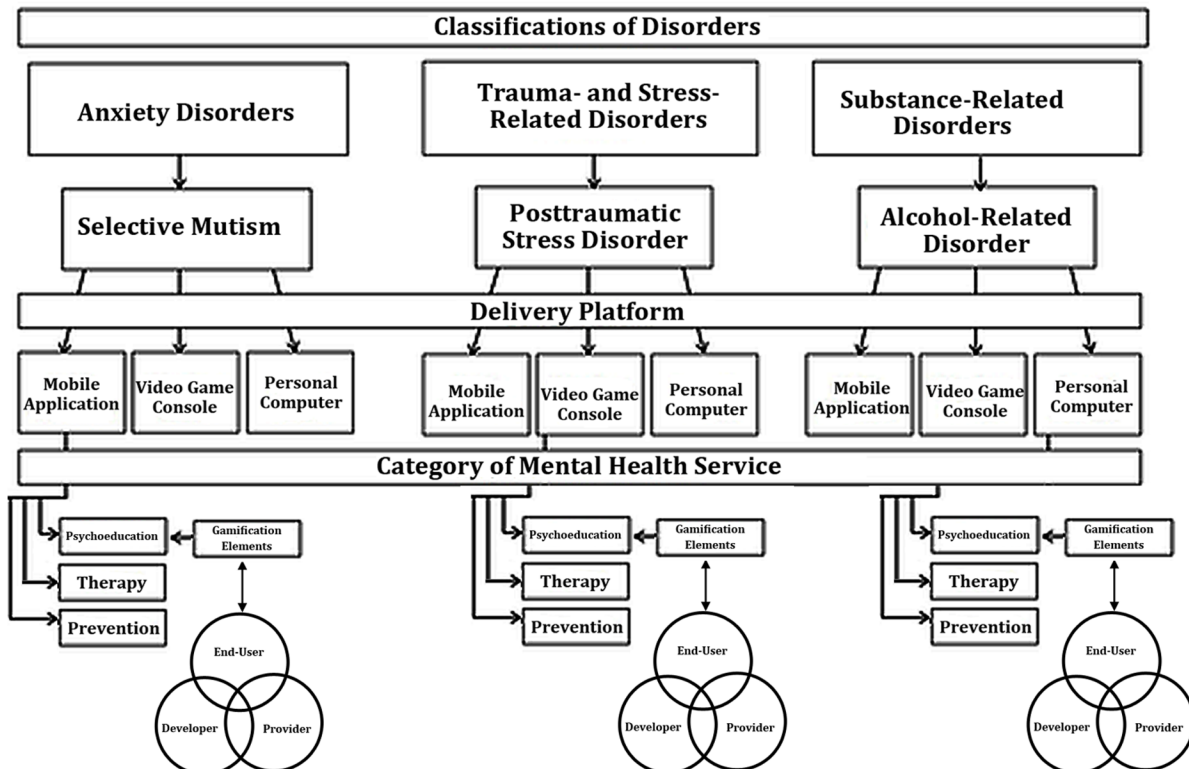
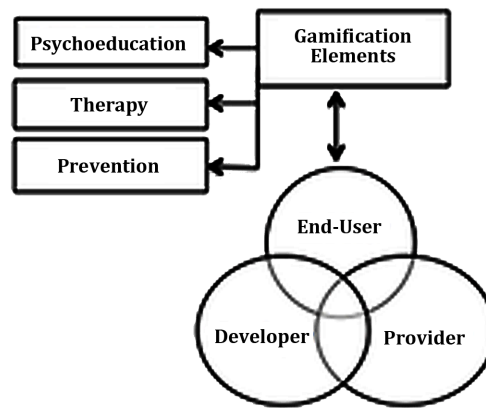


Figure 3. Updated component of the taxonomy of technology and mental health



CONCLUSION

The integration of provider, developer, and patient into the creation and development of mental health related technology will be crucial for ensuring success. Thus, in order ensure success, including increasing accessibility and utilization of mental health technology along with balancing mechanism of action, usability and entertainment, mental health providers and software developers must not forget the end-user, patient, in the creation and development of mHealth. Without a doubt, technology will be as relevant tomorrow as it is today, even more so, as technological advancements continue at an ever increasing pace and patient's become more reliant and dependent upon, and integrate technology into everyday life. As researchers and practitioners, the goal should be to create technology that will encourage repeated and continuous use of said technology, and not just technology acceptance in order to move the field forward toward the provision of low-cost, effective mental health services. Furthermore, each of the foregoing must ensure the continued evolution of such apps as new delivery platforms come to fruition. The Internet of Things is here to stay.

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Chapter 8

Heart Sound Analysis for Blood Pressure Estimation

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ABSTRACT

This chapter aims to give a perspective on how the study of the heart sound relation with blood pressure has evolved. The use of heart sound as a surrogate of the BP has been used with more emphasis on the detection of pulmonary hypertension patients, considering the frequency content, amplitude, and split the second heart sound and its subcomponents, which arise following the closure of the corresponding heart valves. Estimation of BP using the analysis of heart sound is characterized by the simplicity of the equipment used to obtain data, which after analysis allows to achieve promising results that until now were only obtained with techniques requiring far more complex and expensive equipment. The main objective of this chapter is to understand how heart sound analysis may be used to estimate blood pressure and which methods are employed to detect pulmonary hypertension.

INTRODUCTION

Heart disease is one of the main causes of death globally. Some heart diseases may be diagnosed by measuring the pulmonary arterial pressure (PAP), which may be increased due to heart and pulmonary diseases. An increase in the pressure of the pulmonary artery could be an indication of pulmonary arterial hypertension, and may be defined as a mean PAP superior to 25 mmHg (Galie et al., 2009) and outside the 15-30 mmHg range for the systolic PAP (Edwards Lifesciences LLC, 2009).

For diagnostic purposes, most patients undergo an electrocardiogram (ECG), a chest X-ray, an echocardiogram, a computerized tomography scan of the chest, and a cardiac catheterization. The last one,

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the invasive arterial blood pressure (BP) monitoring, is considered the gold standard for BP assessment, providing accurate information, however it is also the most expensive (Chung, Chen, Alexander, & Cannesson, 2013). During a cardiac catheterization, a small flexible tube is inserted into a blood vessel in the arm or the groin, with a contrast dye that makes it possible to see under X-ray and obtain images of the heart structure and vessels. The catheter with a pressure sensor allows measurement of pressures in the vessels and heart chambers, which provide clues to a pulmonary hypertension diagnosis. Despite the catheterization procedure being performed with the patient awake, and bring little or no pain, the patient may still feel pain in the blood vessel where the catheter is inserted. There is a mandatory rest time after the procedure. Also financial costs and risk discourage patients to undergo right heart catheterization procedure and from seeking potentially life-saving diagnosis and treatment of elevated PAP. Elevated PAP can be an indicator of pulmonary hypertension, a condition that may worsen over time, although treatments can relief symptoms and give patients a better quality of life. The diagnostic we want to focus in pulmonary hypertension is the pulmonary arterial hypertension (PAH) that is a type of high BP that occurs in the right side of the heart and in the pulmonary arteries. PAH occurs when the pulmonary arteries thicken or grow rigid, this makes blood flow more difficult. The right side of the heart has to work harder to push blood through the arteries, and the arteries are not able to carry adequate blood to oxygenate in the lungs. It is difficult to continuously assess pulmonary arterial hypertension evolution, which motivates the search for accurate noninvasive PAP measurement devices.

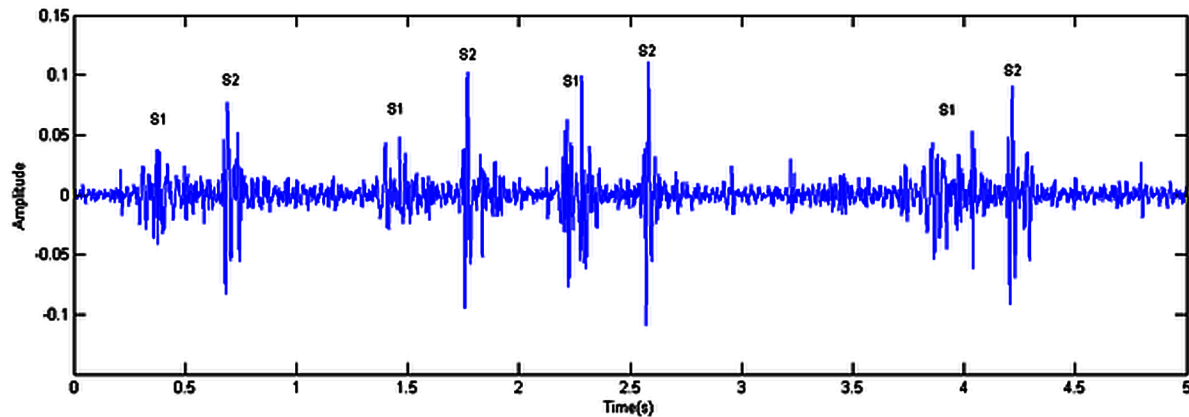
BACKGROUND

A noninvasive estimation of the PAP is already in clinical use, the Doppler echocardiography; it uses ultrasound technology to measure PAP by analyzing the speed of blood flowing through the heart. Doppler is widely used by cardiologists, it requires specific equipment, a specialized and trained doctor, and therefore it is difficult to be used for continuous monitoring, or in places without specialized healthcare professionals. Also some patients are not candidates for Doppler due to physiological constraints or poor signal-to-noise ratio: PAP cannot be estimated in 34 to 76% of patients with chronic obstructive pulmonary disease, 10 to 20% of patients with elevated PAP, and the most important in approximately half of patients with normal PAP (Xu, Durand, & Pibarot, 2003); also the Doppler estimations present an average error of 30% compared to right heart catheterization (Smith & Ventura, 2013).

Another method proposed for PAP noninvasive estimation is the heart sound analysis. Phonocardiography is a technique that generates a record of sounds produced by the contracting heart, resulting from valves and associated vessels vibration, the phonocardiogram (PCG), as we can see in Figure 1.

The sound is collected with a stethoscope over the main auscultations points on the chest; for the detection of pulmonary hypertension, usually the second heart sound exhibits an hyperphoresis of the pulmonary component, more audible over the pulmonary auscultation site (Young, 2001). Recent rebirth of the stethoscope, with electronic record of the PCG, has led to the search of automatic signal processing techniques to detect this clinical sign, and few studies have addressed this issue in the literature (J Xu et al., 2002; Lim, Shin, Park, & Bae, 2013; Nigam & Priemer, 2004). Phonocardiography has been used to estimate PAP from noninvasively recorded heart sounds using models for how these sounds correlate with PAP. There are however several research questions that need to be answered in the PCG study, namely the robust segmentation of heart sounds, and modeling of the heart components that allow the

Figure 1. Phonocardiogram (PCG) representation with first (S1) and second (S2) heart sounds annotated



extraction of relevant clinical information. It is a necessity to better understand the PCG and its relation with the PAP. To allow a better comprehension of the problem, the following sections provides a brief introduction to the anatomy, physiology, and the heart sound genesis.

HEART SOUND ANALISYS FOR HYPERTENSION DETECTION

Several studies have addressed the way information contained in the heart sound may be related to the arterial BPs at the heart output. This method has been studied with more emphasis on the detection of patients with PAH, considering the frequency, the amplitude, and split of the constituent components of the S2 - aortic (A2) and pulmonary (P2) - corresponding to the closure of the homonym heart valves (Nigam & Priemer, 2004; Jingping Xu, Durand, & Pibarot, 2001).

In order to estimate the BP it is important to separate the S2 components, meaning the aortic and pulmonary components, which has revealed to be a challenging task. In this section we intend to describe the main challenges for the second heart sound analysis, with emphasis on the PAH detection, since this is the most developed to the moment.

The first task in the analysis of the second heart sound is to detect the boundaries between the reference sounds. The concern here is that when the heart sound is registered several other sounds are mixed together, and the objective is to recover the heart sound components from that combined signal.

One of the most cited papers on this subject is the Liang et al., their algorithm segments the heart sound into four parts: the first heart sound, the systole, the second heart sound, and the diastole. The authors consider segmentation of the PCG the first and the most important step of analysis in automatic diagnosis of heart sounds. This algorithm first applies a low-pass filter with a cutoff frequency at 882Hz, to reduce noise outside the range of interest, and then converts to energy with a normalized average Shannon energy of the PCG signal. They compared different envelope methods and demonstrate that the Shannon entropy is the best to attenuate the effect of high amplitude noise that contaminates the envelope.

The peaks are detected based on the following criteria: one peak is always picked up; more than two neighbor peaks detected means the existence of split first or second heart sound, so the first peak is picked up in order to get the onset of each sound. To exclude peaks that do not correspond to any of the heart

sounds, the following criteria are used: (1) when two peaks appear within 50 ms, which is the largest normal sound interval, and the energy of the first peak is not too small compared to that of the second one, the first peak is chosen, otherwise the second peak is selected; (2) when the interval between two adjacent peaks exceeds 50 ms, their energies are compared. If the energy of the first peak is larger than that of the second one, and the last interval meets certain consistency of every second interval, they pick up the first one, otherwise the second one is picked.

To find which peaks are S1 and S2 the authors assume that the largest interval of a recording (within 20 seconds) is the diastolic period, and that the systolic period is relatively constant compared to the diastolic one. They decided to confine the duration of heart sound between 20 ms and 120 ms. The performance evaluation was made using 515 PCG signal segments recorded from 37 subjects, including normal and abnormal (Liang, Lukkarinen, & Hartimo, 1997).

There are more recent and complex studies of this problem like (Nieblas, Alonso, Conte, & Villarreal, 2013) that uses a matching pursuit algorithm achieving a detection rate between 96 to 97.5%, or (Papadaniil & Hadjileontiadis, 2014) that analyses PCG by employing ensemble empirical mode decomposition combined with kurtosis features to locate the presence of S1, S2, achieving a detection rate of 94.5%.

To diagnose pathologies from the right side of the heart we have to separate the aortic and pulmonary components of S2 and that it is a very difficult task from a computational view.

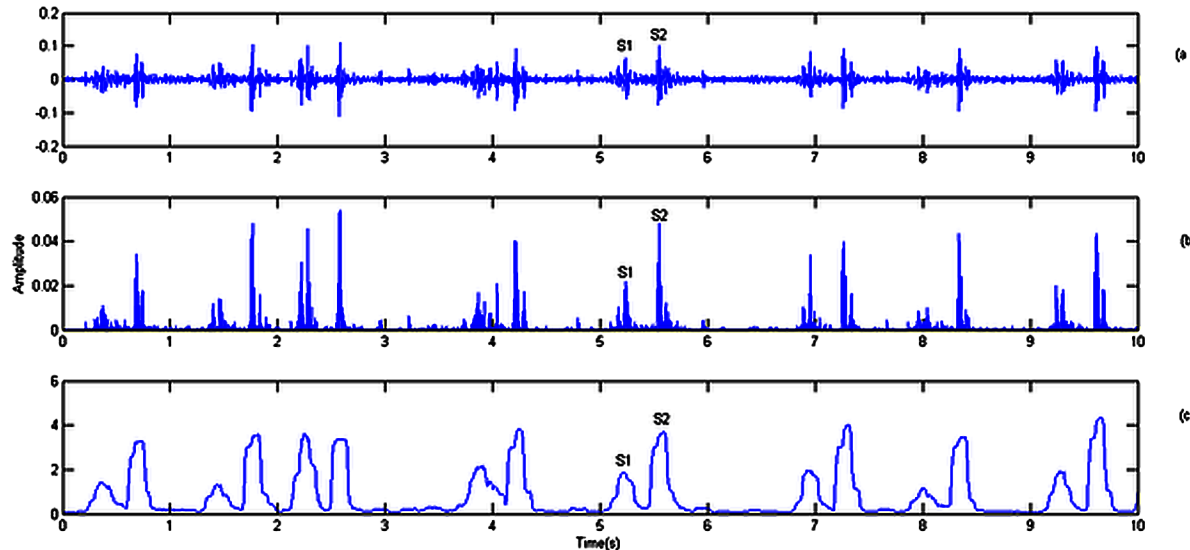
In Bartels et al. the authors explored the noninvasive BP estimation by heart sound pattern analysis. Having a total of 17 patients participating in this study, measurements of BP were made in the radial artery catheter, also gathering synchronously PCG and ECG data. Only 9 of 17 were sufficiently free from disturbances to be used to investigate the PCG features. The accentuated second heart sound of a patient was converted into a computer-aided pattern recognition process for the second heart sound. After a learning phase of the model, during which the second heart sound is recorded, analyzed and correlated with a set of systolic BP values of the individual patient (calibration phase), the computer is able to determine the future systolic BP values of the same patient from the acoustic spectrum of the second heart sound with an error of 6 to 8 mmHg (Bartels & Harder, 1992).

In a different perspective Chen et al. tested a noninvasive method based on spectral analysis of S2 to estimate PAP in 89 patients with a bio-prosthetic heart valve. The technique was compared with continuous-wave Doppler estimation of PAP in these patients. The heart sounds were recorded at the pulmonary area on the chest and digitized to a computer. The spectra of S2 and its components A2 and P2 were computed using a moving window fast-Fourier transform. In Figure 2 we can see an example of a PCG signal from a patient with PAH, and an envelope calculated with a moving window over the Shannon energy; in all stages we can see S1, S2 and its sub-components A2 and P2.

Seven features were extracted from these spectra: dominant frequency of S2 (F_s) corresponds to the frequency associated with the maximal amplitude of the power spectra of S2; dominant frequency of P2 and A2 (F_p), dominant frequency of A2 and P2 (F_a), quality of resonance of P2 (Q_p), which is defined as: where $(f_2 - f_1)$ represents the difference between the frequency values above and below F_p , respectively, for which the amplitude of the power spectrum falls to 50% of the maximal value; quality of resonance of A2 (Q_a), similarly to Q_p :

The ratio of the dominant frequencies of P2 and A2 (F_p/F_a), which can be considered as a type of normalization between patients; the ratio of the quality factors between P2 and A2 (Q_p/Q_a). The statistical analysis performed showed that the best estimation of PAP obtained by spectral phonocardiography was provided by the following equation, as evaluated by the Pearson linear correlation coefficient, with a standard estimation error of 5.6 mmHg, (Chen, Pibarot, Honos, & Durand, 1996):

Figure 2. a) Filtered phonocardiogram segment; b) shannon energy segment; c) shannon energy with a moving window segment



In Zhang et al. the authors propose a method to distinguish the two components of the S2, which may be overlapped. For that purpose they use the matching pursuit method to decompose a signal into a series of time-frequency atoms by using an iterative process for the PCG. Compressing or expanding the frequency band of the signal can be performed without perceptible change in its spectral characteristics. It is also possible to shift a frequency band up or down to a desired frequency range without changing the temporal properties of the signal. With these characteristics in mind their technique has been tested on 11 PCG containing heart sounds and different murmurs. The spectrogram and a matching pursuit based Wigner-Ville distribution were used for visual comparison in the time-frequency domain. The results showed that their technique is suitable and effective for the time-frequency scale transformation of the heart sounds (Xuan Zhang, Durand, Senhadji, Lee, & Coatrieux, 1998).

Xu et al. in an animal study, used a nonlinear transient chirp signal modeling approach for the analysis and synthesis of the overlapping A2 and P2 sound components of the second heart sound. This approach is based on the time-frequency representation of multicomponent signals for estimating and reconstructing the instantaneous phase and amplitude functions of each component. The basic procedure consists in estimating the component which has the higher energy first, because it is the component most easily identified in the time-frequency plane. Then, the estimated component is subtracted from the original signal, after coherent alignment using a cross-correlation technique. The method is then re-applied iteratively until all components are detected and isolated. Each component is defined by a pair of functions describing its instantaneous amplitude (signal envelope) and its instantaneous phase. In practice, the instantaneous frequency (IF) of A2 and P2 are derived from the time-frequency representation of the S2 signal and the phase functions are then estimated by integrating the IFs as a function of time. For decomposition of a multicomponent signal time-frequency this is a good tool, especially when each component is located in a different region of the time-frequency plane or has limited overlap with the other components.

They considered that the splitting interval between A2 and P2 and the exponentially decaying IF functions of both components could be advantageously exploited in the time-frequency plane to filter out and extract each component from the background noise. Since it is known that the A2 component generally appears first, its IF is estimated first using the Wigner–Ville distribution of the S2 signal and a masking operation (time-frequency domain filter) to remove the cross terms, the P2 component, and the background noise.

The technique can also be applied to physiological signals having three or more nonlinear chirp components, but the results show that is very effective for extracting the two components, even in the presence of noise. The normalized root-mean-squared error between the original A2 and P2 components and their reconstructed versions varied between 1% and 6%, proportionally to the duration of the overlapping interval, and it increased by less than 2% in the presence of noise

The validated technique was then applied to S2 components recorded in pigs with normal or high PAP. The results show that this approach can successfully isolate and extract overlapping A2 and P2 components from successive S2 recordings obtained from different heartbeats of the same animal, as well from different animals (Jingping Xu et al., 2001).

Tranulis et al. objective was also to develop a non-invasive method for the estimation of PAP using a neural network (NN) and features extracted from the S2. To obtain the information required to train and test the NN, they conducted an experiment in 9 pigs and analyzed the heart sounds under different conditions of PAP, including pulmonary hypertension. The data recorded from each subject was the ECG, the PCG, and the PAP. Around 15 to 50 S2 sounds were isolated for each PAP stage and for each animal studied. A Coiflet wavelet decomposition and a pseudo smoothed Wigner-Ville distribution were used to extract features from the S2 and train a one hidden layer NN using 2/3 of the data. The NN performance was tested on the remaining data. NN estimates of the systolic and mean PAPs were obtained for each S2 and then ensemble averaged over the 15 to 50 S2s selected for each PAP stage. Their classification accuracy, using a 23 mmHg mean PAP and a 30 mmHg systolic PAP thresholds between normal PAP and pulmonary hypertension was of 97% and 91% respectively (Tranulis, Durand, Senhadji, & Pibarot, 2002).

In a different study, Xu et al. employed the same method as described in (Xu et al., 2003) for the estimation of PAP in animal and human subjects. It was shown that this new non-invasive method based on advanced signal processing of the second heart sound provides an accurate estimation of the PAP in those populations.

Dennis et al. study describe the development of a prototype system, called pulmonary hypertension diagnose (PHD), that uses patient data with machine learning algorithms to build models of how pulmonary hypertension affects heart sounds. They designed the PHD with three sets of parameters: chest wall location, heart sound features subset, and machine learning algorithm. In the first parameter, chest wall location, they chose 5 locations and try to determine which locations are most useful for PH diagnosis. Then they extract 46 features for each recorded heart sound in the PCG traces. Some of these features were proprietary (Inovise Medical, 2013) and correspond to the intensity or width of the heart sounds, but they also use several features already described in literature such as dominant frequencies of S2, A2, and P2, quality of resonance of A2 and P2, 8 types of ratios such as F_{P2}/F_{A2} and Q_{P2}/Q_{A2} , the splitting interval of S2, and systole duration. For the classification set 5 models of machine learning algorithms were used: decision tree, k-nearest neighbors, multilayer perceptron, naive Bayes, and support vector machine. Their main findings from the feature list were: the features extracted from the S2 sound are helpful in classifying a patient and also the percentage of the heartbeat taken for ventricular systole was

much more predictive than the absolute duration time of ventricular systole, the others features had less impact on the predictive model.

The PHD tries to determine whether the PAP is above or below a certain threshold, diagnosing pulmonary hypertension in the validation set with 77% accuracy and 0.78 area under the receiver-operating-characteristic curve (Dennis, Michaels, Arand, & Ventura, 2010).

An interesting work from Angel Lopez-Candales et al. studied the split of the S2 in people with chronic pulmonary hypertension. The authors used a pulsed Doppler to measure the total duration of right and left ventricular outflow tract spectral signal to identify this narrowing between the ejections of both ventricles. Doppler data and standard measures of right and left ventricles were collected from 85 patients divided into two groups according to their estimated pulmonary artery systolic pressure (estimated by echocardiogram). Chronic pulmonary hypertension patients had a shorter total duration between right ventricle output and left ventricle output ejection time than individuals without pulmonary hypertension (-15 ± 16 ms vs. 22 ± 14 ms; $P < 0.01$), that explain the split second heart sound in chronic pulmonary hypertension patients (Lopez-Candales, Edelman, Gulyasy, & Candales, 2011).

Peretto et al. in their study present a comparison between two non-invasive approaches for the estimation of PAP. The study was conducted on 40 athletes, aged between 8 and 67 years, practicing sports at different levels. The first method uses the Pulsed Doppler which has been used for the measurement of maximum tricuspid transvalvular pressure gradient. The second method is based on the analysis of PCG sounds and particularly of the S2 and uses ECG as a trigger, extracting features from S2 and its components as suggested in previous studies. The signals were digitally acquired simultaneously, and analyzed with a software developed in LabView™. Results show encouraging matching between the two methods and also that the proposed method may be relevant for PAP estimation on athletes without significant cardiovascular diseases and practicing different sports (Peretto et al., 2011).

Chan et al. examined the relationship between acoustic characteristics of S1 and S2 and underlying cardiac structure and hemodynamics in patients with isolated PAH and controls. They did a cohort study in referral and community hospitals, evaluating 40 PAH patients undergoing right-heart catheterization with a digital acoustic cardiography and two-dimensional transthoracic echocardiography. As control they had 130 participants without clinical or hemodynamic evidence of PAH or congestive heart failure. Ten second artifact-free recordings were selected and analyzed utilizing proprietary software with wavelet-based signal processing techniques for acoustic analysis. A time-frequency analysis allows the separation of heart sounds from murmurs and an Audicor algorithm was used to reduce external noise like speech and movement. Two acoustic cardiographic characteristics of S1 and S2 were analyzed: intensity and complexity. A value for heart sound intensity is generated based on the peak-to-peak amplitude of the sound, and complexity is determined using time-frequency measures of width, intensity and frequency content of the signal. Complexity and intensity were normalized and expressed as a ratio between S2 and S1 to account for variations in anthropomorphic characteristics. Then univariate and multivariate linear logistic regressions were applied to examine the relationship between hemodynamic variables and S1 and S2 complexity. The authors reported that acoustic characteristics of both S1 and S2 are related to the severity of PAH and are associated with right ventricular enlargement and systolic dysfunction. The reciprocal relationship between S2 and S1 complexity may also reflect the underlying ventricular interaction associated with PAH (Chan et al., 2013).

Some studies with noninvasive experiments found that the time delay from the peak of ECG R wave to the onset of the second heart sound had a close inverse correlation with arterial systolic BP (Xin-yu Zhang, Macpherson, & Zhang, 2008); Lim et al. used PCG to determine whether the ratio of S1 to S2

analyzed by esophageal stethoscope transmitted via a wireless bluetooth connection can be an accurate indicator of the BP. A total of 33 adult subjects, without cardiac disorder and with normal heart rhythm were enrolled and randomly selected to be subjects of the study, also all patients undergo a total intravenous anesthesia induced with propofol and remifentanyl by target controlled infusion. Two microphones were used: one for the acquisition of heart sound by connecting it to the esophageal stethoscope; the other was used to measure the background noise in the operating room. After transmission of the heart sounds measured with the esophageal stethoscope to the receiver by using a bluetooth module, the portion of the recorded data through the esophageal stethoscope that coincided with the noise in the operating room was removed; noise such as the respiration sound was removed with low-pass filtering. S1 and S2 were detected with computation of the ratio of S1 to S2. Correlations between the systolic BP with S1, S2 and S1 to S2 ratio were examined. The ratio of S1 to S2 presented the highest correlation with the systolic BP (Lim et al., 2013).

Smith et al present a machine learning model based on heart sounds characteristics to estimate PAP; some features were derived from heart sounds, and machine learning techniques were applied on a large patient dataset to choose a specific model and features for PAP values prediction. Two machine learning models were tested, support vector machines and multilayer perceptron. A greedy search through the 38 possible features was conducted within the following categories; binary features, dominant frequency, quality of frequency, power, splitting interval, ratios, systole duration and heart rate, using a 109-patient cross-validation to find the most predictive features. The best model had a standard estimate error of 8.3mmHg (Smith & Ventura, 2013).

The methods presented in the literature demonstrate that several important features of the cardiovascular system may be estimated through the relations between the signals measured on the body surface; the heart sound analysis presents encouraging results for the systemic and pulmonary blood pressure estimation, however further studies are necessary to improve accuracy and validate the technique for clinical use.

SOLUTIONS AND RECOMMENDATIONS

The use of heart sounds for BP estimation is a very promising noninvasive method, however it needs to be further studied so that it may be widely used in clinical practice, and as a complement to existing methods. There are several issues in the method that need to be better understood, one of these problems, and also one of the most complex, is the separation of A2 and P2 components. Advancing the techniques for heart sound segmentation as referred earlier will allow to improve overall results; several studies use the ECG as a triggering method for heart sound segmentation, which although improves S2 detection, increases complexity of such a system. Commercially available digital stethoscopes, already define the best characteristics for heart sound acquisition, however the lack of a data collection standard tends to generate less homogeneity of the various studies. Noise interference is also a concern, and it should be controlled for better results. The definition of a data collection standard will play an important role for the success of such a system. The impact of different biotypes on sound quality also needs to be addressed, as well as the determination of the best set of parameters for BP estimation. In general there is a need for larger multicentric studies to validate the method.

FUTURE RESEARCH DIRECTIONS

To estimate BP using heart sounds there are three areas that are critical and must be extensively studied in the coming years, starting with the most complex, the separation of A2 and P2 components. Also complex enough is what kind of features should be extracted from heart sounds to estimate BP, it is necessary to look for a faster way and a more analytical method to find an optimal feature subset for on-line implementation, therefore these issues should continue to be subject of specific and more focused studies. Finally the estimation models algorithm that best correlate heart sound features with BP also have a lot of potential to be further developed, although promising results were already achieved.

CONCLUSION

Digital phonocardiography and the analysis of the second heart sound is an evolving area; studies demonstrate that it is possible to separate the A2 and P2 components of S2, even when the overlapping interval of the two components is relatively high. Since the operating pressure and basic elastic properties of the aortic and pulmonary valves and vessels are different, their instantaneous resonant frequency functions should also be generally different. It is possible with an auscultation to determine pathologies from the left side of the heart (A2 component and systemic circulation), and from the right side of the heart (P2 component and pulmonary circulation). The advantage of using auscultation to detect heart and lung pathologies is the fact that it is a noninvasive method, with a simple and easily accessible technology. These systems could bring advantage due to its practical application, making the management of PAH patients easier, and improving patient comfort.

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KEY TERMS AND DEFINITIONS

Blood Pressure (BP): The pressure exerted in the walls of blood vessels by circulating blood.

Digital Stethoscope: Equipment used to digitally amplify and record sounds from the body.

Electrocardiogram (ECG): A record and representation of the electrical activity of the heart.

First Heart Sound (S1): Sound resulting from mitral and tricuspid valves closure.

Phonocardiogram (PCG): The record and representation of the heart sound.

Pulmonary Arterial Hypertension (PAH): An increase of blood pressure in the pulmonary artery.

Second Heart Sound (S2): Sound resulting from aortic and pulmonary valves closure.

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Chapter 9

Sociological Perspectives on Improving Medical Diagnosis Emphasizing CAD

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ABSTRACT

Healthcare costs worldwide are increasing because of new medicines, new techniques, and more expensive and extensive research on diseases. It is essential that healthcare delivery systems be implemented that take advantage of these advances in a cost-effective economic manner. One critical aspect of the healthcare delivery system is the improvement in diagnosis of disease. This chapter emphasizes diagnosis and the need to collect key patient information (pivotal information) at the earliest possible point in the patient's disease process and put such pivotal information in physicians' hands. There is a potential for huge benefits in cost savings and greater effectiveness of treatment from these actions, but challenges must be overcome to realize their full benefits. The major problems include (1) market incentives in the current healthcare system, which fail to encourage collecting pivotal medical information as early as possible, (2) physician resistance to some of these ideas, and (3) technical and ethical problems that remain to be solved.

INTRODUCTION

Health care costs worldwide are increasing because of new medicines, new techniques, and more expensive and extensive research on diseases. It is essential that health care delivery systems be implemented that take advantage of these advances in a cost effective economic manner. One critical aspect of the health care delivery system is the improvement in diagnosis of disease. This paper emphasizes diagnosis and the need to collect key patient information "pivotal information" at the earliest possible point in the patient's disease process, and to put such pivotal information in physicians' hands. There is a potential for huge benefits in cost savings and greater effectiveness of treatment from these actions, but challenges must be overcome to realize their full benefits. The major problems include (1) market

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incentives in the current health care system fail to encourage collecting pivotal medical information as early as possible (2) physician resistance to some of these ideas and (3) technical and ethical problems that remain to be solved.

BACKGROUND

Previously, Fisher and Fisher (2014) discussed the problems of improving medical diagnosis as both a management and information problem. Their analysis focused on three specific strategies: improving medical histories of patients by using discourse analysis, public education about selected major diseases that if ignored can lead to health impairment and even death, and use of computer assisted diagnosis (CAD).

THE PROCESS OF DIAGNOSIS

Diagnosis is sociologically a process of bounded rationality, consisting of evidence gathering punctuated by a series of conjectures about a patient's ills before arriving at the *best* conjecture and treatment plan. This view of diagnostics originates from Zeldenrust's (1990) version of the garbage can model of organizational behavior that sees diagnosis as a linkage between a demand (patient with an illness) and a solution (physician guesses nature of underlying problem and offers a plan for treatment). The solution may include medicine, behavioral modification such as bed rest, change in diet etc., and perhaps tests to rule out certain competing diagnostic hypotheses consistent with applicable constraints. The physician builds on the information learned not only from the patient reports but also on test results and on other objective data obtained. The physician treats symptoms uncovered until the patient either is cured and a final diagnosis is achieved or at least until all competing hypotheses about the condition are ruled out.

Improving the diagnostic process hinges on rapidly expanding the diagnostic information available to the physician. This diagnostic information is not just any data but the sort that expands the number of hypotheses of possible diagnoses, *i.e.* pivotal data. The physician can then examine the maximum number of plausible hypotheses. The idea is that *the more hypotheses the physician needs to rule out at the outset the more likely* the physician will find the disease(s) behind the patient's complaint and provide the proper treatment (including referral for specialized services). The process also covers multiple possible pathologies that may exist at any moment, although the clinician may place ordering priorities on these possible multiple pathologies.

A. The Medical History and Discourse Analysis

Medical authorities agree that the most important basic information beyond a description of the patient's medical complaints is the patient's health history. An encounter with any provider usually begins with some kind of questionnaire or interview with regard to that history. The needs of different providers often result in different kinds of questionnaires or approaches about health history. They likely cover all the same major issues, but the differences can be important. There is little evidence that these initial interviews involve people trained in discourse analysis. Since the Fisher and Fisher (2014) analysis, almost no real advances or progress have been described. In fact, clinical people are almost expected to develop interviewing skills by "osmosis" on the job. A surprising finding was that neither nursing nor

medical curricula include formal course work on this although some medical schools give orientation lectures and guides to such interviewing skills. The technique is not included in the so-called “patient assessment courses.”

Discourse analysis, popular in the United Kingdom, is basically the study of language in context (Elwyn and Gwyn, 1999). The subject shares much in common with assessments of communication that look at gestures (often referred to as “body language”) –the “silent language” (Edward Hall, 1973). The discipline examines conversational processes: how is one version of events selected over another? How is a familiar reality described to give it an unquestionable authority? It then brings to bear on the patient’s diagnosis *all the information* that patients are providing, and *saves it for future use*. It can identify and elicit previously hidden patterns and perspectives (for example, in patient clinics, among health visitors, and in transcripts of interviews conducted by HIV counselors). Their extensive list of references suggests that the technique has been widely applied in health care related situations with promising results.

The technique has a sound basis in social science and can be applied quickly by medical practitioners and should be included in the basic course work of the field. Discourse analysis seems to be easiest to implement in medical practices serving ethnically relatively homogeneous areas whose residents have a relationship with the medical staff. This has major implications for CAD.

B. Public Education

Although public education is not a diagnostic procedure, it garners public cooperation in early diagnosis and treatment of many serious illnesses. Its purpose here is not to impress on people to take better care of themselves, but rather to have targeted campaigns about specific conditions that if treated early are easily cured or managed, but if ignored, become extremely expensive to treat and perhaps lethal. Public education should put *pivotal* information in the hands of both the physicians and patients as early as possible in the disease process to maximize the probability of effective treatment at the lowest possible cost.

Patients who recognize the possible variety of symptoms of heart attack and stroke etc. will more likely seek treatment when the physician’s intervention may be most certain to work, and probably least expensive. Some diseases, such as colon and pancreatic cancers often show few or no early warning symptoms and only make you uncomfortable enough to seek medical attention in their advanced stages. These diseases typify a propensity of people to avoid medical attention until they are in pain or their normal functioning seems to have been greatly impaired. Much current public education work seems to have a “disease of the month” flavor, reflecting what specific illnesses have become objects of attention in the news media.

C. Computer Assisted Medical Diagnosis (CAD)

The most important suggestion is CAD, and it is where the most progress has been made. CAD does not diagnose the problem but only suggests a range of hypotheses for the physician to check out. Put simply, computerization of the diagnostic process might advance medicine by looking at individual symptoms, clustering symptoms, and providing a kind of pattern matching algorithm that generates the needed conjectural hypotheses consistent with the information in the medical data banks.

CAD offers the major advantages of a nearly unlimited virtual library or information facility, a communications facility, and an inexpensive infrastructure. Scadding (1967) hoped that physicians would soon take advantage of the possibility of instantaneous correlation of groups of clinical and laboratory

findings with the established features of specific diseases. Physicians would also capitalize on the computer's ability to *suggest* a wide range of possible diagnoses without necessarily discriminating among them although it could include risk assessment algorithms that rank them by probability of occurrence and seriousness of outcome if left untreated). These special information tools have become a major focus for big data and information specialists in many fields.

When Fisher and Fisher (2014) examined the issue a universal CAD system did not exist in the United States. Early considerations by the military to develop one remained basically in the conceptual stage. There is still none, but a review of CAD systems at large indicated a number of interesting findings.

1. The most widespread and successful medical CAD usage has been in medical imaging, a highly limited area of diagnosis. Qiang and Nishakawa (2015) have produced a state-of-the-art compendium of its use for various types of imaging to detect and evaluate carcinomas. That may highlight the difficulties in expanding the tool to a wider area of medical diagnostic concerns. Watson, a supercomputer from IBM, involves a look at diagnosing certain kinds of cancer. (Mearnian, Lucas, 2013) One of the tasks of Watson is to continuously update and comment on the literature. The scientists working on Watson hope to make it widely available soon. Watson's developers at IBM mention that its major feature is that it can focus its massive data processing capabilities on personal genomes. Note, however, that work involving the human genome tends to raise certain ethical and privacy issues, major sociological concerns. In looking at a CAD system, one is really not currently easily able to relate to the sociological issues of privacy and ethics beyond indicating that the operation and access of the system to information be in accord which respects privacy and adheres to ethical norms.
2. A CAD system has been used extensively in France (Seka, Fresnel et al, 1997) and the French researchers have proposed expansion for the Internet at large. Although France has a diverse ethnic and demographic population, compared to the United States' diversity of ethnic and demographic features, the French might be considered a somewhat ethnically and demographically a smaller, possibly homogenous cultural unit. The French system accommodates information on about 10,000 diseases. This may or may not be a suitable number for system guidelines, but since various forms of cancer, a disease with probably the most variations and types has over 1,000 separate disease designations, it may be satisfactory.
3. Various groups are using CAD systems in rural India and areas of sub-Saharan Africa where the medical problems have unique geographic and ethnographic features. (Kalode, Kempar, and Deshpande, 2012; Friedman, 2009). A major thrust in CAD systems for diagnosis is for rural areas that are medically underserved mainly because sociologically this is not an area where clinicians seem anxious to practice. It often lacks infrastructure, access to researchers and research facilities, and other desirable features.

The *sociological* implications are that a *universal CAD may not necessarily be either optimal or desirable*. Rather, one might develop a series of CAD systems related to smaller regions with ethnic, geographical and demographic unique considerations as well as the most common pathologies universally encountered, unique to certain regions with a subroutine to search other systems based on information in a patient's history about travel, residency and other factors that may become important. This is the most important new direction that this diagnosis work should take.

CAD's biggest technical hurdle is the fiendishly complex nature of a diagnosis (see: Innocent & John, 2004). Some symptoms, such as fever, are always important; but for other symptoms the importance depends on context. An effective CAD in generating hypotheses will include a provision to note that certain symptoms are especially significant in the presence of others in confirming a diagnosis.

The many and diverse bases for deciding a disease behind the symptoms include cause, description, site, symptom/syndrome, variation from statistical norm, and treatability. Further, diagnoses change as individuals, professions or society dynamically modify the boundaries of what they consider respectively normal or problematic. For example, not all physicians accept chronic fatigue syndrome or even fibromyalgia as diseases. In the 1970's United Nations publications listed world-wide fatalities from juvenile prostate cancer as a single cause of death, but the most recent compendia list over six different categories of the disease. Psychiatric disorders continue to be sources of controversy as to what is a symptom or syndrome or condition. This has even prompted legal arguments as to the legitimacy of certain diagnoses. These are mainly *social issues*.

Jutel (2011) endorses Aronowitz (2001) that *social influences* have largely determined which symptom clusters have *become* diseases. CAD may not cover every condition that physicians treat because no societal or professional consensus exists as to whether the condition is a disease and to what is its appropriate treatment. That fact should not inhibit CAD. Computer programs can assign conditions with appropriate data in special categories where there is no societal or professional or societal consensus, or such identity has not been sought or even rejected. A CAD system should accommodate certain symptoms or syndromes as identifiable even if they are professionally not recognized, simply because they occur so often that to ignore them is foolhardy. The patient still suffers from the condition regardless of any societal or professional agreement as to the legitimacy of the diagnosis.

CAD can assist in reducing misdiagnosis. Since the Fisher and Fisher (2014) paper, this has become something of a two-sided issue. On one side, CAD can offer a comprehensive list of hypotheses and indicate what additional pivotal facts, such as test results, are needed to confirm each of them. On the other side, there seems some feeling that reliance on CAD could result in increasing errors of medical malpractice. Several websites of attorneys have appeared recently soliciting clients who may have been improperly treated because the diagnosis and treatment were traceable to hypotheses of recommendations from a CAD system. This should not discourage development of CAD because it only provides information, it does not formally diagnose.

In discussing misdiagnosis, Bradley (1993) found that the physician typically begins with three or four hypotheses but rarely more than seven. He counsels physicians who cannot avail themselves of a CAD that one of the four hypotheses should be a "catch-all"—*i.e. any* of the above, or even *none* of the above. There needs to be considerable computer work to specify the features and operating protocols for this "catch-all" category.

When facts support one of the three starting hypotheses, it is important to maintain the possibility of the true diagnosis being something else. Good diagnosticians do this, or something akin to it. The author of this paper lives in an area characterized by a fungal disease known as "Valley Fever." It has symptoms that may suggest flu, various kinds of pneumonia, tuberculosis, unusual allergy situations, certain kinds of seizure disease orders and a host of more common ailments (Malo et al, 2014). A CAD system for the physician in this area should include Valley Fever in all proposed hypotheses if the symptoms comport. Another disease that has caused similar misdiagnoses because of its many symptom manifestations is Lyme disease (Pachner, 1989; Stanek, 2012; see also fact sheet from CDC, 2015).

Pivotal facts often differ between men and women. Recent studies have shown that men and women tend to present different sets of symptoms for heart attacks and strokes. These gender differences require considering more possibilities when certain symptoms are present. Campbell (2015) has written extensively on this issue with respect to women's heart conditions.

Sometimes a misdiagnosis arises from prematurely accepting a positive confirmation of an initial. Bradley warns physicians to guard against misusing information by over-emphasizing positive findings when a negative finding may be just as diagnostically significant. There is a natural tendency to prefer positive evidence proving a hypothesis over negative evidence disproving it. A test that could confirm a diagnosis because of a positive outcome tends to mean that the assumed diagnosis that called for the test is likely to be correct. However, to improve diagnosis, a negative test [finding] should have the converse effect of making the original assumed diagnosis less likely. Bradley notes that often the clinician ignores this negative evidence. The disease often gives negative or ambiguous test results from immunological and serological studies despite a patient having the disease). This becomes especially important when the confirming test result is subject to a false positive error, or when a confirming test result can also suggest other hypotheses, which may or may not have been in the original cluster of assumed diagnostic conjectures. A CAD should include a feature that alerts the provider with guidelines to question if a particular result may originate from assuming that a certain diagnosis is confirmed by a certain test.

A negative finding does not always disprove a diagnostic conjecture. Many patients are asymptomatic for certain conditions and a particular test may prove negative for that person even under the condition it is designed to highlight. [see references on Lyme disease at end of paper, Pachner 1989 and Stanek, 2012]. This author had *normal* sinus rhythm from an EKG while having a near fatal heart attack, and only a physician's recognition of other signs led to a life saving diagnosis.

CAD can reduce misdiagnosis by having a "parallel testing feature"—it can offer a list of hypotheses fitting the same set of facts. A physician not accessing a CAD may settle on just one of the possible hypotheses (without ruling out the others) and choose the wrong one. The frequency of such situations of misdiagnosis is unknown, but missing the correct diagnosis of a disease such as MDR tuberculosis as a possible tropical parasitic infection has serious public health consequences (Naik, 2012).

A CASCADE OF SMALLER CAD SYSTEMS AND A SUPERCOMPUTER

Computer technology continues to advance at exponential levels. The computers have greater storage, more flexibility, smaller sizes and a host of great features which should now be augmented with the diagnosis requirements. There is a need to link smaller CAD systems individually emphasizing regionally specific diseases into a cascade, or through access to a supercomputer designed to obtain information needed for a patient with an unusual history of travel, residence, or other factors. By keeping local systems small, they prevent management overload with regard to information, and minimize problems related to network function and oversight for the clinician.

The local systems can include provisions for symptoms and diseases which have not yet received either professional or social acceptance or those being debated at various professional levels of practice. The local systems can also indicate which techniques, tests, and protocols are experimental, or have not received peer review but are still in use. The larger system can provide information as to the status of any disease or treatment with regard to national or governmental authorities, both locally and internationally,

and provide for appropriate mechanisms of information translation where the local CAD system has linguistic differences from another CAD system's language of inquiry.

Many current medical systems have enhancements that allow patients to access their medical records from home computers and "smart phones" through "patient portals." This technology also allows rapid conferencing among medical colleagues. This could reduce some costs associated with second opinions needed for a diagnosis and increase the quality and extent of care available in medically underserved areas by focusing on the kinds of consultations needed. The patient portal approach could make the CAD usage patient friendly. The proponents of Watson see this as one of their major goals.

CAD can foster major infrastructure improvements. CAD can provide links to consulting physicians in distant medical centers to augment a health care provider's local network. One major system links physicians on call in Australia and Europe to provide 24 hour consultation possibilities because of time zone differences and working hours in the United States. Even diagnosis and treatment in outer space is possible, as astronauts can follow instructions from remote centers on earth to deliver health services to others in space with them. And we should not overlook the benefits to doctors in medical centers who deliver much of the health care to people who use the emergency room as their family physician.

FUTURE RESEARCH DIRECTIONS

Getting wider physician use of a CAD may be a problem, although this author believes that the physician resistance to CAD as machine replacing their work is largely unfounded. Even if the profession's leading members endorse CAD, others might not readily fall in line. The current United States approach is to produce "best practices" papers and manuals to reflect the new knowledge. Professional societies have taken a positive lead here, but some government agencies, notably the Veterans Administration, see the need for these documents as internal procedures and protocols and have made their use more accepted and widespread. CAD can act as an assistant in producing these documents through its information archival capabilities, as well as by incorporating the results of these documents to assist clinicians when looking at possible hypotheses of diagnosis and treatment.

CONCLUSION

The importance of good diagnostic tools will go far to improve health and health care delivery systems in a new environment of high medical costs, special insurance requirements, record mobility and big data usage. Because quantity and quality of medical care are not evenly distributed in the United States, one way to improve the quality across the country is to focus on improving the accuracy of and speed with which physicians make diagnoses.

A comprehensive CAD offers the current best hope to improve diagnosis. The tool need not be perfect to be valuable in reducing physician diagnostic errors and in making more precise the needs for consultations and second opinions, and possibly in speeding up diagnostics.

The most useful and successful CAD systems for other than special technical protocols or single diseases, are regionally specific. That seems the key to improved diagnostic usage. A series of smaller CAD systems should emphasize the diseases unique and common to certain areas. These smaller sys-

tems can contain linkages to other systems or a supercomputer when the patient information, either from medical history or encounter questionnaire/interview shows residence, work, and travel or simply traversing certain locations which feature diseases whose symptoms may confound others or offer additional hypotheses in a specific diagnosis.

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KEY TERMS AND DEFINITIONS

Computer Assisted Diagnosis (CAD): A conclusion as to the disease reached with the assistance of a computer.

Diagnosis: A conclusion or assumption the pathology represented by a patient's inquiry, particular set of symptoms, or complaints.

Diagnostic Process: The process of arriving at a diagnosis using various informational inputs from a patient's inquiry, symptoms or complaints.

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Section 4

Healthcare Administration

Chapter 10

Electronic Health Record (EHR) Diffusion and an Examination of Physician Resistance

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ABSTRACT

Since the enactment of the United States Health Information Technology for Economic and Clinical Health (HITECH) Act in 2009, there has been substantial progress in the diffusion of electronic health record (EHR) systems in medical clinics throughout the United States. Many physicians, however, continue to resist adopting EHR technology despite several accepted, long-term benefits and available government-sponsored financial incentives. The objective of this chapter is to provide insight into the question as to why physicians are resistant to adopting EHR technology. This chapter details several of the benefits of EHR systems and uses a systematic review of literature to critically analyze and detail the most common perceived physician barriers to the adoption of EHRs. With the awareness of the major physician barriers to the adoption of EHR technology, stakeholders and policymakers can address barriers and pursue actions to mitigate or reduce physician resistance to achieve nationwide diffusion targets and pursue initiatives to digitize all patient records.

INTRODUCTION

Since the enactment of the United States Health Information Technology for Economic and Clinical Health (HITECH) Act in 2009, there has been substantial progress in the diffusion of Electronic Health Record (EHR) systems in medical clinics throughout the United States. Many physicians, however, continue to resist adopting EHR technology despite several recognized long-term benefits and available government sponsored financial incentives. The objective of this article is analyze physician resistance to EHR technology adoption. Previous researches indicate that physicians have been reluctant to adopt

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EHR systems due to high implementation and maintenance cost besides the uncertainties associated with EHR's return on investment. Apart from financial cost, physicians also seem to encounter challenges in adopting EHRs due to lack of technical skills, time, and technical support. Workflow disruption, loss of autonomy, confidentiality issues, and interoperability are major challenges hindering the adoption of EHRs (Ajami & Arab-Chadegani, 2013; Lorenzi, Kouroubali, Detmer, & Bloomrosen, 2009). Moreover, an annual report prepared by the United States Department of Health and Human Services (2014) shows that, loss of productivity, lack of adequate training and incompatibility of EHRs with practice needs are the top reasons why physicians resist the adoption of EHR systems. With the awareness of the major physician barriers to the adoption of EHR technology, stakeholders and policy makers can address barriers and pursue actions to mitigate or reduce physician resistance to achieve nationwide diffusion targets and pursue initiatives to digitize all patient records.

Although physicians are hesitant to adopt EHR technology, there are several benefits of EHR systems that make the technology worth adopting. Evidence from healthcare research and systematic reviews show that the benefits of EHRs continue to grow and include: enhancing the accurate collection, storage and sharing of medical information of patients with authorized personnel to support informed decision making, prevention of medical errors, availability of data for clinical research and analysis (United States Department of Health and Human Services, 2014). The Institute of Medicine and other stakeholders in the healthcare field suggest that the wide-scale adoption of EHR systems could be pivotal for improving patient safety and health care quality and could reduce the costs of providing ambulatory care (Ajami & Bagheri-Tadi, 2013). It is generally accepted that EHRs could also improve efficiency, portability and research capabilities (Pipersburgh, 2011).

Given the potential benefits of EHRs, physicians could be helped to overcome their barriers to adopting EHR technology. For example, physicians can be more productive or efficient and effective if their routine tasks are automated. With the input of physicians, automated technologies could be produced to handle repeated tasks and daunting processes. Physicians will then be able to spend more time with patients and workflow interruptions will be eliminated as well. This research illuminates the challenges encountered by physicians in adopting EHRs, and suggests how future research could tackle these.

BACKGROUND

An EHR can be defined as a digitally stored record of an individual's healthcare information used for supporting the continuity of care, education, and research (Ajami & Arab-Chadegani, 2013). The Health Information Technology for Clinical Health (HITECH) Act, which was enacted as a part of the American Recovery and Reinvestment Act (ARRA) of 2009, served as a turning point in the evolution of EHR technology in the United States. The HITECH Act was signed into law with the explicit intention of accelerating the adoption of Electronic Health Records (EHRs) by physicians, and since its enactment, the program has distributed billions of dollars to physicians for adopting certified EHRs through the meaningful use (MU) program (Mennemeyer, Menachemi, Rahrkar, & Ford, 2016). One research study noted that through December 2015, the federal government had made \$13 billion worth of EHR incentive payments to physicians and other eligible professionals who met stage 1 of meaningful use (Cohen, 2016). Overall, the stimulus act included a requirement that grant recipients achieve all meaningful-use requirements, including interoperability, by the end of 2017 (Sandler, 2016).

In acute care hospitals, there has been substantial growth in the adoption of basic and certified EHR systems (Charles, Gabriel, & Furukawa, 2014). In 2014, 3 out of 4 hospitals had adopted at least a basic EHR system which represents an increase of 27% from 2013 (Charles et al., 2014). Figure 1 delineates the growth in the percent of non-federal acute care hospitals with adoption of at least a basic EHR system and possession of a certified EHR system from 2008 to 2013 (Charles et al., 2014).

EHR adoption has also been on the rise for rural practices which has reversed initial trends (Hirsch, 2015). A new study by the Journal of the American Medical Informatics Association (JAMIA) revealed that EHR adoption in rural areas was 56 percent compared to 49 percent in urban areas, and the study concluded that 27 states have adoption rates statistically higher in rural areas than in urban areas (Hirsch, 2015). The USA is not alone in its efforts of EHR implementation and use. Figure 2 shows notable efforts by other organizations in key developing countries.

Despite the progression of the technology and broad agreements on the benefits of EHR technology, many physicians in the United States remain hesitant to adopt. Research shows that the diffusion and physician acceptance of EHR technology may be hindered by a variety of intrinsic and extrinsic barriers (Paré et al., 2014). The purpose of this study is to explore the most prominent perceived challenges and barriers that physicians face in adopting EHR technology. Specifically, this study is intended to answer the question, “Why do physicians resist the adoption of EHR technology?”

This study utilizes a systematic review of literature on physicians’ resistance to the adoption of EHRs. The literature on physicians’ resistance and perceived barriers to the adoption of EHRs and EHR technology was completed through a research database search engine. The search employed various combinations of keywords such as electronic health record, electronic medical record, barriers, physicians, resistance, and adoption to search for previous research and literature related to this study. Journal articles used in this study were based on relevance to physician barriers to the adoption of EHR technology although many of the detailed barriers to adoption of EHR technology are applicable and relevant to other user groups. Research databases leveraged in this study include journal articles and digital articles or reports. Approximately thirty-three articles were reviewed for this study and twenty-seven of the articles met or supported the specific criteria of this study which focused on physician barriers to adoption of EHRs. Moreover, approximately 67 percent of all the reviewed journal articles were cross-referenced and analyzed.

*Figure 1. EHR system adoption for non-federal acute care hospitals in the U.S.
Charles et al., 2014.*

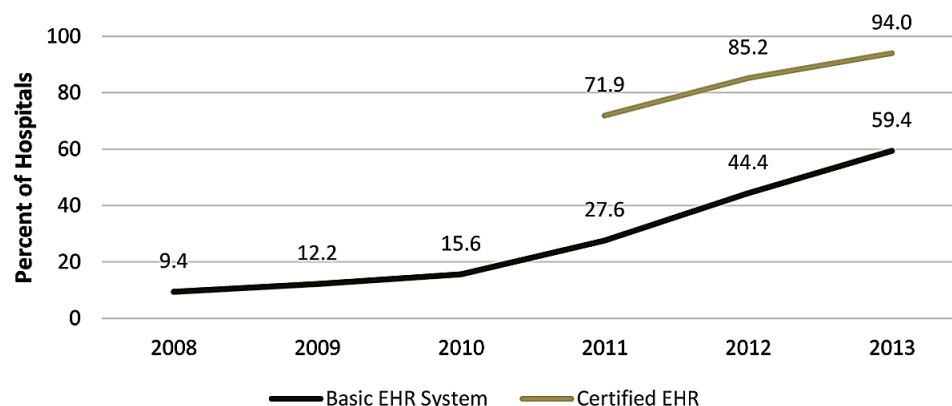
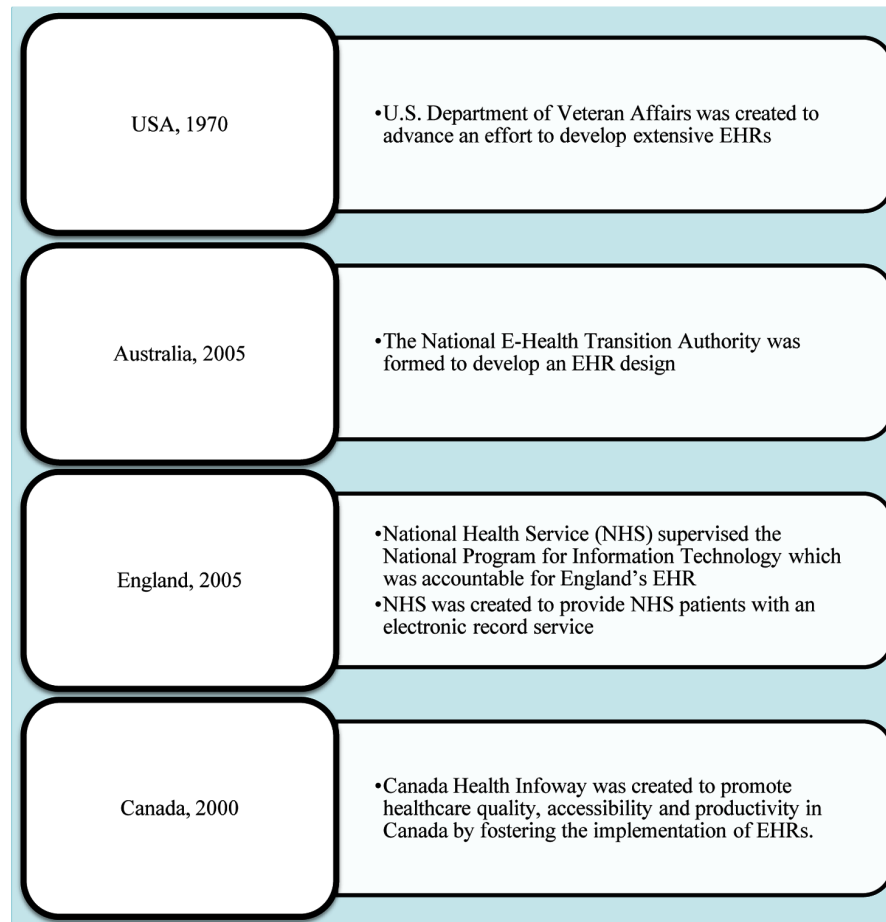


Figure 2. EHR initiation in the USA, Canada, England, and Australia
Aminpour, Sadoughi, & Ahamdi, 2014.



PHYSICIAN BARRIERS TO ADOPTION OF EHRs

In most clinical settings, physicians' orders trigger most determinants of healthcare quality and costs (Zaroukian, 2011). Although other users, groups, or factors may influence the adoption of EHR technology in a clinical setting, this study focuses on physician resistance since efforts to achieve health information technology (HIT) transformation will not succeed unless the physicians support the desired improvements in quality and value of new technology (Zaroukian, 2011).

The professional journals reviewed in this study maintained many similarities in categorizing or sub-categorizing physician barriers to adoption of EHR technology. The most common barriers identified in this study are outlined in the following categories: cost restraints, technical constraints and system limitations, time constraints and workflow disruptions, physiological constraints, social influences, and privacy and security concerns. A review of twenty-seven articles from 2004 to 2016, found in twenty-five databases showed that there are six major categories of physician barriers to EHR adoption as follows:

Cost Restraints

The short-term and long-term financial investments for an EHR system remains a significant barrier to EHR system adoption for practices without large IT budgets (Ajami & Bagheri-Tadi, 2013). Financial issues including adoption and implementation costs, ongoing maintenance costs, loss of revenue associated with temporary loss of productivity, and declines in revenue may deter physicians from adopting an EHR system (Menachemi & Collum, 2011). Given the infancy of EHR systems and its use in the United States, there is not substantial evidence on the long-term return on investment (ROI) of EHR systems. Thus, studies reveal that physicians worry that their practices will face substantial financial risk without a promise of return (Boonstra & Broekhuis, 2010). Additionally, research shows that many financial benefits of an EHR do not accrue to the provider but rather to the third-party payers in the form of errors averted and improved efficiencies, which generally translate to reduced claim payments which can be another concern for physicians (Menachemi & Collum, 2011).

Technical Constraints and System Limitations

The successful implementation of EHR technology requires users and suppliers to have enhanced technological capabilities. Most users, even highly regarded and leading healthcare organizations, consider EHRs to be challenging to use because of the multiplicity of screens, options and navigational aids (Miller & Sim, 2004). Research has concluded that physicians generally have insufficient technical knowledge and skills to deal with EHRs which results in resistance (Boonstra & Broekhuis, 2010). The skills needed to communicate with a patient, analyze medical relevance, complete interventions as well as type notes simultaneously would require a significant level of concentration, typing skills, and familiarity with the application's user interface. These multiple requirements and additional tasks resulting from the use of EHR technology could be seemingly overwhelming to physicians (Ajami & Bagheri-Tadi, 2013). To foster efficiency and ease of use for physicians, many vendors of EHR technology have worked to improve usability of their systems, but many vendors doubt that even the most significant upgrades to their systems, such as voice recognition, will dramatically simplify EHR usage (Miller & Sim, 2004). For physicians, a lack of technical skills paired with complex usability requirements is likely to create further resistance to their acceptance or adoption of EHR technology.

Given the complexity of EHR systems, vendor technical support and troubleshooting are crucial factors in the successful implementation and continuation of EHR systems. Many physicians who have implemented EHR systems complain of poor service, follow-up, and training from contracted vendors. These complaints have created a negative perception for non-users who are considering the technology (Boonstra & Broekhuis, 2010). Poor vendor reputation is a barrier to adoption as many physicians are concerned that vendors are not qualified to provide the proper service or will go out of business and disappear from the market, leading to a lack of technical support and financial loss (Ajami & Bagheri-Tadi, 2013).

Another major physician barrier to the adoption of EHR technology is the concern about system capabilities and limitations. Many physicians report that they cannot find an EHR system that meets their specific needs or requirements (Boonstra & Broekhuis, 2010). Results of a study indicated that approximately 54 percent of physician participants who did not have access to an EHR system, could not find a system to meet their specific needs (DesRoches et al., 2008). Despite the progression of EHR system technology and a willingness of many EHR vendors to tailor clinic services and functionalities,

customization typically comes at a premium and may raise concerns of system stability and longevity. These factors can deepen financial concerns and be viewed as another risk that may add to physician resistance for EHR system adoption.

Another technical barrier to adoption is EHR system reliability. Reliability, in this context, is described as the dependability of the EHR technology systems (Randeree, 2007). In leveraging EHR systems, reliability is notably important for a system dealing with patient information, and many physicians are concerned about losing access to patient records if computers crash, viruses attack or during events of power failure (Boonstra & Broekhuis, 2010). Research reveals that physicians are also hesitant to adopt EHR technology out of fear of the possibility of record loss due to technical deficiencies which could translate into financial loss and be costly for a clinic (Boonstra & Broekhuis, 2010).

Given the immaturity of EHR technology, EHR systems must be adapted or altered to connect with other devices that complement the EHR system. However, many physicians have reported problems of interconnectivity leading to a negative perception of the transfer capabilities of current EHR technology (Boonstra & Broekhuis, 2010). The majority of EHR systems are not compatible with existing practice systems; consequently, physicians may be hesitant to replace fully functional systems with a fully integrated EHR system (Boonstra & Broekhuis, 2010). Additionally, research shows that there are hundreds of varying types of EHR software programs currently in use, and inconsistent data standards have prevented existing systems from being capable of transferring data (Valdes, Kibbe, Tolleson, Kunik, & Petersen, 2004). Manual data transfer to a new, fully integrated EHR system could lead to a loss in productivity or could increase costs for a clinic if third-party data transfer is required. Physicians may be resistant to adopt EHR technology because several EHR systems lack data transfer capabilities, which is a potential source of inefficiency and high cost.

Time Constraints and Workflow Disruptions

EHR systems are complex and require extensive research, training, and adaptations to workflow to be successful. Physician involvement during system initiation and selection is important because participation in the assessment and implementation of EHR systems will provide an opportunity for physicians' information needs to be communicated, considered or addressed during the implementation process (Lorenzi, Kouroubali, Detmer, & Bloomrosen, 2009). Additionally, several research studies have found that successful EHR system implementation is usually driven by a core team that includes physician champions. Physician champions are imperative to the successful implementation of a new EHR system as they typically drive change and motivate staff to buy-in to the new system. Despite the need for physician involvement in a core team or in the EHR selection processes, perceived time constraints serve as a significant physician barrier to EHR system adoption. During initiation stages, research uncovers that many physicians are not willing to invest time in EHR system selection and procurement as they believe that they should spend their time and efforts with patients (Paré et al., 2014).

Physicians have also expressed concerns over the potential time constraints that would result from the implementation of an EHR system which also serves as a barrier to EHR system adoption (Boonstra & Broekhuis, 2010; Paré et al., 2014). It is accepted that physicians will need to spend a considerable amount of time, effort, and training learning how to use an EHR system. Unfortunately, many physicians believe that learning an EHR system would slow their workflow and increase their workload besides thinking that they would not have the time needed to effectively learn an EHR system given the demands and pressures of delivering office-based care (Boonstra & Broekhuis, 2010). Although utilizing an EHR system

could increase efficiency for physicians in the long term, the complexity of EHR systems paired with a seemingly daunting training timeline creates resistance to EHR adoption for physicians. This resistance occurs especially if physicians do not support or believe that EHR systems will increase their efficiency.

With regard to concerns over post-implementation time loss, many physicians believe that EHR systems will interfere with the doctor-patient relationship (Boonstra & Broekhuis, 2010). This negative perception might have come from some physicians who have used EHR systems and are reporting that sometimes they stop using the technology during interactions with the patient because hunting for menus and buttons disrupts the clinical encounter (Ajami & Bagheri-Tadi, 2013). Therefore, physicians may be led to believe that they will need to spend more time with each patient due to EHR system usage (Paré et al., 2014). Taking extra time to use an EHR and not being compensated for taking on more work also suggests why physicians may hesitate to adopt EHR system (Ajami & Bagheri-Tadi, 2013).

Physiological Constraints

Personal resistance and physician skepticism towards EHR systems also serves as a barrier to EHR system adoption. Studies have found that more than half, approximately 58 percent, of physicians without an EHR doubt whether or not the technology can really improve patient care or clinical outcomes, and other research studies argue that those physicians who are unwilling to use such a system are skeptical about claims that EHRs can successfully improve the quality of medical practices (Boonstra & Broekhuis, 2010). Physicians' negative perceptions are generally derived from social influences; and to compound the barriers that social influences may create, people are generally afraid of change which can further slow the diffusion of technology (Boonstra & Broekhuis, 2010).

Professional autonomy, which can be described as an individual's control over the environment, processes, procedures, or content of their work, is important in the working practices of physicians (Boonstra & Broekhuis, 2010). In regard to professional autonomy, some physicians are concerned that using an EHR platform may result in a loss of their control of patient information and working processes since data will be shared with and assessed by others (Boonstra & Broekhuis, 2010). Other research findings reveal that physicians are concerned that policymakers, insurers, and administrators will use EHRs as a proxy mechanism to influence, or dictate how they practice medicine (Ford, Menachemi, Peterson, & Huerta, 2009). Threats to professional autonomy are an important factor in EHR acceptance or resistance because privileges associated with professional autonomy directly link to social value systems, status, and economic outcome. Therefore, physicians are likely to support elements that foster their autonomy and resist those that may threaten their professional autonomy (Walter & Lopez, 2008). A survey of physicians found that 68 percent agreed or strongly agreed that having clinical freedom was essential in practicing medicine and that constraints to clinical freedom should be fought (Walter & Lopez, 2008).

Social Influences

Lack of support from external entities is another barrier to physician adoption of EHR technology. One study noted that one-third to one-half of physicians reported that their decision-making was affected by local and regional organizations that were not active in the EHR debate (Boonstra & Broekhuis, 2010). Internally, many physicians also experience lack of support from other colleagues or their management team which may demotivate them to pursue EHRs for their clinic. Overall, lack of internal and external support may create further physician hesitation to EHR adoption as research suggests that support from

either within a physician's practice or from reliable third parties is essential to overcome knowledge barriers and to configure EHR applications in ways that facilitate improved clinical practices (Davidson & Heslinga, 2007).

Privacy and Security Concerns

Many physicians' perceptions of EHRs is that they are not secure, and that patient information may become accessible to unauthorized entities which can translate into legal problems and be costly for a clinic (Boonstra & Broekhuis, 2010). Even among physicians who use EHRs, most believe that there are more security and confidentiality risks involved with EHRs than with paper records (Boonstra & Broekhuis, 2010). There have been many reports of accidental loss or theft of sensitive clinical data as EHRs can be vulnerable to hackers, viruses, and worms (Fernández-Alemán, Señor, Lozoya, & Toval, 2013).

With EHR systems, it is also difficult to maintain privacy as administrative staff could access information without the patient's explicit consent (Fernández-Alemán et al., 2013). Although patient privacy and confidentiality have been a major topic of discussion through the progression of EHR technology in the healthcare field, one study finds that physicians may harbor more concerns for patient privacy and confidentiality than the patients themselves (Simon et al., 2007). Reports of internal and external data breaches have heightened physicians' concerns over patient privacy and confidentiality and may serve as another potential detriment to their acceptance and adoption of EHR technology.

IMPLICATIONS FOR RESEARCH AND PRACTICE

This review of literature provides a broad range of the perceived physician barriers to adopting an EHR platform. All reviewed research suggests that the diffusion and physician acceptance of EHR technology may be hindered by a variety and/or mixture of intrinsic and extrinsic barriers. The barrier categories identified are not all inclusive, but outline the most common physician barriers to the adoption of EHR technology as discovered through the analysis and systematic review of multiple articles and journals related to physician resistance to adoption of EHRs. With regard to EHR system adoption, the most common barriers encountered by physicians include: cost restraints, technical constraints and system limitations, time constraints and workflow disruptions, physiological constraints, social influences, and privacy and security concerns.

Widespread adoption of EHR technology, applied correctly, could benefit clinics and improve healthcare in the United States (Kumar & Aldrich, 2010). The detailed physician barriers uncovered in this research, however, could continue to slow the diffusion of the technology and negatively impact the adoption of EHR systems by healthcare organizations and/or doctors who were already reluctant to adopt. As EHR technology progresses, those organizations who choose not to adopt will face a technological lag relative to their competitors which may be unattractive to patients seeking a modern healthcare experience. Apart from not being able to leverage the benefits of an EHR system, physicians who choose not to adopt an EHR platform may face financial penalties, in the form of Medicare payment cuts, for failing to meet federal electronic health record incentive-payment program standards (Conn, 2014). Research shows that there was a 1 percent penalty in Medicare reimbursements for physicians who failed to achieve meaningful use stage 2 in 2014, and that penalties will escalate to 2 percent in 2016 and 3 percent in 2017 (Conn, 2013).

Overall, failure to adopt an EHR platform could also hinder data sharing and data collection that is needed for research and analysis. Specifically, EHRs offer access to longitudinal data that could be used to predict future outcomes or diagnoses, providing opportunities for personalized decision making for a given patient (Wu, Roy, & Stewart, 2010). Physicians who choose not to adopt an EHR platform will not have the ability to efficiently contribute to data sets or benefit from the analysis of the data collected through EHRs. Therefore, the single most important implication of this research is that, the evidence-based information about the major barriers to physician resistance in adopting EHRs will be useful in formulating solutions to overcome these barriers. Equally important, more concrete solutions to the barriers highlighted in this study may be explored in further research and analysis.

CONCLUSION

Despite accepted long-term benefits and available government sponsored financial incentives for the adoption of an EHR system, complete diffusion of EHR technology has not been realized in the United States as the technology continues to meet resistance from physicians. Overall, successful EHR adoption requires extensive research, investment, training, and adaptation to workflow to improve patient health and safety. The synopsis of physician barriers outlined in this study show that stakeholders and groups driving EHR system adoption need to be aware of the issues surrounding resistance to the system. By understanding and detecting physician barriers that are preventing the widespread adoption of EHR technology, stakeholders can work to mitigate resistance.

Although it is accepted that physicians' intrinsic barriers and social influences may be difficult to overcome, positive advancement in EHR technology usability and functionality could foster the creation of a stronger reputation for the technology thus reducing or removing negative perceptions. In consideration of financial constraints, the imbalance of cost versus return will continue to be a major factor and drive physician resistance until further research is provided on the potential ROI of the technology. The adoption of EHRs should be viewed as an ongoing process that will continuously need to evolve through system upgrades, interoperability, and continued training of staff (Mack et al., 2016). Overall, stakeholders must recognize that the "one size fits all" approach to EHR system technology and implementation is impractical and that, to meet targets of EHR system implementation to achieve positive healthcare outcomes, more work, time, education for physicians and evolution in the technology will be required.

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KEY TERMS AND DEFINITIONS

EHR Adoption Barrier: An obstacle that restricts, prevents, or discourages the adoption of EHRs.

EHR Diffusion: The adoption or spread of EHRs.

EHR Resistance: The opposition to accepting EHR technology.

EHR Technology Adoption: The selection and use of EHR technology.

Electronic Health Records (EHR): A digital record of an individual's healthcare that is collected over their lifetime.

Healthcare Stakeholders: An individual or group with interest in the progression and technological advancement of healthcare.

Meaningful Use: The U.S. government mandate of 2010 requiring an eligible provider to use certified technology to meet specified government benchmark outcomes.

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Chapter 11

Internet of Things Applications for Healthcare

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ABSTRACT

This chapter shows how the internet of things (IoT) can be applied for various purposes in the health-care domain. The functioning of this concept has enabled the collection of a number of technologies in the field of telecommunications, information technology, electronics, and social sciences. M-health as a part of e-health could be defined as synergistic solution of mobile computing, medical sensor, and communications technologies for healthcare, whose common goal is wirelessly monitoring the psycho-physical state of health or remote patient monitoring. This concept represents the evolution of e-health systems to wireless and mobile configurations. This chapter aims to provide a comprehensive review of recent solutions as well as possible future implementations from the m-health perspective. Further developments in wireless communications and configurations will have a huge impact on future health-care delivery systems.

INTRODUCTION

According to the US National Intelligence Council, there are six technologies with potential impacts on the US interests out to 2025 (the US National Intelligence Council, 2009):

- Biogerontechnology as a technology related to the biological aging processes;
- Energy Storage Materials;
- Biofuels and Bio-based Chemicals;
- Clean Coal Technologies;
- Service Robotics;
- The Internet of things.

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The great potential offered by the Internet of Things technology enables their wide applications in many areas of society, which would significantly increase and improve the quality of their functioning. By equipping various environments, i.e. domains, even with devices with primitive intelligence and modest communication capabilities, the communication of these entities with each other would be possible, with an aim to ensure data management. Such systems can be widely used in the following areas:

- Healthcare Domain;
- Smart Environment Domain;
- Personal and Social Domain;
- Transport and Logistics.

BACKGROUND

The Internet of Things (IoT) refers to wireless networks between objects (things). ‘Things’, i.e. objects, become entities with virtual properties which operate and communicate in smart spaces using intelligent interfaces.

Also, the “Internet of Things” is the general idea of things, especially everyday objects that are readable, recognizable, locatable, addressable, and controllable via the Internet - either via Radio Frequency Identification (RFID), Bluetooth, Wi-Fi, telephonic data services, wide-area network, or other means (the US National Intelligence Council, 2009).

In their research paper, Atzori et al. (2010) state that the Internet of Things can be realized in three paradigms: internet-oriented (middleware), things-oriented (sensors) and semantic-oriented (knowledge).

Over the last 20 years, continuous changes in the healthcare domain have taken place, caused by the wide use of information and communication technologies in the medical field. IoT plays a significant role in the broad range of healthcare applications which could be grouped as follows (Atzori et al. (2010)):

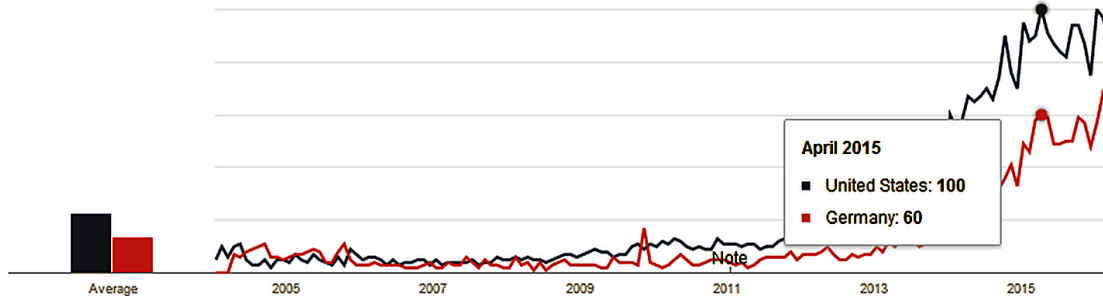
- Tracking of Objects and People (Staff and Patients);
- Identification and Authentication of People;
- Automatic Data Collection and Sensing.

The rapid growth of IoT has resulted in a massive growth of data generated by these devices and sensors put on the Internet. The physical-cyber-social big data consist of these IoT data, complemented by the relevant Web-based and social data (Sheth, 2016).

The Internet of Things has been identified as one of the emerging technologies in the IT field. The market adoption of IoT has been forecast to take 5–10 years (Gubbi et al., 2013).

The popularity of different paradigms varies with time. The web search popularity regarding the term IoT in industry, as measured by the Google search trends (n.d.) during the last 10 years, is shown as the red line for Germany and as the blue line for United States in Figure 1. As can be seen, the search volume is consistently increasing, and according to the Google search forecast, the trend is likely to continue. Average interest over time for United States is 22 and for Germany are 13. Numbers represent search interest relative to the highest point on the chart.

Figure 1. Google search trends since 2005 for the term Internet of Things.



E-health in Serbia has been the subject of some studies. It was concluded that information and communication technologies are rarely implemented (Milenkovic et al., 2012).

IoT is a vision which refers to the humanization of technology.

IoT IN HEALTHCARE DOMAIN

Medical sensors are devices that measure a number of physical, chemical, or biological parameters and then transmit or report these data. Some sensors are designed to work outside the body, and others are implanted in the body.

In the healthcare domain, the Internet of Things in its essence covers the following (Li et al., 2009):

- **Body Area Network (BAN):** The thermometers, smart t-shirts, smart devices and sensors for health, paper-based home pregnancy tests, etc. supporting personal medical treatment and healthcare.
- **Wireless Body Area Network (WBAN):** Supporting remote medical treatment and healthcare.
- **Local Area Network (LAN):** The wireless access-based remote patient monitoring system, the smart devices as a hospital interface, pulse oximeter also known as the blood-oxygen monitor, etc.
- **Wide Area Network (WAN):** Telemedicine solutions, distance medicine, etc.
- **Very Wide Area Network (VWAN):** The smart healthcare solutions as e-health services everywhere, no longer tied to physical locations.

Tracking involves memorizing the positions in real time (e.g. patient flow monitoring) in order to improve work processes in hospitals, but can also refer to the general tracking of motion (e.g. the access to certain rooms, warehouses or inventory material tracking such as blood samples and other materials necessary for the hospital functioning). Identification of patients includes activities, actions and tasks aimed at reducing incidents harmful to patients (e.g. wrong drug, dose, time, and procedures), the maintenance and updating of the complete medical archives in the digital form. Identification and authentication include protocols and procedures regarding the work of medical staff, which promote morals and ethics of employees in order to increase patient safety. The automatic data collection and transfer

involves the automation of various processes as well as the management of medical supplies. This function is supported by the integration of the Radio Frequency Identification (RFID) technology and other health information and technologies. RFID is a method of storing and downloading data remotely, using devices carrying tags. From the RFID group's point of view, the Internet of Things is the worldwide network of interconnected objects uniquely addressable based on the standard communication protocols (Gubbi et al., 2013). Sensor devices allow more successful diagnosis of patients in real time, provide various solutions in the field of telemedicine, warnings about the patient's condition and so on. They offer numerous opportunities that would provide, for example, a wireless access-based remote patient monitoring system, which would be designed so as to accompany the patient everywhere in real time, thus enabling continuous monitoring of the patient's bio-signals (Niyato et al., 2009).

CONCEPT OF M-HEALTH

As mobile technology becomes more affordable and widespread all over the world, using the mobile-enabled technology when providing healthcare services has great potential to improve the health of millions.

Mobile Health, mHealth is a term used for medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, etc.

MHealth is a relatively new concept, but its main advantage is that it enables healthcare professionals to collect data about their patients at any time. The data is processed, analyzed and wirelessly communicated to a gateway device over a cloud. (Paschou et al., 2013; Paschou et al., 2015; Istepanian et al., 2004).

Considering that MHealth, as a part of eHealth, can be defined as the synergistic solution of mobile computing, a medical sensor, and communications healthcare technologies, whose common goal is wireless monitoring of the psycho-physical state of health or remote patient monitoring. In the Republic of Serbia, electronic health cards are a pioneering venture aimed at promoting mobile healthcare services (Milenkovic et al., 2012).

An MHealth solution usually consists of a unit designed for patients, which is composed of sensors for medical measurements and accessories, as well as a communication device for 2G and 3G communication, which forwards the data to the health system via the cloud. Because of their miniature dimensions, high performance and low cost/price, different sensors, which can be easily wirelessly connected, are used for the measurement of chemical, biological and physical parameters in the body. Also, there are a lot of web-based platforms that provide additional opportunities for the expansion of social networks for different purposes (e.g. health education of patients worldwide). Even more, the network of sensors can be connected via patient's mobile phone to a server that is located in a medical institution. The data collected by the sensor network can be periodically or in real time sent to the server, which approaches the patient's doctor suggesting corrective actions via e-mail or SMS. The program can be set so as to, if the sensor encounters some irregularities, immediately notify a doctor, who could react momentarily.

Thanks to this approach, patients with chronic diseases can be under continuous remote supervision at home. In addition to the increased safety of the patient, it represents significant savings of hospital resources, and hospital beds remain available for other patients who need them. Also, this solution helps hospitals manage beds efficiently and consequently decreases hospital costs. Hospitalized patients whose health status requires full attention can be constantly monitored using IoT-driven monitoring (sensors).

The market division is as follows:

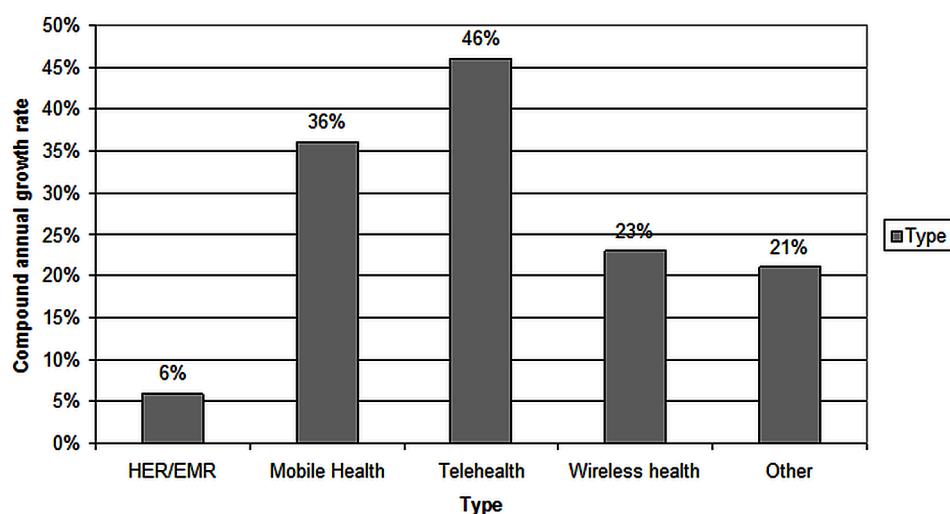
- Preventive care tools which help people stay healthy (e.g. Behavioral change, Community communication, Education).
- Curative care tools as new efficient ways to treat patients (e.g. Remote monitoring, Assisted living, Tele-consultations).
- Productivity tools which improve efficiency and availability (e.g. Electronic health records, Professional communication).

TELEHEALTH

Telehealth (telemedicine) is a health delivery system which refers to the exchange of medical information between two sites via electronic communications in order to improve a patient's health status. Telehealth includes a growing range of applications and services using two-way video telephony, wireless tools and networks, emails, smart devices, Internet and cloud services and infrastructures, and other forms of telecommunications technology. Clinical telemedicine practice supported by video conferencing, medical connectivity through m-health, remote patient monitoring, disease management, home treatment, continuing medical education, medical call centers, are all considered part of telemedicine and telehealth. Health professionals providing telehealth services should have the continuing education, training, licensure, in order to acquire the necessary knowledge and competencies needed to provide safe and high-quality telehealth services.

Figure 2 shows the projected compound annual growth rate (CAGR) for the global digital health market from 2013 to 2020, by segment. During this period, the telehealth market's compound annual growth rate is expected to be around 46 percent. The digital health market is expected to reach 233.3 billion US dollars by 2020 (Statistic, n.d.).

Figure 2. Projected CAGR for the global digital health market from 2013 to 2020, by segment. Source: (Statistic, n.d.)



TECHNICAL REQUIREMENTS FOR REAL-TIME INTERACTIVE SESSIONS

The quality of a video healthcare interactive session primarily depends on the characteristics of the network connection between the conferencing sites. The H.323 standard specifies the components, protocols, and procedures for the transmission of real-time audio, video, and data communications over IP (Internet Protocol), i.e. packet-based, networks. In the case of H.323, a high-quality conference, which implies excellent audio and video, needs from 768 kbps (kilobits/second) to 2 Mbps (megabits/second) in each of the downlinks and uplink directions.

In the case of “Point to point video conferencing”, two H.323 video conferencing systems communicate to each other over the Internet. One station initiates the call, and the other either accepts or rejects it. Once accepted, encoded and compressed audio and video flow between the two stations. In the case of “Multipoint video conferencing” more than two sites communicate with each other. In the H.320/ISDN world, a Multipoint Control Unit (MCU) was used. This allowed three or more user stations to connect to the MCU. In the case of the voice switching mode, the MCU made a decision about which site was currently talking. Smartphones and tablets (such as iPhones and iPads) do support live conferences; however, 3G/4G/LTE/WiFi connections are not sufficiently reliable for participating in online sessions. It is highly recommended to use a computer with a wired internet connection. In the case of high-quality (HQ) resolution, 640x360@15, 30 fps (frame per second) is recommended, but in the case of full High Definition resolution (FHD), 1920x1080 30 fps is recommended. Graphical cards must be compatible with DirectX 10.0, from 512MB (min. NVidia 8600 GS, Radeon HD 2600 XT, Intel HD Graphics 2000) to 2GB (min. NVidia GT640, AMD Radeon HD 6670, Intel HD Graphics 4000).

Minimum system requirements for conference hosts are: Windows XP 32 bit or Windows 7 (32bit or 64bit); Core2 Quad, Intel i3, i5 or i7 equivalent CPU; 4 GB of RAM; 100 MB of available HDD space (additional space recommended for conference recording features); 100 MB NIC or higher; High speed broadband Internet access (at least 1 Mbps upstream and 4 Mbps downstream); DirectX 9.1 or later compatible webcam; DirectSound compatible audio input and headset or speakers (Video Conferencing System Requirements (n.d.), Web & Multiparty Video Conferencing System Requirements (n.d.), VCI - Next Generation Video Conferencing (n.d.)).

The video conference software should be able to adapt to changing bandwidth environments without losing the connection. Health organizations should have the appropriate redundant systems in a place that ensures availability of the data transmission infrastructure for critical connectivity.

DIGITAL TRANSFORMATIONS IN MEDICINE

mHealth has the potential for use in the following areas:

- Education and training of healthcare workers;
- Remote data collection and remote monitoring;
- Remote diagnostic and treatment support.

The main advantages brought by the concept of mHealth imply the increase in the quality of health care while creating new opportunities on the one hand, and reduced costs on the other hand. About 75%

of patients suffer from chronic diseases (high blood pressure, diabetes, heart disease, cancer, etc.). Using mHealth solutions, the biomarkers of these chronic patients can be monitored ensuring the quality management of their diseases in order to improve the quality of their life. These technologies exist and have been adopted, and their examples are the wireless Halter monitors, weight scales, blood pressure cuffs and glucometers (Malvey et al., 2014).

In order to be cost-effective and commercially-sustainable for the mass-market, mobile health services should be standardized. One of the problems is that today there is not an organization in the world which deals with the standards in the field of mHealth. For example, the International Standards Organization (ISO) has developed standards (IEEE 11073) for the transmission of blood pressure in a basic binary data format between two low-level devices, which can be transferred into a human-readable format using health messaging standards, such as HL7 (Engineering in Medicine and Biology Society, n.d.).

Some of the mHealth categories (Applications and Devices) are Nutrition Application, Glucometers, Biometrics devices, Sleep Trackers Applications and devices, Tobacco Cessation Applications and Programs, Medication Adherence Devices and so on (Validic, n.d.).

Some examples of the use of medical sensors are as follows: the sensors can help detect, and thus avoid, about 5000.00 known viruses that cause serious illness around the world. Biochemical sensors can continuously scan a billion miles long chain of Deoxyribonucleic acid (DNA) and look for changes and potential diseases. Taking into account the fact that the human heart throughout a life pumps about 15 million gallons of blood, cardiac sensors or heart rhythm sensors can provide information about how efficiently a heart works. The human brain has about 100 billion neurons. Gum sensors have the preventive effect on the development of other diseases in the organism because people who suffer from a gum disease represent 50% of those who are predisposed to suffer brain and heart attacks. New sensors can detect a high level of blood sugar without drawing blood. By using an ultra-sensitive sensor to detect the presence of tumors and early abnormal cell growth, cancer can be recognized at an early stage and thus effectively treated. Biosensors may provide insights into disease processes that are hard to detect directly, such as dysfunctions in brain chemistry that are thought to play an important role in many mental disorders (Health Sensing Infographic, 2014; Sensors, n.d.).

The next generation of IoT quantified tracking devices falls into the category of wearable electronics and multi-sensor platforms. These products include smart watches, wristband sensors, wearable sensor patches, artificial reality-augmented glasses, brain-computer interfaces, wearable body metric textiles.

Other important categories include smartphone applications and their enhancements, and environmental monitoring and home automation sensors.

For example, Hexoskin products give insight into the physical training, sleep, and personal daily activities:

- Track heart rate and view real-time ECG with great precision.
- Heart rate variability (HRV) is an essential tool to measure stress and training fatigue to avoid overtraining.
- Breathing rate in order to control own breathing, increase performance and reduce stress.
- Breathing volume in order to control lung capacity for each of daily activities and avoid hyperventilation and apnea.
- Sleep tracking device in order to measure resting heart rate, breathing, and sleep positions.

CONCLUSION

The advances in science, technology, engineering, and medicine will allow the use of sophisticated sensor technologies in the further medical research that could drastically improve the quality of life of people, particularly people with serious disabilities. Also, technological advancement in the healthcare area revolves around the following outcomes: improved access to care, increased care quality and reduced care costs. At the end, we can conclude that the technological The Internet of Things is potentially disruptive because global society, global economy and governments are unprepared for a possible future when the Internet nodes will be able to remotely control, locate, and monitor everyday things. Having in mind that everyday objects become information security risks, the IoT could distribute those risks far more widely than the Internet has to date.

FUTURE RESEARCH DIRECTIONS

Generally, the next Internet revolution will be the interconnection between everyday existing objects in order to create a smart grid and intelligent environment. The future application of technology in health care will lead to the creation of an entirely new level of personalized, digital health care, where everyone is responsible for monitoring their own health and the quality of their own life. Further research is aimed at improving the existing sensors through increasing their capabilities and enhancing their efficiency. In the coming period, IoT is expected to play the key roles in all the aspects of modern medical treatment and health management - prevention, diagnosis, disease monitoring, treatment monitoring.

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KEY TERMS AND DEFINITIONS

Body Area Network: A network that can collect information about an individual's health, fitness, and energy expenditure.

Health Care Monitoring: The medical applications can be of two types: wearable and implanted. Wearable devices are used on the body surface of a human or just at a close proximity of the user. The implantable medical devices are those that are inserted into the human body.

Health Informatics (Healthcare Information Systems): Software solutions for appointment scheduling, patients' data management, work schedule management and other administrative tasks regarding health.

Internet of Things (IoT): A new concept that has emerged thanks to the development of new technologies, especially the Internet Technologies and Wireless Sensor Networks that together enable the existence of the health system at the global level.

Mobile Health (mHealth): A collection of mobile technologies as tools and platforms for health research and healthcare provision.

Sensor Network: A network that consists of multiple detection stations called sensor nodes, each of which is small, lightweight and portable.

Sensor Node: A node in a sensor network that is capable of performing some processing, gathering sensory information and communicating with other nodes connected to the network. The main components of a sensor node are a microcontroller, transceiver, external memory, power source and one or more sensors.

Telemedicine: A physical and psychological diagnosis and treatment at a distance, including tele-monitoring of patients' functions.

Wireless Sensor Networks (WSN): A network that consists of spatially distributed autonomous sensors used to monitor physical or environmental conditions, and to forward their data jointly to the main location through the network.

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Chapter 12

Maintenance Policies Optimization of Medical Equipment in a Health Care Organization

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ABSTRACT

The aim of this chapter is to minimize the corrective breakdowns produced in the electromedical equipment of a healthcare organization. To this, an optimization plan of maintenance policies will be developed. This plan includes the creation of preventive maintenance datasheets. The data used in this research has been obtained from the computerized maintenance management system, which is owned by the healthcare organization. Different types of rankings have been made in the stocks to prioritize items by family of equipment and by average work orders by equipment generated. The maintenance tasks are optimized to preserve the satisfactory working conditions and the performance of equipment in the healthcare organization optimizing available resources. All of this is intended to anticipate the maintenance activity to breakdowns and to prevent the care quality from diminishing by increasing the patient waiting time by unavailability of medical equipment in the treatments and diagnostic tests.

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INTRODUCTION

For a long period of time, maintenance has only focused on repairing breakdowns occurring in the machines as a result of its production. Maintenance policies has not been extensively analyzed and implemented in the actual companies; this aspect has been taken more into account in manufacturing companies than in service ones, where the maintenance was considered a department without influence on the service final quality (Gómez, Ruiz de la Hermosa, & Carnero, 2009). The concept of maintenance has evolved to be considered as a productive activity of the organization, since the correct operation of the equipment ensures the availability of production.

In a healthcare organization, the electromedical service is the department responsible for maintaining the entire healthcare equipment and specific facilities that cover the center, as well as its management through inventory control. It is essential that all medical equipment is properly maintained to ensure the highest level of availability and reliability. It is also important to have a maintenance strategy in which the maintenance policies are defined in order to keep track of medical equipment and to give priority to those required on critical operations (Jamshidi, Abbasgholizadeh Rahimi, Ait-kadi, & Ruiz, 2015).

The aim of this chapter is to minimize the corrective breakdowns produced in the electromedical equipment of a healthcare organization. To this, an optimization plan of maintenance policies will be developed in the equipment that needs it. The objective pursued is to increase scheduled preventive maintenance shutdowns carried out by Electromedical Department and to reduce the corrective maintenance. This plan includes the creation of preventive maintenance datasheets in which the activities undertaken, the periodicity, the estimated time to do the activity, etc. are identified.

The data used in this research has been obtained from the Computerized Maintenance Management System (CMMS) owned by the healthcare organization. Different types of rankings have been made in the stocks to prioritize items by family of equipment and by average work orders (WOs) by equipment generated. According to this analysis, the maintenance tasks are optimized to preserve the satisfactory working conditions and the performance of equipment in the healthcare organization optimizing available resources. All of this is intended to anticipate the maintenance activity to breakdowns and to prevent the care quality from diminishing by increasing the patient waiting time by unavailability of medical equipment in the treatments and diagnostic tests.

The structure of this chapter is as follows. Next section draws a literature review where the concept of overall maintenance and maintenance of electromedical equipment in particular is detailed. Also, the ABC analysis is defined. Then, a general description of the healthcare center in which the study is carried out, an example of instruction datasheet and the analysis undertaken is done. The results obtained are shown below. Later, the conclusion of the research is presented. Finally, the references, additional readings and key terms used are shown.

BACKGROUND

For a long time, maintenance has been understood as part of the work that encompassed only the repairing breakdowns occurring in the machines and therefore, the employer included it as an economic burden to bear. However, this concept has progressively evolved over time until nowadays that is considered as a productive activity of the organization. Therefore, the role of maintenance has gained great interest and importance. Improving maintenance in a company is seen as an investment that will have a positive

impact on quality and availability of the product as well as on productivity of the organization (Alrabghi & Tiwari, 2016).

It is common to consider in literature (see Dekker, 1996; Scarf, 1997; Eti, Ogaji, & Probert, 2006; and Hamdi, Oweis, Zraiq, & Sammour, 2012), that maintenance is the function responsible for ensuring availability of equipment and machines of a company; that is, it is associated with a set of actions that aim at preserving the assets (equipment and facilities) of the company during the period of useful life of these. Based on the criteria developed by cited authors above, the definition of maintenance is set as the range of activities performed to a system, equipment or component to ensure that it continues to perform desired functions within an operational context given at the lowest possible cost. The main objective is to preserve its function, good operating conditions, to optimize performance and to increase the useful life, by ensuring optimal investment of resources.

Maintenance management includes all activities that determine the objectives, strategies, maintenance responsibilities and the implementation of all these. There are several significant factors to take into account to carry out an adequate management such as the importance and criticality equipment, the cost, the reliability and security, the environmental impact, etc. (Carnero & Gómez, 2016).

Maintenance department should have a software called Computerized Maintenance Management System (CMMS) to manage the maintenance of all equipment and facilities of a company, which incorporates a database and facilitates maintenance management with scheduling tasks to be performed by the maintenance department. This way, it will be possible to have a real time control of the whole system. This tool helps plan and manage the necessary functions to achieve an effective maintenance (Gulati & Smith, 2009).

Three basic kinds of maintenance policies are defined depending on the moment in time in which they are made, the purpose for which they are implemented and the resources used:

1. **Corrective Maintenance:** Performed activities to repair equipment when a failure appears (Carnero, 2009).
2. **Preventive Maintenance:** Scheduled actions which are performed while the system is running in order to keep it available and improve their conditions to avoid unpredicted failures (Doostparast, Kolahan, & Doostparast, 2014).
3. **Predictive Maintenance:** Actions that predicts system failure before it happens. The purpose is to mitigate the failures looking for the underlying causes, and thus reduce the cost incurred by corrective maintenance (Faiz & Edirisinghe, 2009).

Particularly, medical equipment is essential in the prevention, diagnosis, and treatment of illness, as well as patient rehabilitation in hospitals (Noor, Magray, & Chawla, 2016). Electromedical equipment maintenance in a healthcare organization includes all equipment and high level of technology facilities in any field in bioengineering (Gómez, 2013) for instance: capturing and processing images of high level of digital resolution techniques, diagnosis and treatment with radioactive isotopes, conventional and laser surgical techniques, obtainment analytical techniques by robotized chains, cryogenic systems, precision mechanics, microscopy, with highly advanced components and advanced control systems.

Maintenance management in hospitals is much more complex than other manufacturing organizations, for it undertakes medical and health responsibilities that deal with the patient's life (Sadaghiyani, 1998). Moreover, there are a large amount of medical devices with high technology. For these reasons, it must be incorporated an excellent management tool to classify all equipment effectively.

The ABC analysis allows the classification of items according to their importance. It is based on the application of the Pareto principle, also known as 80-20 rule according to which, about 80% of the effect come from 20% of the main causes (Koch, 1998). This technique is the most commonly used in inventory management to categorize a large number of articles into three ordered and predefined groups: group A includes the very important items, group B contains the moderately significant pieces and category C includes the relatively insignificant items (Douissa & Jabeur, 2016).

This tool can be used in a lots of applications. If applied to the maintenance of electromedical equipment, machines can be divided into 3 groups:

- **Group A:** It includes approximately 10-20% of total machines, but accounts for 60-80% of the total maintenance cost.
- **Group B:** It constitutes about 30-40% of equipment and account for 20-30% of the total maintenance cost.
- **Group C:** A numerous groups of machines around 50-60% represent only 5-10% of the total maintenance cost.

The really important are groups A and C since they provide information about a few medical devices that are significant and a large number of machines that are relatively insignificant. The percentage may vary depending on the case. The objective of this technique is to manage in an effective way a maintenance management program by determining which equipment is more important to keep available.

HOSPITAL DESCRIPTION

Medical equipment of a new generation hospital is analyzed. Equipment and facilities of all branches of bioengineering such as different capturing and processing images techniques, diagnosis and treatment with radioactive isotopes, conventional and laser surgical techniques, obtainment analytical techniques, cryogenic systems, precision mechanics, microscopy and generally, equipment with latest generation components are included.

The hospital has the following services (Gómez, 2013): 540 hospital beds, 17 oncohaematological outpatient care stations, 28 dialysis stations, surgical and obstetrical wing, Intensive Care Unit (ICU), emergency department, nuclear medicine, radiation therapy, physical therapy and 119 outpatient visits. It also has support services such as laboratories, blood bank and hospital pharmacy.

PREVENTIVE MAINTENANCE DATASHEETS

In order to reduce the corrective maintenance, preventive maintenance datasheets are created, in which the activities undertaken, the periodicity, the estimated time to do the activity, etc. are identified. Using preventive maintenance datasheets, apart from meeting the recommended safety parameters for each family of electromedical equipment, aims to reduce corrective maintenance. Such approach shows the most optimal and suitable for health care center facilities because if it is a serious breakdown to stop a service for a long time, it may be a decrease in care quality by increasing the patient waiting time.

Moreover, it is cost-effective to replace a worn component of a machine when it is detected in a preventive maintenance review than having to repair if a catastrophic failure occurs, since these often induce failures in other components of medical equipment.

Preventive Maintenance Datasheets of Electrosurgical Equipment

An example of the content included in a preventive maintenance datasheets of electrosurgical electro-medical equipment developed is showed below. The datasheet consists of the following sections:

1. General test
2. Leakage test
3. Power test
4. Frequency test
5. Electrical safety

Also, the measurement devices used, the name and signature of the technician and the date are included in all preventive maintenance datasheets.

All instruction datasheets have been made following the specific electromedical equipment regulation. When the appropriate preventive maintenance has been performed, each maintenance technician must fill in the datasheet. Figure 1 and Figure 2 shown the electrosurgical datasheet template.

Figure 1. Section 1 and 2 of electrosurgical datasheet

Source: (Own elaboration, 2016)

ELECTROMEDICAL EQUIPMENT ANNUAL MAINTENANCE			
SERVICE	Maintenance department	OT number	
EQUIPMENT	Electrosurgical	EQUIPMENT	

Good
Bad

1 GENERAL TEST

1.1 Power, network cable and plug

1.2 Switches, buttons, auxiliary control and foot control

1.3 Acoustic and light indicator

1.4 Sheets and accessories condition

2 LEAKAGE TEST

OPEN CONFIG. (F)

I (mA)

REFERENCE

I (mA)

2.2 Leakage measurement

2.1 Leakage measurement

≤ 150 mA

OPEN

CLOSE

≤ 150 mA

≤ 100 mA

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Figure 2. Section 3, 4 and 5 of electrosurgical datasheet

Source: (Own elaboration, 2016)

3 POWER TEST (According to UNE-EN 60601-2-2)

Measuring range $\leq \pm 20\%$

MODE		$R_C = 200 \Omega$			$R_C = 500 \Omega$			$R_C = 750 \Omega$			$R_C = \Omega$		
		Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max
PWR													
I (mA)													

4 FREQUENCY TEST



5 ELECTRICAL SAFETY

MEASUREMENT DEVICES USED	Calibration Date

NAME AND SIGNATURE OF THE TECHNICIAN

DATE:

ELECTROMEDICAL EQUIPMENT ANALYSIS

In order to establish a ranking according to the impact regarding the preventive maintenance work orders that are produced, two analyses have been made that encompass 187 electromedical equipment belong to the healthcare center. Two rankings are established under Pareto principle are:

1. By work orders by family of equipment.
2. By average work orders by equipment.

According to Pareto analysis, Table 1 and Table 2 show the results included in A category of first and second ranking respectively. All equipment is not shown because of a lack of space.

A simply method of classification is considered to get successful results. The key of this arrangement is that while there is not used a creative contribution, it is a tool that works efficiently. In other words, it consists in ensuring that electromedical equipment are ranked in order of importance in a suitable manner.

Maintenance Policies Optimization of Medical Equipment in a Health Care Organization

Table 1. ABC by family of medical equipment

Code	Equipment Description	Number of Devices	% System Accumulated	N° WO Family	% Wo Accumulated by Family
1	Auto-analyzer	2	0.53%	103	5.22%
2	Hematologic analyzer	5	1.07%	97	10.13%
3	ECG2	27	1.60%	85	14.43%
4	Blood pressure monitor with pulse oximetry	20	2.14%	79	18.43%
5	Anesthetic respirator	16	2.67%	71	22.03%
6	Pulse oximetry	23	3.21%	70	25.57%
7	ECG1	5	3.74%	69	29.06%
8	Volumetric respirator	16	4.28%	50	31.59%
9	Perfusion pump	22	4.81%	48	34.03%
10	Multi-parameter monitor with SpO2, NIBP, PI (Touch Screen)	10	5.35%	38	35.95%
11	Ultrasound scanner	12	5.88%	35	37.72%
12	Could light source	6	6.42%	34	39.44%
13	Portable RX Equipment	2	6.95%	33	41.11%
14	Pyxis	8	7.49%	32	42.73%
15	Ontological microscope (NT)	10	8.02%	30	44.25%
16	Electroencephalograph	2	8.56%	28	45.67%
17	Autoclave	3	9.09%	27	47.04%
18	Washing machine for endoscopy tubes N° 3	3	9.63%	27	48.41%
19	Autoclave miniclave	5	10.16%	26	49.72%
20	Engine traumatology	4	10.70%	25	50.99%
21	Electrosurgical	7	11.23%	25	52.25%
22	Surgical table	7	11.76%	25	53.52%
23	Neonatal incubator	8	12.30%	25	54.78%
24	Multi-parameter monitor with SpO2	7	12.83%	23	55.95%
25	Muti-energy linear accelerator	1	13.37%	22	57.06%
26	Multi-parameter monitor	9	13.90%	22	58.18%
27	Electronic sphygmomanometer	7	14.44%	21	59.24%
28	Slip lamp	5	14.97%	21	60.30%
29	Ophthalmic chart projector	4	15.51%	20	61.32%
30	Blood pressure monitor with pulse oximetry and temperature	7	16.04%	20	62.33%
31	Applanation Tonometry	6	16.58%	19	63.29%
32	Coagulometer	3	17.11%	18	64.20%
33	RX emergency room	1	17.65%	18	65.11%
34	Equipment washing machine	2	18.18%	16	65.92%
35	Cardiotocograph	5	18.72%	15	66.68%
36	Packaging machine solid forms	1	19.25%	14	67.39%
37	Central monitors	4	19.79%	14	68.10%
38	Freezer	6	20.32%	14	68.81%

Maintenance Policies Optimization of Medical Equipment in a Health Care Organization

Table 2. ABC by average work orders by medical equipment

Code	Equipment Description	Number of Devices	% System Accumulated	Average WO by Equipment Family	% WO Accumulated by Family
1	Auto-analyzer	2	0.53%	51.50	6.39%
25	Muti-energy linear accelerator	1	1.07%	22.00	9.12%
2	Blood pressure monitor	5	1.60%	19.40	11.53%
33	RX emergency room	1	2.14%	18.00	13.76%
13	Portable RX Equipment	2	2.67%	16.50	15.81%
16	Electroencephalograph	2	3.21%	14.00	17.54%
36	Packaging machine solid forms	1	3.74%	14.00	19.28%
7	ECG1	5	4.28%	13.80	20.99%
42	Incubator for anaerobic	1	4.81%	11.00	22.36%
43	Steam Autoclave 80 l	1	5.35%	11.00	23.72%
45	Automated glass coverslipper	1	5.88%	10.00	24.96%
46	Dual-head gamma camera (N° Sist DPN00002)	1	6.42%	10.00	26.20%
17	Autoclave	3	6.95%	9.00	27.32%
18	Washing machine for endoscopy tubes N° 3	3	7.49%	9.00	28.44%
47	Multi-parameter monitor with SpO2	1	8.02%	9.00	29.55%
34	Equipment washing machine	2	8.56%	8.00	30.55%
49	RX generator	1	9.09%	8.00	31.54%
51	Formaldehyde autoclave	1	9.63%	8.00	32.53%
52	SCTL receptor microbiology	1	10.16%	8.00	33.52%
58	Multi-parameter monitor with SpO2, PNI	1	10.70%	7.00	34.39%
59	Cryostats	1	11.23%	7.00	35.26%
20	Engine traumatology	4	11.76%	6.25	36.04%
32	Coagulometer	3	12.30%	6.00	36.78%
39	Water purifier	2	12.83%	6.00	37.52%
64	Multi-parameter monitor with SpO2	1	13.37%	6.00	38.27%
65	Digital mammography and acquisition workstation	1	13.90%	6.00	39.01%
66	Engine maxillofacial surgery	1	14.44%	6.00	39.76%
67	PET-CT (N° Sist. DPN00012)	1	14.97%	6.00	40.50%
68	Immunochemical system	1	15.51%	6.00	41.25%
69	Arthroscopy control unit	1	16.04%	6.00	41.99%
12	Could light source	6	16.58%	5.67	42.69%
19	Autoclave miniclave	5	17.11%	5.20	43.34%
29	Ophthalmic chart projector	4	17.65%	5.00	43.96%
74	Multi-parameter monitor with SpO2	1	18.18%	5.00	44.58%
75	Ortopantomography	1	18.72%	5.00	45.20%
76	spectrophotometer	1	19.25%	5.00	45.82%
77	Robot for analytical.	1	19.79%	5.00	46.44%
78	Tower digestive endoscopy	1	20.32%	5.00	47.06%

SOLUTIONS AND RECOMENDATIONS

The following results have been achieved in the ABC analysis. In the first ranking, the result obtained is that 20.32% of the family of medical equipment accounts for 68.71% of work orders whereas in the second case, 20.32% of the medical equipment accounts for 47.01% of work orders.

The first analysis is classified according to the highest work orders irrespective of included equipment, whereas in the second, they are taken into consideration. In other words, in the first study, equipment that has many WOs and a large number of equipment are at the top for not taking into account the number of equipment while after making the second analysis, the ranking position decreased because WOs by equipment are reduced. Figures 3 and 4 illustrate this.

In line with this classification, the first 38 families of medical equipment that set up Pareto which produce the most WOs have been examined in order to optimize the Preventive Maintenance Plan as well as to achieve the objective of diminishing breakdowns, that is to say, smaller corrective work orders.

The following stages have been carried out:

Step 1: Identification of breakdowns:

- Number.
- Cause (failure mode).

Figure 3. ABC graph by family of medical equipment

Source: (Own elaboration, 2016)

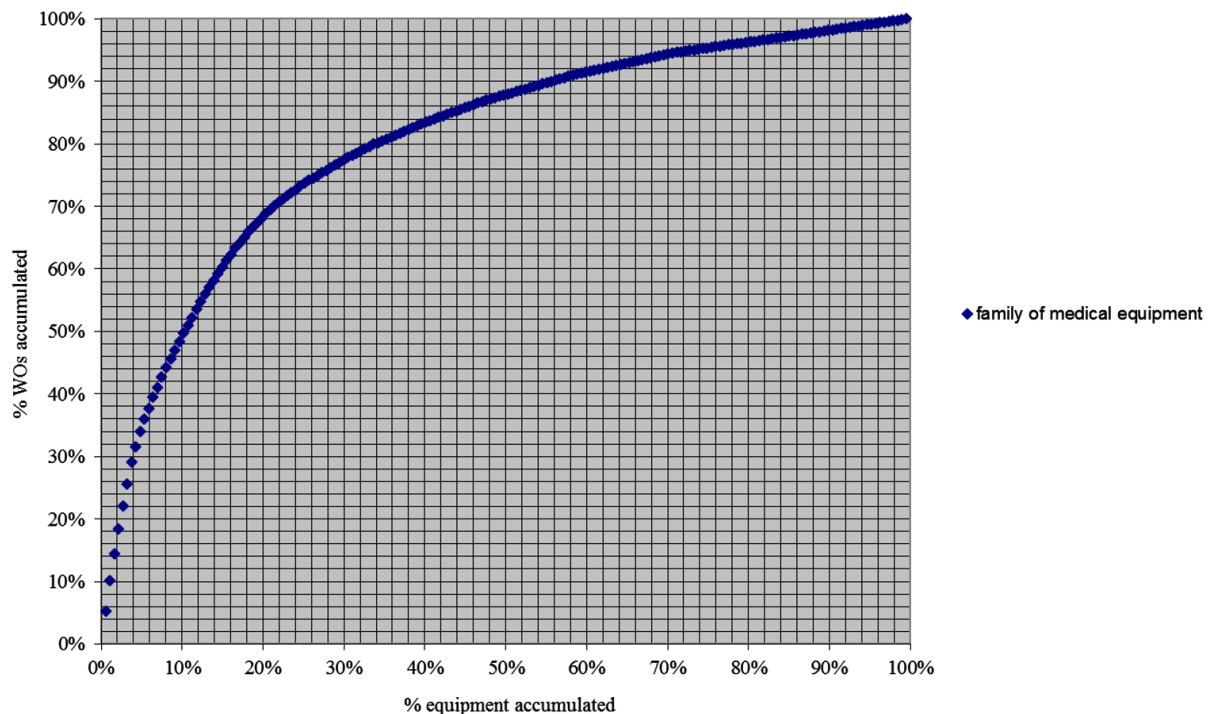
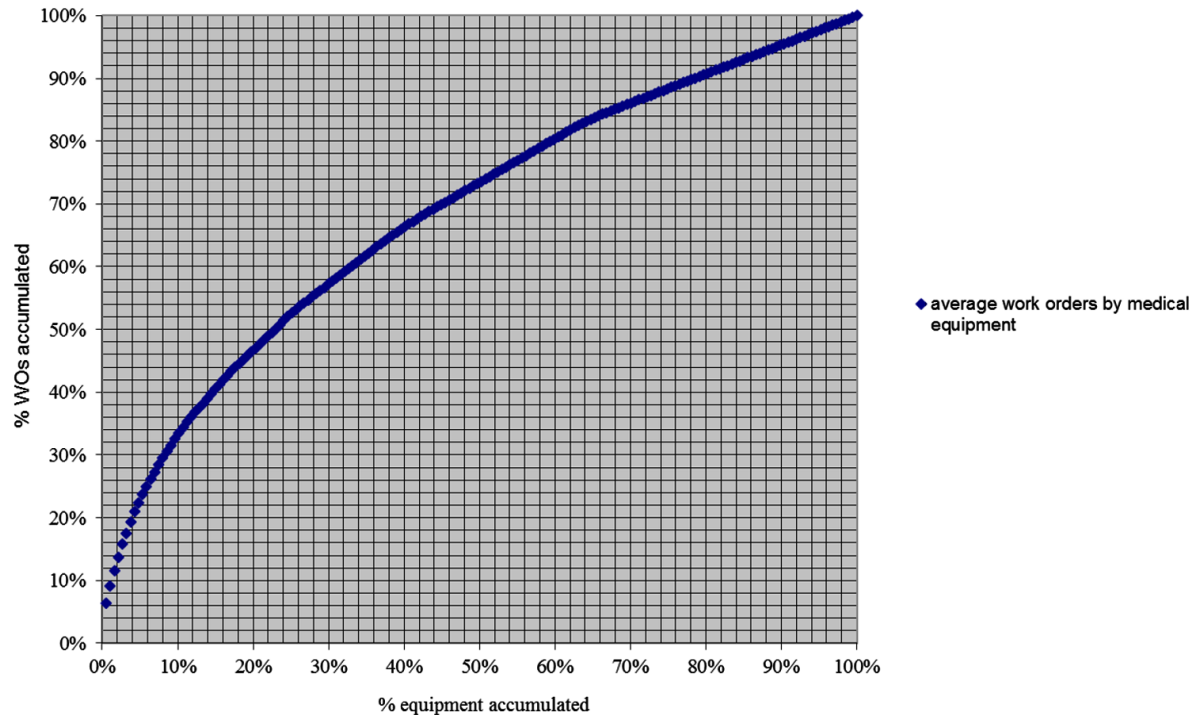


Figure 4. ABC graph by average work orders by medical equipment

Source: (Own elaboration, 2016)



Step 2: Establishment of overall conclusions taking into account several aspects:

- Repetitive failures linked to badly use on the part of the user. Design training activities for those responsible for the services involved. Training action plan.
- Repetitive failures due to normal use. Identification of tasks and the frequency to be implemented in the range of preventive maintenance to be created for reducing the repetition of this failure mode.

Some examples are shown below.

Neonatal Incubator

Device whose function is to create an environmental with humidity, temperature and oxygen concentration suitable for growth of neonates.

Step 1: Identification of breakdowns: fan breakdowns.

- **Number:** 5 WOs are produced (20% of total failures).
- **Cause - Misplacement of the Fan:** Damping spring adjustment or bearings lubrication.

Step 2: Established findings:

- Training guide or video to install correctly the fan.
- Preventive maintenance (operation to include in the existing range):

- **Visual Review:** Determine if there are problems that can apparently be detected and the lack or the loss of accessories that are part of equipment as signs of short or damages.
- **Cleaning:** Clean at least some parts and equipment surfaces, using suitable cleaning compounds for each of them.
- **Test Runs:** Check that the equipment are completely operational within the specific limits with in the implementation of the software auto-test.

Electrosurgical

Electrosurgical device based on electronic technology be able to produce a given set of high frequency electromagnetic waves for the support of remove or cut soft tissue.

Step 1: Identification of breakdowns: damage in the bipolar forceps cable and failures due to performance reviews.

- **Number:** 6 WOs are produced (24% of total failures) and 7 WOs (28% of total failures) respectively.
- **Cause:** Part failure and misuse.

Step 2: Established findings:

- Implementation of a daily protocol review by the user to avoid performance reviews in which no action is taken.
- Preventive maintenance:
 - **External Cleaning:** To keep equipment clean.
 - **Connector and Electronic Boards:** Dirt accumulation on the boards produce breakdowns so they must be kept clean. Ensure that all connector are properly connected.

Multi-Parameter Monitor

Equipment for the simultaneous display of different biological patient parameter such as electrocardiogram, arrhythmia analysis, cardiac output, blood pressure, breathing, blood oxygen saturation, etc.

Step 1: Identification of breakdowns: failures in non-invasive blood pressure cuffs and in the sensors.

- **Number:** 4 WOs are produced (18.18% of total failures).
- **ause:** Break of sensors or cuffs and imbalance of parameters. They have no review protocol. Failures due to the user.

Step 2: Established finding:

- Implementation of a daily protocol review by the user to avoid performance reviews in which no action is taken.

RX Emergency Room

Equipment for a non-invasive medical test used to diagnose and treat medical conditions. Imaging with x-rays implicates exposing a part of the body to a small amount of ionizing radiation to produce images of the inside of the body.

Step 1: Identification of breakdowns: Breakdowns on the grid to filter the radiation produced (Bucky).

- **Number:** 6 WOs are produced (33.33% of total failures).
- **Cause:** Inappropriate way of working with the equipment producing an imbalance in the Bucky drive mechanism

Step 2: Established finding:

- Implementing a training program about the way of working with the system.
- Analyze failures next year to assess whether problems in the Bucky continue to exist. Thus, the origin must be identified and the problem solved.

FUTURE RESEARCH DIRECTIONS

According to this analysis, apart from achieve an increasing patient satisfaction by decreasing waiting times, a continuous improvement in the control and management of maintenance will be accomplished. In future research, it should be checked that benefits have been obtained and for the following years, similar studies will be performed in order to update the examination and to implement a continuous improvement process. Also, due to the medical technological renewal current rate, it has become necessary to update analysis with new family of medical equipment that are being introduced into hospital.

In short, all of this is intended to optimize maintenance policies of electromedical equipment belonging to the hospital. As a result, it is expected to get a reduction of corrective activities, just as substantial improvement in the effective use of resources by electromedical department.

CONCLUSION

An ABC analysis of electromedical equipment in a healthcare organization has been performed to introduce a preventive maintenance ranges in the equipment that need it. Daily maintenance tasks that minimize unscheduled shutdowns have been generated. This will greatly improve available resources in electromedical department. A healthcare organization has large amount of maintenances requirements for the electromedical facilities because of the equipment are used directly with patients. For this, it is important improvement maintenance policies carried out by the workers. This straightforward investigation will help the maintenance department in order to achieve this aim.

The maintenance control in a healthcare center is essential to carry out maintenance tasks optimizing resources without negatively affecting care quality. The issue of optimizing maintenance policies in healthcare organizations is not well known, thus, there are almost non-existent contributions. Applying this new analysis, in addition to achieving increased patient satisfaction, an improved management and control of maintenance will be accomplished.

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KEY TERMS AND DEFINITIONS

ABC Analysis: Rating method based on Pareto principle. In maintenance of equipment, allows to identify items depending on generated impact and divide them into three group to establish an order of priorities when managing maintenance.

Computerized Maintenance Management System (CMMS): A software package which manages resources of maintenance department, incorporating a database continuously updated. It allows to schedule preventive, corrective and predictive maintenance tasks.

Electromedical Department: Technical service department whose activity includes total maintenance of medical equipment in a healthcare organization and specific facilities which provide coverage the same, as well as management through the inventory unit responsible for updating existing equipment.

Electromedical Equipment: Equipment and facilities belonging to a healthcare organization.

Healthcare Organization: Center that provides health services such as diagnosis of diseases, surgical operations and treatment and recovery of patients. Also, research and teaching assignments can be performed.

Maintenance: A set of actions responsible for ensuring machines and production equipment availability in a company.

Maintenance Datasheet: Document which specifies preventive maintenance activities that are required to minimize corrective maintenance of electromedical equipment to comply with safety parameters.

Work Orders (WOs): Generated document when a failure of any equipment occurs in order to achieve maintenance tasks to solve the problem.

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Chapter 13

The Optimal Workforce Staffing Solutions With Random Patient Demand in Healthcare Settings

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ABSTRACT

Staffing planning is paramount for cost-efficient workforce management. An accurate assessment of the required staffing level for the specific time period is an integral part of the hospital budgeting and planning process. Daily fluctuations of patient census create staffing planning challenges to many organizations. There is a growing trend for hospitals to use data analytics for determining the optimal staffing solutions. The dynamic nature of the staffing process creates two types of issues: (1) overstaffing vs. the planned budgeted level, which hurts operations margins, or (2) understaffing, which requires costly overtime and/or premium pay that also hurts margins and causes substandard quality of care. The goal of this chapter is providing an overview and examples of application of the methodology called the “newsvendor” framework. This methodology helps to develop the optimal nursing and other skill mix staffing solutions that minimize the total cost of over- and understaffing occurrences within the specified time period for the units with random patient census fluctuations.

INTRODUCTION

The current demand for more efficient use of healthcare resources, cost reduction, and patient safety improvement stimulates developing the novel operations management solutions. Workforce management has emerged as the one with the biggest impact on cost efficiency and quality of care in the USA. Indeed, labor cost typically absorbs about 54% of total hospital’s operating revenue (Herman, 2013). Therefore, an accurate assessment of the required staffing that matches the highly variable patient demand is an integral part of the hospital’s budgeting and planning process. Healthcare administrators must accomplish multiple clinical and quality goals while simultaneously developing realistic staffing plans and budgets.

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Random fluctuations of patient demand present staffing planning challenges to many hospitals. There is a growing trend for using data analytics to address these challenges.

The objective of this chapter is providing an overview and examples of application of the data analytics methodology called the “newsvendor” framework. This methodology helps to determine the optimal staffing solutions for the specified time periods for hospital units with randomly fluctuating daily patient census.

BACKGROUND

The newsvendor model is the widely used analytic model in which the optimal inventory level is determined for a specified time period. Historically, it originates from the problem in which a newsvendor has to decide on the optimal stocking quantity of the newspaper (a single product) to be ordered from the publisher in some defined ahead time period; hence it is called the newsvendor problem. If too many issues are ordered there will be some financial loss due to unsold inventory. If not enough issues are ordered there will also be some financial loss due to unmet customer demand. The problem is determining the optimal quantity order that will minimize the total financial loss due to both over- and understock during some time period.

The newsvendor framework has been widely applied to problems in which decisions should be made on the fixed supply level with an uncertain (random) demand. Such problems are often occurring in supply chain management, retail, transportation, manufacturing, banking, and many other industries (Choi, 2012; Arıkan, 2011; Porteus, 2002). Motivated by the importance of various practical applications of the newsvendor model, the entire special issue of the Decision Sciences journal (Chen et al., 2016), and the review paper (Qin et al., 2011) were dedicated to its novel advances and applications.

At the same time, the use of the newsvendor framework was rather limited in healthcare management for planning and budgeting the hospital units’ staffing while patient demand is uncertain.

For example, in the handbook of newsvendor problems, which is the first handbook dedicated exclusively to the state of the art in this area (Choi, 2012), the optimal nursing staffing problem with uncertain patient demand was not presented at all. However, this is a fruitful area of application of the newsvendor framework. The long-term nursing staffing plans should be developed on the annual basis. The medium-term staffing plans should usually be developed for a 4-6 weeks period, and be posted 1-2 weeks before the start of the planned period. Because of inevitable occurrences of unforeseen deviations from the planned staffing level, some short-term staffing adjustments should be made shortly before each shift to determine whether overtime, pooled or agency nurses are needed, or if the unit is overstaffed and some nurses are not currently needed. There is a cost associated with flexing staff up or down, along with issues of staff dissatisfaction with the erratic unpredictable schedules. There is an empirical evidence that the frequent staffing adjustments costs are accumulated to significant amounts that were not previously budgeted for. The optimal staffing level determined by the newsvendor model minimizes these accumulated costs, thus making nursing staffing plans and budgets more realistic.

One of a few publications that mention the use of the newsvendor framework for determining the optimal nursing staffing level is Hopp and Lovejoy (2013). These authors included the newsvendor framework as one of the management principles: in a single time period (month, quarter, or year) with uncertain staffing demand, the staffing level which corresponds to the minimal (optimal) possible total cost of under- and overstaffing is given by the solution, S , of equation

$$F(S)=Cu/(Cu+Co) \quad (1)$$

where $F(S)$ is the cumulative distribution function of staffing demand, Cu and Co are the hourly costs of under- and overstaffing per nurse, respectively. Derivation of Equation 1 is given in Appendix.

These authors assumed that staffing demand in any single time period is normally distributed with the known mean, m , and standard deviation, σ . Therefore, the optimal staffing level S is given by $S=m+Z*\sigma$, where Z is the inverse standard cumulative normal distribution function, i.e. $Z=\Phi^{-1}[Cu/(Cu+Co)]$.

At the same time, the assumption of normal staffing demand distribution is rarely true (if ever). Staffing demand is usually a skewed distribution function that poorly fits any theoretical distribution. This is pointed out by Davis et al. (2014) in which the newsvendor framework is applied for analyzing nursing staffing under demand uncertainty. The authors propose the use of distributional robust formulations of the newsvendor problem suggested by Perakis et al. (2008). In this formulation, it is sufficient to know only the moments of the demand distribution. However, the closed-form solutions to these models are not available. The authors propose to solve those using linear programming for sub-problems.

One important condition for application of the classic newsvendor framework is that the staffing distribution function must be stable and applicable both for the current and for the future time periods. This requires forecasting the demand which is itself a separate challenging problem. Usually, the demand forecast generated, for example, by a time series analysis can be reasonably accurate only for about a week or so. Beyond that time horizon, the forecasting errors are similar to that coming simply from the historical demand distributions (Davis et al., 2014). It is quite restrictive to assume that the future demand distribution is well known. Therefore, there have been some efforts to relax this assumption. One direction has been the nonparametric (data-driven) approach. In this approach, independent past demand data are used to estimate the minimal number of observations required for the estimated solution to be near-optimal. Rudin et al. (2013) applied this approach to estimate the optimal nursing staffing in a hospital emergency room. The authors investigated the newsvendor problem with past demand observations and a number of features to predict the future demand, such as the day of the week, time of the day and the number of past demands. This setting is similar to He et al. (2012) who considered staffing in a hospital operating room with two features (number and type of cases) to predict the required OR time.

However, selecting the right features is not easy and requires multiple models' cross-validations for testing the predictive power of the chosen features. Regardless of the sophistication of the prediction technique, if a sudden rare one-time event occurs such as mass casualty or a large epidemic outbreak that could not be previously accounted for, such an event would result in significant bias in the optimal staffing level.

There are several software products commercially available that facilitate daily staffing planning and management, such as McKesson ANSOS One-Staff, Kronos Workforce Scheduler, API/GE Healthcare Staffing & Scheduling, Cerner Clairvia Care Value Management Scheduling, among others. None of them offer predictive data analytics capability that foretells the optimum staffing level and the costs of deviation from that level that the newsvendor framework is providing.

Note that no popular nowadays machine learning algorithms will improve the solution proven as mathematically optimal. The term 'optimal' means that the staffing solution provides the minimal possible total cost of under- and overstaffing occurrences compared to any other staffing values within these time periods.

In the next sections, examples are provided in which the optimal workforce staffing solutions are determined using the newsvendor framework. In these examples, empirical staffing cumulative distribu-

tion functions (ECDF) are used, and Equation 1 is solved numerically assuming that the staffing demand is a random sample from a stable but unknown distribution. Numerical solutions are produced using a computational procedure that was built in the excel spreadsheet. In contrast to the previous research, no best fit theoretical staffing distribution functions, or distribution moments or any other special information on the staffing distribution is needed.

MAIN FOCUS

Method

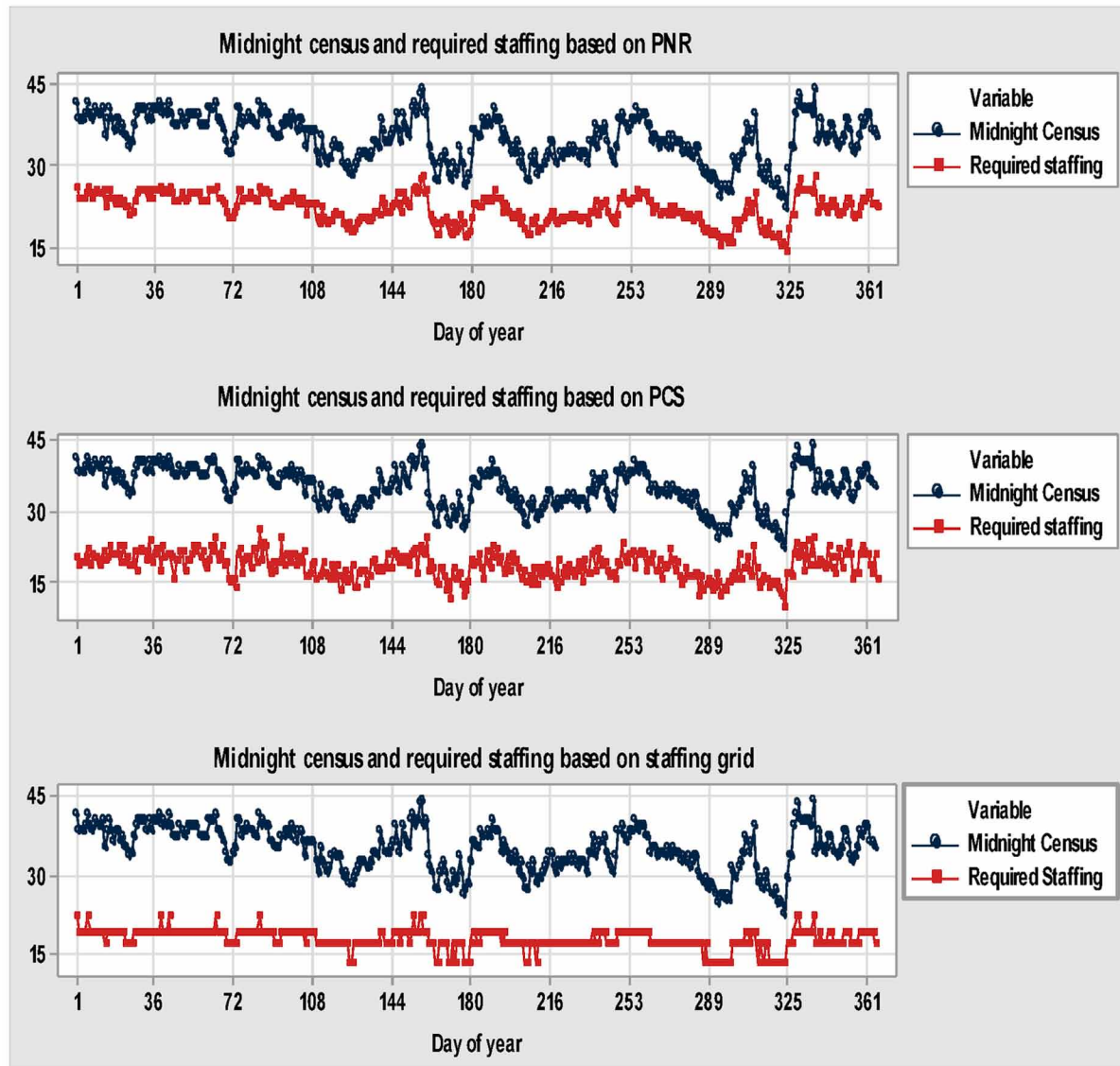
Implementation of the newsvendor framework includes the following steps: (i) variable patient census is converted into the corresponding variable staffing demand for a specified time period, (ii) the staffing demand is converted into the staffing empirical cumulative distribution function (ECDF), (iii) the cost ratio is calculated $r = Cu / (Cu + Co)$ using the hourly costs of under- (Cu) and overstaffing (Co) per nurse, and (iv) steps (ii) and (iii) are combined to solve Equation 1 numerically using a computational procedure described below.

Conversion Variable Patient Census Into Variable Staffing Demand

Conversion the variable patient census into variable nursing staffing can be performed using: 1) established patient-to-nurse ratio (PNR) that takes or does not take into account the patient acuity levels, or 2) hours per patient day benchmark standards or the calculated hours of care from the patient classification system (PCS), or 3) a staffing grid indicating for each census range the number of each caregiver skill for each shift.

1. **The Use of Patient-To-Nurse Ratio (PNR):** To illustrate, daily midnight census data for a medical-surgical unit is presented on Figure 1 for the entire year to account for some seasonal census variation. Three levels of PNRs were established in this unit. Typically, 28% of patients with the high acuity level require PNR 1:1; 67% of patients with the medium acuity level require PNR 2:1, and 5% of patients with low acuity level require PNR 3:1 (These percentages vary seasonally but are kept fixed here for simplicity. Other nursing units can have different acuity percentages and PNRs). Each census value was multiplied by the weighted sum of inverted PNR values to convert it to the corresponding staffing, i.e. $\text{staffing} = \text{census} * (0.28/1 + 0.67/2 + 0.05/3)$. Results are presented on Figure 1 (upper panel). Note that dividing each census value by the average $\text{PNR} = (0.28*1 + 0.67*2 + 0.05*3) = 1.77$ is not correct because dividing by the average is a non-linear operation that produces a biased staffing value. (Dividing census by PNR would be correct if PNR is an exact number, not the average).
2. **The Use of Patient Classification System (PCS):** In general, PCS is a system that quantifies categories of care in order to estimate the required nursing hours for direct patient care (Malloch et al., 2013). PCS-generated hours of care for each patient are summed up, and the sum is then divided by the shift length hours. This gives the required staffing for the particular period. An example of the variable staffing generated by the PCS is presented, for comparison, on Figure 1 for the same daily midnight census used for the above PNR example (middle panel).

Figure 1. Annual daily census and the corresponding staffing



3. **The Use of the Staffing Grid:** A staffing grid reflects the perceived nursing workload by the nursing management. It is usually budget target based, and serve as a baseline guide. The skills and competency of the staff is also a consideration. An example of a simplified staffing grid for a medical-surgical unit is presented in Table 1.

An example of the variable staffing generated by this grid is presented, for the comparison, on Figure 1 for the same daily midnight census used for the above examples (bottom panel). Notice that the required staffing generated by the grid is less sensitive to census variation because the staffing levels stay constant within each patient census range.

Table 1. A simplified staffing grid for the Medical-Surgical unit

Patient Census Range	Nursing Staffing
<24	10
24-28	13
29-35	17
36-40	19
41-44	21
>44	24

Conversion of Staffing Demand Into the Empirical Cumulative Distribution Function (ECDF)

If a random set of n data points $S_1, S_2, \dots, S_n$ contains m data points that are less than or equal to some value S_k , then ECDF $F_k(S)$ is defined as the fraction m/n . The ECDF is calculated using the rule:

$$F_k(S) = \begin{cases} 0, & \text{if } S_k < S_{min} \\ m/n, & \text{if } S_{min} \leq S_k \leq S_{max}, k = 1, 2, \dots \\ 1, & \text{if } S_k > S_{max} \end{cases}$$

To illustrate, consider required staffing values presented on Figure 1 (upper panel). They range from $S_{min}=14$ to $S_{max}=28$. The sample size is $n = 364$ data points. The ECDF for these values is presented on Figure 2. The ECDF is not usually a smooth analytic function. In general, ECDF poorly fits the common theoretical distributions.

The Hourly Costs of Under- and Overstaffing per Nurse and the Cost Ratio

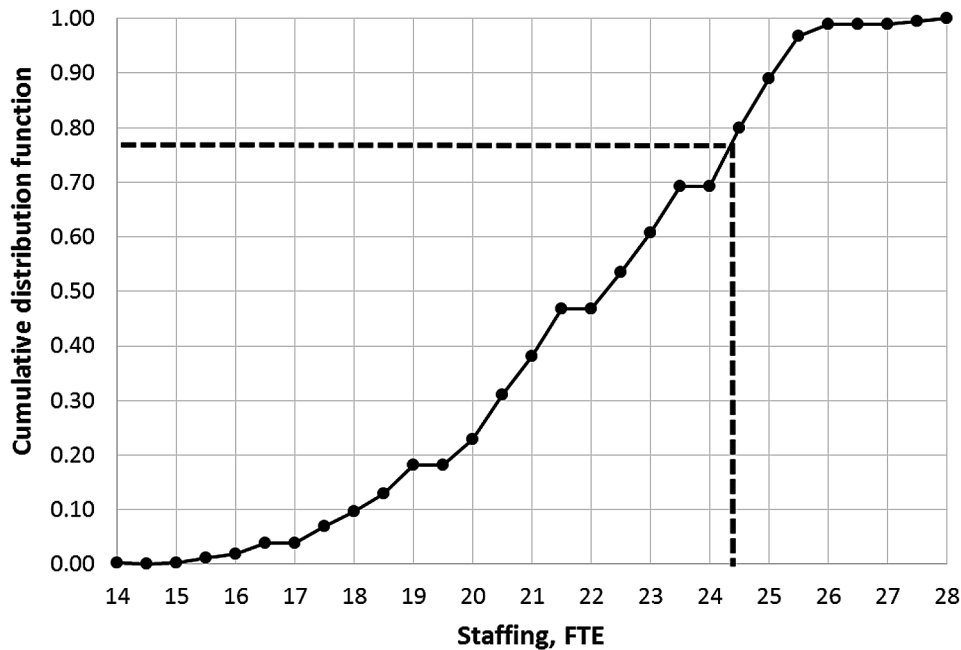
If too few nurses are planned and staffed vs. the actual nursing demand (understaffing case), then the additional nurses can be called on from the internal float pool at no extra cost (if a trained nurse is available), or from the off-duty nursing pool, or a staffing agency at a premium above the base pay rate.

To illustrate, suppose that a trained nurse is available in the internal pool 50% of time. Hence, a nurse from a staffing agency should be called on 50% of time. The premium above the base pay is 150%. Thus, the additional cost per called-on nurse in excess to the base pay rate

$$P(\$/hour) \text{ is } C_u = (1-0.5) * 1.5 * P(\$/hour) = 0.75 * P$$

If too many nurses are staffed (overstaffing), then the extra nurses can be called-off either into the internal float nursing pool or offered to take paid/unpaid vacation or put on call. If the nurse is put on call then she/he is not usually get payed (in majority USA hospitals). This makes an impression that calling-off a nurse does not cost anything (except the case for contractual obligation to pay for putting

Figure 2. ECDF for variable staffing: The dotted lines illustrate the graphical solution of Equation 1



on call, if any). Hence, the unit always has a financial incentive to staff to the maximum. While this might be true for the unit's base payroll, there is a fixed cost for the called-off nurse. KPMG reported (KPMG, 2011) that the average nursing hourly costs in the USA is about $P = \$45/\text{hour}$. This includes the base payroll cost of $\$35/\text{hour}$, and the total of insurance, recruiting, training and other costs per nurse of about $\$10\text{--}11/\text{hour}$, on average. Therefore, even if the called-off nurse is not get paid through the unit's payroll, she/he still costs the hospital about 22%–24% of the base pay, i.e. $0.24 * P (\$/\text{hour})$, but brings no patient care value. Using this fixed cost of overstaffing, the cost ratio is $r = 0.75 / (0.75 + 0.24) = 0.76$. Notice that the base pay rate is cancelled out in this ratio.

In most cases, the understaffing costs more than the overstaffing. Therefore, usually $r > 0.5$. In rare cases of the same under- and overstaffing costs, $r = 0.5$.

Note that an approach was suggested in which the cost parameters C_o and C_u were imputed from the observed actual staffing rather than treated as the model inputs (Olivares et al., 2008). However, this approach assumes that the actual staffing was already close to the optimal. Otherwise, the imputed cost parameters will be significantly biased.

Computational Procedure for Solving Equation 1

Solution of Equation 1 is the staffing value, S , for which $F(S)$ is equal to r . It is illustrated graphically on Figure 2 by dotted lines for $r = 0.76$. The optimal staffing solution is 24.5. This value can be fractional because, in general, staffing is expressed by FTE (full-time-equivalent) which is not necessarily a whole number. One FTE is usually 40 hours per week. For staffing software, Equation 1 should be solved numerically. A simple computational procedure for doing so is the following:

1. Make the FTE bins from minimal to maximal staffing values with the increment 0.25 FTE. (From a practical standpoint it is usually enough to get the staffing solution accuracy ± 0.125 FTE. Hence, 0.25 FTE staffing increment is usually suffice).
2. For each incremented FTE value S test if the corresponding ECDF value $F(S) < r$. If this condition is TRUE then go to the next value of $F(S)$, and so on.
3. If $F(S) \geq r$ then STOP. The optimal staffing will approximately be the mean value

$$S_{opt} = [\text{FTE (previous step bin)} + \text{FTE (current step bin)}] / 2.$$

This procedure can easily be implemented in the Excel spreadsheet, as well as coded in R, Python, Microsoft .NET, or in any other coding language.

SOLUTIONS AND RECOMMENDATIONS

In this section, the optimal nursing staffing solutions for some nursing units are presented. The particular hospitals are not named here because some data used in the examples are considered proprietary.

Example 1: Annual and Monthly Optimal Nursing Staffing

The daily variable required nursing staffing for the medical-surgical unit is presented on Figure 3 (panel A), as well as the corresponding ECDF (panel B).

Using the unit's available financial data, the extra cost of understaffing was assumed \$30/hour per nurse, while the overstaffing per nurse was assumed being the fixed rate \$11/hour. This makes $r=0.73$. The staffing bins and ECDF values are presented in Table 2 (abbreviated to save space). It is seen that $r=0.73$ lies in the interval between ECDF values 0.715 and 0.759. Thus, the annual optimal nursing staffing level is the mean of the corresponding FTE bins, i.e. $(6.5+6.75)/2=6.625$ FTE, as shown in the third column in Table 2. The graphical solution is indicated by the dotted lines on Figure 3 (panel B).

It was previously pointed out that the newsvendor's optimal staffing level always corresponds to the minimal possible total cost of under- and overstaffing. Thus, any other heuristically adjusted (higher or lower) staffing level would inevitably result in a higher total cost of deviations from that level. To illustrate, let us compare two costs of deviation using (i) the optimal staffing value from Table 2 and (ii) the suboptimal average staffing for the same period. The average value is frequently used as a basis in traditional staffing planning.

The total annual cost of deviations of the daily required staffing FTE from the optimal 6.6 FTE (above or below this level) was calculated as the sum of these deviations multiplied by the corresponding hourly costs and by the shift duration 8 hours. The result was \$94,979.

The average annual staffing for data presented on Figure 3 (panel A) was 5.3 FTE. The total annual cost of deviations for this suboptimal level calculated similarly was \$115,012. Thus, the optimal staffing level resulted in about 17% lower costs compared to the average one.

It was mentioned earlier that staffing plans are frequently developed for shorter time periods such as monthly or every 4-6 weeks. To illustrate, the month-to-month optimal staffing levels were calculated

Figure 3. The daily nursing staffing demand for the medical-surgical unit (panel A) and the corresponding ECDF (panel B)

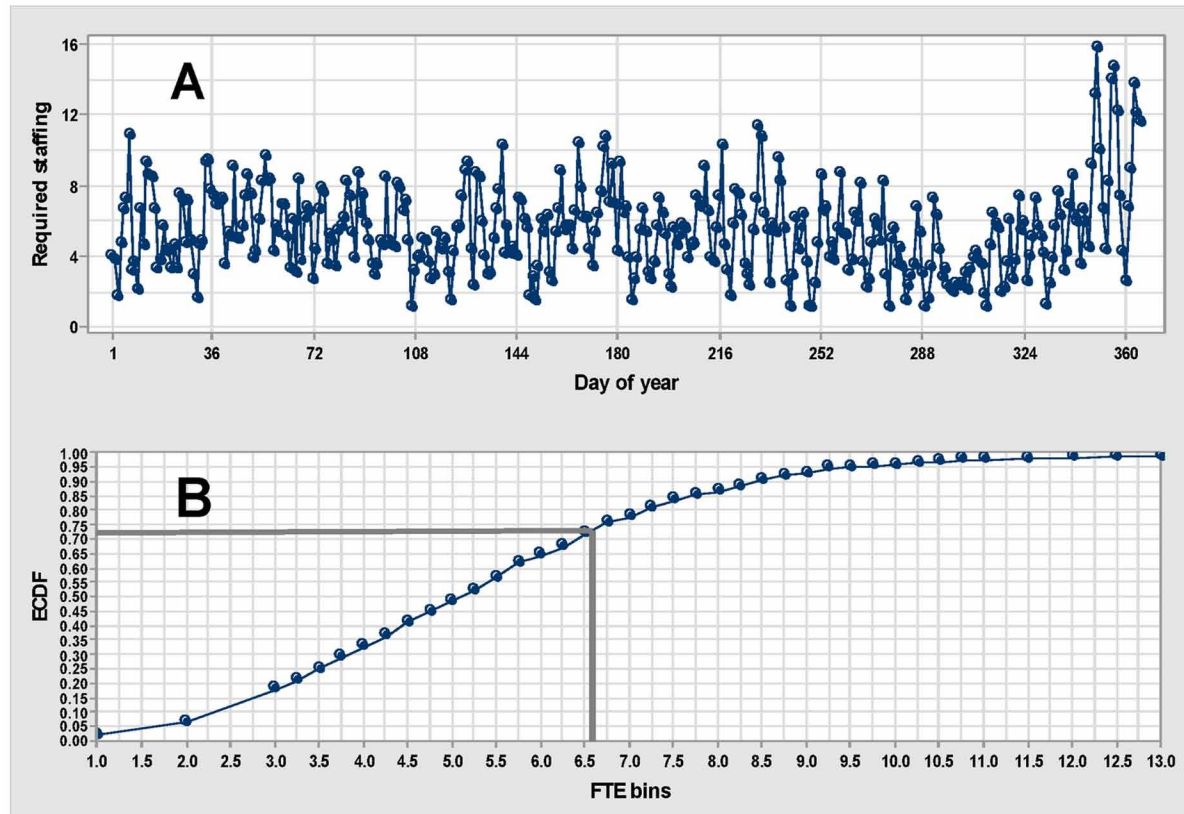


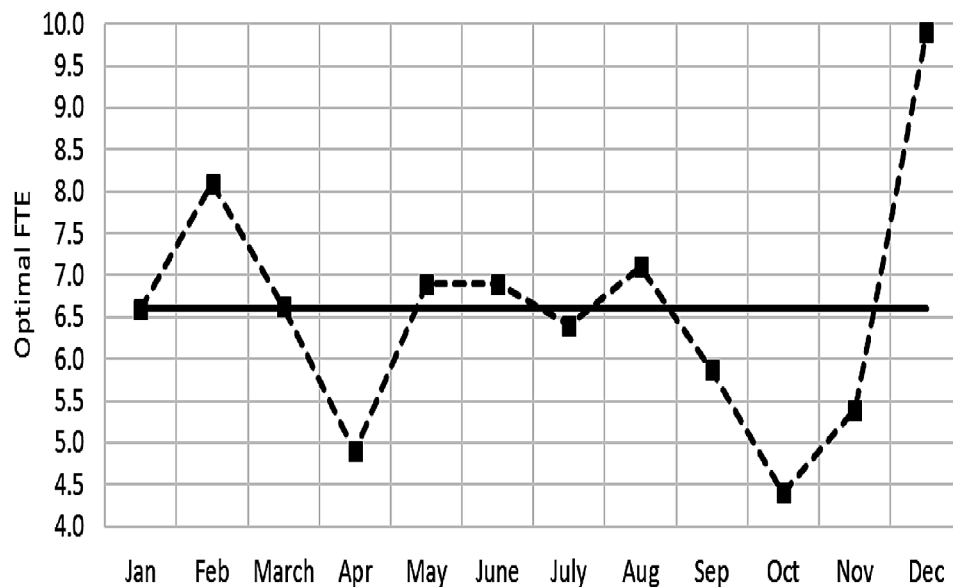
Table 2. FTE bins, ECDF, and the optimal annual nursing staffing level

Staffing FTE Bins	ECDF, $F(S)$	Optimal Staffing, FTE
6.25	0.674	
6.50	0.715	
6.75	0.759	6.625
7.00	0.775	
7.25	0.811	

using the same computational procedure. Results are presented on Figure 4, along with the annual optimal staffing level (flat solid line) for the comparison.

It is seen a significant month-to-month variation of the optimal FTE vs. the annual one. The bump of the optimal FTE for December reflects the corresponding staffing demand peak for this time period (Figure 3, panel A), apparently due to increased patient census related to typical end-of-year seasonal flu epidemics. Thus, the shorter term month-to-month optimal staffing is typically better accounts for seasonal patient census and required staffing variations.

Figure 4. The optimal monthly staffing and the annual optimal staffing level (flat solid line)



The total costs of under- and overstaffing for the monthly optimal staffing FTE were compared to that for the average staffing FTE in Table 3.

Example 2: The Optimal Staffing for Caregivers' Skills Mix

Previous examples demonstrated the optimal staffing calculation only for one category of caregivers—the nurses. However most nursing units include other staff skills mix, such as nursing assistants (NA), clinical nurse specialists (CNS), nurse practitioners (NP), among others.

Let's consider, as an example, a nursing unit that is staffed with three caregivers' skills mix: nursing assistants (NA), registered nurses (RN) and certified nurse specialists (CNS). In this unit a typical share of workload by the skills mix is 28% for NA, 57% for RN and 15% for CNS. Standard hours of care per patient day (HPPD) for various levels of patient acuity are presented in Table 4.

Patient data for this unit are presented in Figure 5 (only three weeks' worth of data is included to save space).

The typical cost of under- and overstaffing for RN in this unit was similar to the one used in the previous example. However, the costs for NA and CNS were not readily available. It was assumed that the costs of under- and overstaffing for NA were about the same (\$13-\$15/hour) resulting in the NA cost ratio $r=0.5$. The understaffing costs for CNS was assumed twice the cost of overstaffing resulting in $r=0.67$. At the same time, the calculated optimal staffing values for these caregiver categories turned out not too sensitive to the r values. Due to the particular staffing demand and, hence, the shape of ECDF, the NA optimal staffing is not changed with r values in the range $r=0.43-0.56$. CNS optimal staffing is not changed with r values in even wider range $r=0.56-0.75$. Thus, some variations of the poorly known costs were not too critical for the calculated optimal staffing values presented in Table 5, which also

Table 3. Monthly optimal and average FTE and the total costs of under- and overstaffing

Month	Optimal FTE	Monthly Average FTE	Total Costs of Under- and Overstaffing		
			For Optimal FTE	For Average FTE	Cost Saving, %
Jan	6.6	5.1	\$ 7,766	\$ 9,697	20%
Feb	8.1	6.5	\$ 5,200	\$ 7,486	31%
Mar	6.6	5.7	\$ 4,988	\$ 7,094	30%
Apr	4.9	4.6	\$ 5,093	\$ 5,893	14%
May	6.9	5.3	\$ 7,870	\$ 9,887	20%
Jun	6.9	6.2	\$ 7,165	\$ 8,167	12%
Jul	6.4	5.0	\$ 5,104	\$ 7,232	29%
Aug	7.1	5.5	\$ 8,924	\$ 10,670	16%
Sep	5.9	4.7	\$ 5,545	\$ 7,477	26%
Oct	4.4	3.4	\$ 6,511	\$ 7,195	10%
Nov	5.4	4.0	\$ 5,087	\$ 6,749	25%
Dec	9.9	8.0	\$ 13,625	\$ 15,351	11%

Table 4. Standard hours of care per patient for various levels of patient acuity

Acuity Level	Standard Hours of Care
Level 03	2.8
Level 04	3.4
Level 05	4.0
Level 06	4.6
Level 07	5.5
Level 08	6.6
Admissions	0.5
Discharges	0.5

includes the total costs of under- and overstaffing for three categories of caregivers both for the optimal FTE and for the suboptimal average FTE. It is seen that the costs of the former is much lower than that for the latter, similar to results demonstrated in Example 1.

In summary, these examples demonstrated that the optimal staffing levels vary with the time periods for which they are calculated (annual, monthly, or any other). They also demonstrated that the mathematically proved minimal total costs of under- and overstaffing for the optimal staffing values are indeed less than that for any suboptimal staffing levels such as the average. Another goal of these examples was demonstrating the use of ECDF and a simple computational procedure for numerical solving the newsvendor Equation 1. It is recommended that the newsvendor framework is applied to justify a staffing plan whenever it is being developed and budgeted for.

The Optimal Workforce Staffing Solutions With Random Patient Demand in Healthcare Settings

Figure 5. The number of patients at various levels of acuity, admissions & discharges (ADT) and the daily required staffing FTE for three categories of caregivers NA, RN, and CNS

Date	Level 03	Level 04	Level 05	Level 06	Level 07	Admissions & Discharges (ADT)	Total hours of care	NA share of total hours of care (28 %)	RN share of total hours of care (57%)	CNS share of total hours of care (15%)	NA staffing, FTE	RN staffing, FTE	CNS staffing, FTE
1/1/12			1	16	3		93.9	26.8	53.7	13.4	3.3	6.7	1.7
1/2/12			1	17	4	3	107.0	30.5	61.2	15.3	3.8	7.6	1.9
1/3/12			3	11	7	6	107.3	30.6	61.3	15.3	3.8	7.7	1.9
1/4/12			1	21	5	7	134.9	38.5	77.1	19.3	4.8	9.6	2.4
1/5/12	2			22	3	11	133.9	38.2	76.5	19.1	4.8	9.6	2.4
1/6/12				23	5	4	137.0	39.1	78.3	19.6	4.9	9.8	2.4
1/7/12				23	4	7	134.5	38.3	76.8	19.2	4.8	9.6	2.4
1/8/12		1		18	4	7	115.0	32.8	65.7	16.4	4.1	8.2	2.1
1/9/12				18	4	3	107.6	30.7	61.5	15.4	3.8	7.7	1.9
1/10/12				14	9	2	116.0	33.1	66.3	16.6	4.1	8.3	2.1
1/11/12				23	6	7	145.5	41.5	83.2	20.8	5.2	10.4	2.6
1/12/12				20	3	1	109.2	31.1	62.4	15.6	3.9	7.8	2.0
1/13/12			1	21	4	7	129.3	36.9	73.9	18.5	4.6	9.2	2.3
1/14/12			1	20	4	2	119.8	34.1	68.4	17.1	4.3	8.6	2.1
1/15/12				17	3		94.4	26.9	54.0	13.5	3.4	6.7	1.7
1/16/12			5	11	1	5	81.1	23.1	46.3	11.6	2.9	5.8	1.4
1/17/12			1	25	1	5	129.0	36.8	73.7	18.4	4.6	9.2	2.3
1/18/12			1	26	2	8	142.1	40.5	81.2	20.3	5.1	10.2	2.5
1/19/12		1		28	3	9	157.2	44.8	89.8	22.5	5.6	11.2	2.8
1/20/12		1		14	5	7	102.3	29.2	58.4	14.6	3.6	7.3	1.8
1/21/12				14	7	4	106.9	30.5	61.1	15.3	3.8	7.6	1.9

Table 5. Optimal and average staffing FTE for three caregiver categories and the total costs of under- and overstaffing

Caregiver Category	Optimal FTE	Average FTE	Total Cost of Under- and Overstaffing	
			for Optimal FTE	for Average FTE
Nursing Assistant (NA)	4.4	4.3	\$20,705	\$25,681
Registered Nurse (RN)	9.9	8.6	\$49,701	\$75,245
Certified Nursing Specialist (CNS)	2.4	2.2	\$8,414	\$15,146

FUTURE RESEARCH DIRECTIONS

The author believes that the following problems merit further research.

Determining the optimal staffing for the future time periods with some projected gradual non-random trend in demand. This trend should be incorporated into the current ECDF to account for some shift in the future staffing demand distribution.

A related problem is incorporating sudden demand spikes into the prior staffing demand distribution, e.g., caused by a mass casualty event or an infection outbreak. One approach for doing this could be the use of the Bayesian framework.

One more problem is related to the true costs of occurrences of under- and overstaffing. The called-on float or agency nurses are usually new to the unit, thus they are less productive than the regular staff nurses. Similarly, calling-off nurses by putting them on call or floating into the pool after scheduling up for work usually negatively impacts their morale and productivity. These non-monetary factors could result in underestimating the true costs of under- and overstaffing. It seems that this problem was not adequately addressed in prior research.

Also, the classic newsvendor framework assumes that the costs of under- and overstaffing are constant within the time period. However, these costs could be interrelated with staffing demand. Incorporating this interrelation into the newsvendor framework will further advance its area of application in healthcare settings.

CONCLUSION

The author believes that this chapter convincingly demonstrates the power and versatility of the newsvendor framework to determine the optimal staffing levels in healthcare settings. In fact, the newsvendor framework is suitable for analysis of various operations management problems. It is also demonstrated the advantages of the ECDF and a simple computational procedure for numerical solving the newsvendor Equation 1. Using this approach, there is no need anymore for developing the best fit theoretical demand distribution or moments of the distribution suggested in earlier research. The author expects that more newsvendor model based operations management applications will emerge in healthcare settings, along with other appropriate data analytics methodologies.

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KEY TERMS AND DEFINITIONS

Data Analytics: The discipline and practice of using various quantitative methods to aid in solving business or engineering problems.

Empirical Cumulative Distribution Function (ECDF): A fraction of data-points that are less than or equal to some predetermined values within a set of random numbers.

Newsvendor Framework: An analytical model that provides the optimal inventory or staffing level (in terms of the lowest financial loss due to overage and underage) within a specified single time period.

Optimal Staffing: The staffing level that provides the lowest possible total costs of occurrences of under- and overstaffing compared to any other staffing value within a specified time period.

Overstaffing (Overage): Staffing level that is higher than the actually required.

Patient Classification System: The system that quantifies categories of care in order to objectively estimate the required nursing hours for direct patient care.

Understaffing (Underage): Staffing level that is lower than the actually required.

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APPENDIX

Let the distribution density function of demand, D , be $f(D)$.

Then the average loss due to overage, i.e. for staffing $S > D$ is:

$$C_o \int_0^S (S - D) f(D) dD,$$

where C_o is the unit cost of overage.

The average loss due to underage, i.e. for staffing $S < D$ (unmet demand) is:

$$C_u \int_S^{D_{max}} (D - S) f(D) dD$$

where C_u is the unit cost of underage.

Total loss function is:

$$L(S) = C_o \int_0^S (S - D) f(D) dD + C_u \int_S^{D_{max}} (D - S) f(D) dD$$

It is minimized with respect to staffing, S , by taking the derivative and making it equal to 0.

$$\frac{dL}{dS} = C_o \int_0^S f(D) dD - C_u \int_S^{D_{max}} f(D) dD = 0$$

Here, the derivative of $L(S)$ with respect to S is taken using the general rule:

$$\text{If } f(p) = \int_{a(p)}^{b(p)} f(x, p) dx, \text{ then}$$

$$\frac{df}{dp} = \int_a^b \frac{\partial f(x, p)}{\partial p} dx + f(b, p) \frac{db}{dp} - f(a, p) \frac{da}{dp}$$

The 2-nd derivative is

$$\frac{d^2L}{dS^2} = C_o f(S) + C_u f(S) > 0$$

hence this is minimum.

Thus, $C_o F(S) - C_u (1 - F(S)) = 0$. Consequently, $F(S) = C_u / (C_u + C_o)$.

The same result is produced if the demand distribution is a discrete function rather than the continuous one.

Chapter 14

Using Technology to Reduce a Healthcare Disparity

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ABSTRACT

Superior healthcare delivery requires good communication. For people who have English as a second language, this is particularly challenging. Given the advances in technology, most especially with Web 2.0 and cloud computing, the following proffers a technology-mediated solution to address communication barriers that result when delivering healthcare to non-English speakers or limited-proficiency English-speaking patients. This solution serves to reduce healthcare disparities, satisfy meaningful use requirements, and provide superior healthcare delivery that is efficient, effective, and efficacious.

INTRODUCTION

Healthcare costs globally continue to rise and the US in particular is struggling to contain healthcare costs (Wickramasinghe et al., 2015, 2012). This has led most OECD countries to focus on healthcare reform coupled with greater investment in IS/IT to facilitate superior healthcare delivery (Wickramasinghe et al., 2015). At the same time, the federal government has affected policy to emphasize meaningful use of such technology in healthcare (Wickramasinghe et al., 2015; “Meaningful Use,” 2012). Hence, it is now prudent to develop appropriate technology solutions that not only comply with this requirement but also facilitate superior healthcare delivery to ensue.

An area that can particularly benefit from the application of technology solutions is that of equal experience and trying to provide equality of care and access to all citizens. A key area within healthcare disparities relates to access of language services in healthcare or more specifically supporting limited English proficient patients (LEP patients). In particular, English language proficiency should not impinge on access to- and quality of- service for healthcare. Improving access to language services in healthcare has been an ongoing issue that continues to be at the forefront of various healthcare agendas ((Au et al., 2009; Barrett et al., 2008; Chen et al., 2007).

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BACKGROUND

Recent discussions on healthcare disparities (Gibbons, 2011) all note the significant potential benefit technology can make in trying to provide an equal experience to all Americans. Sadly, while there are many good points about the US healthcare system, there also exists a considerable racial and ethnic disparity in the delivery of healthcare across the US (Gibbons, 2011). The underlying root causes for these disparities are all amenable to interventions using IS/IT (information systems/information technology). The thesis of this paper is that technology is well suited to assist is that of limited English proficiency (LEP).

More than 23 million Americans today have limited English proficiency, which in turn has a negative impact on their ability to receive and comprehend appropriate healthcare delivery (Youdelman, 2008; Flores et al., 2008). Integral to the delivery of care is communication between doctor and patient; however, language barriers typically lead to problems such as delay or denial of services, issues with medication management, and underutilization of preventative services (Green et al., 2005; Jacobs et al., 2004; Ghandi et al., 2000; Karliner et al., 2004). The literature suggests that the quality of communication between Although Title VI of the Civil Rights Act 1964 has always required that entities receiving federal funds provide language services to those with LEP, the law has not often been enforced in healthcare settings (Jacobs et al., 2006). However, awareness of the need to provide language services in healthcare has increased in recent years (Gibbons, 2011).

Current Problem

In 2001 The Institute of Medicine has published two key reports “To err is Human” and “Crossing the Quality Chasm”. Taken together these reports highlight that patient safety should be one of the essential components of high quality healthcare and that patients should not be harmed by the care that is intended to help them. These profound statements have had far reaching impacts to policy reform and efforts to address patient safety and quality of care delivered today. The role of language barriers and their impact on adverse events is thus now also receiving heightened attention. Especially given that research is consistently highlighting that adverse events affect LEP patients disproportionately more and result in serious consequences to the patient.

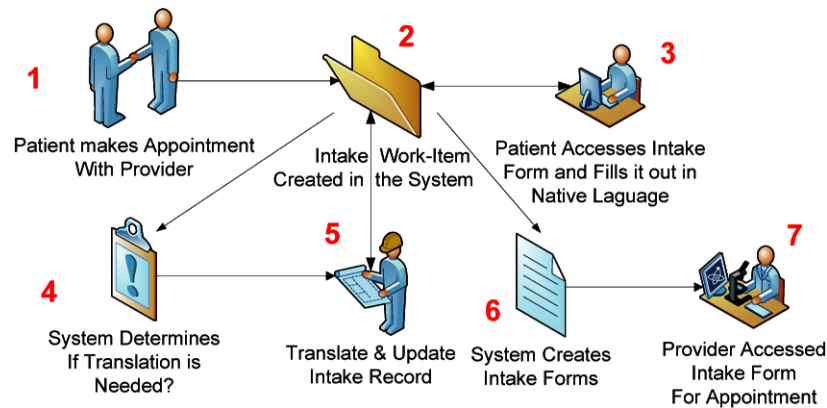
Approximately 57 Million people or more than 20 percent of the US population speak a language other than English and this figure is growing while approximately 8.6 percent of the population is defined as LEP. Thus at least 8.6 percent of the US population is at risk for adverse events because of barriers associated with language issues. This adds further cost pressures to an already strained healthcare system

To address this problem a technology mediated solution is proffered to provide multi-lingual support at in-take and registration for LEP patients.

Development of the Conceptual Model

Web 2.0 technology and cloud computing which provides and facilities anytime anywhere access to (Troshani et al., 2011; Svantesson & Clark, 2010; Mell & Grance, 2010; Gilbert, 2010; Amazon, 2011; Armbrust et al., 2010), affords us the possibility to leverage these technology benefits to design and develop an appropriate solution to address the problem – a portal that support multi language real time translation at intake and registration. Figure 1 provides the conceptual model.

Figure 1. Conceptual model



From the above conceptual model in Figure 1, it is possible to model the intake process into critical steps. All these 13 steps of care must be addressed in the technology solution and/or suite of solutions if the solution is to provide the necessary assistance for LEP patients. Taken together these steps traverse the healthcare encounter at intake.

PILOT STUDY

The developed solution was then tested in a small pilot study to assess its reliability and feasibility. A 2 arm control study was designed where both English proficient patients and Spanish proficient patients were randomly selected at a leading MidWest Multi-specialty healthcare facility. Before the study commenced appropriate ethical clearances were obtained. Table 1 and 2 detail the results from the two week pilot trial as well as the activities that were observed in the study.

Results

The study qualitatively measured the interactions between the patients and the electronic kiosk, the value of a clear and concise intake summary for the physician at the beginning of the medical encounter and the ability of the administrative team in the department to take advantage of the completed electronic intake form for other purposes. There was no attempt to integrate the intake form with electronic medical records. Table 3 summarizes the key findings.

FUTURE RESEARCH DIRECTIONS

Two areas are especially critical when considering future developments of the technology mediated solution. Specifically, one area is to assess the health literacy of the patients no matter if they are LEP or proficient English language speakers. The other key direction involves developing and enlarging the languages offered to include Chinese, Polish, Farsi and German as these are the foreign languages most in prevalent within the US.

Table 1. Study activity

Actor	Before	During Study
Spanish Speaking Patients	Handed an English language intake form and were asked to fill it out to the best of their ability Often had a family member fill out the form, forms were often difficult to read and were incomplete If no family member was present a Spanish speaking staff administrator was taken off their job and asked to serve as interpreter and fill out the form with patient and increased the cost of serving an LEP patient Completed Forms were often difficult to read and of marginal value to physician provider Cultural behaviors limited the ability to gather information, Older Hispanics, men and women are very reluctant to volunteer information Completed form given to administration desk Completed form was placed in patient intake folder and was available to physician, was not available for other purposes Wait times varied as to availability of	Asked to participate in beta study, if agreeable directed to intake kiosk Offered Spanish language form which was translated into English per study description by medically competent interpreter. In some cases family member filled out form in other cases interpreter filled out form. No problems observed in using kiosk technology Form presentation was clear and understandable by patients Completed form given to administration desk Completed form in electronic format was available for other purposes such as Average duration of form completion action was not a factor
English Speaking Patients	Given paper form Filled out form to best of ability Very often completed forms were not easy to read and of minimal value to physician Completed form was placed in patient intake folder and available to physician, was not available for other purposes	Given option of using electronic intake kiosk with drop down menus and input boxes Faster intake form completion Intake form presentation was clear and understandable by patient Completed form was placed in patient intake folder and available to physician and available for other purposes
Physician	Clarity of intake form depended on writing and communication skill of patient	Electronic format provided easy to read and use intake form
Administration	Begins w patient request for appoint and scheduling of appointment, and request for completion of paper forms prior to actual appoint, on appointment date Patients rarely completed intake forms in advance of appointment If patient did not complete intake form prior to visit a blank form was presented to patient at time of visit If patient was a Spanish speaker a family member or staff would assist with intake completion If no family member available administration staff acted as interpreter. Completed form was used presented to administrator	Administration asked English or Spanish speaking patients if they would be interested in completing an intake form electronically and in native language. Once form was complete either handwritten or electronic it was returned to the administration and placed in the intake folder for clinical visit with physician.

CONCLUSION

The US healthcare provider setting is working to deliver the best possible patient care. It must also meet cost of service objectives and provide physicians the best possible tools to meet patient's expectations. Technology in its many applications will continually be employed and adapted to accomplish these goals. Technology that facilitates communication between the patient and the provider (physician and administration) will have an important role. All healthcare interactions begin and end with communication between the provider and patient. This is a determining factor in successful health outcomes. With greater clarity and availability of patient information there is a greater probability of meeting patient need and managing the cost of delivering service. For example, it is well documented that language barriers (communication barriers) between patients and providers are a leading cause of healthcare disparities.

Using Technology to Reduce a Healthcare Disparity

Table 2. Control: English speaking patients

Actor	Event	Outcome
English Speaking Patient	English speaking patients are offered option of traditional paper intake form or completing the form at kiosk with touch screen and drop down menu capabilities.	The Department of Urology serves an aged skewed population. As a general rule the younger the patient the more likely they were to opt for the electronic format. 80% of the patients offered the electronic option chose for to use that. Several patients commented that the electronic version was much faster to use and more consistent with a modern healthcare setting. Other inquired if the electronic form was transferable to other departments. For those patients that chose the electronic version patient satisfaction ranged on the scale of 4 or 5 with 5 being the highest on a 1 to 5 scale.
Spanish Speaking Patient	Spanish speaking patients are offered option of the traditional paper intake form or completing the form at kiosk with touch screen and drop down menu capabilities. The hand written intake form provided by the administration was not translated into Spanish, consequently each Spanish speaking patient opted for the electronic version of the form offered in their native language.	In each case at the electronic kiosk, translator services were incorporated to facilitate the completion of the intake form. Spanish speaking patients were afforded the opportunity to complete the intake in their language while the administration and physician were provided an English language version of the intake form. In each case customer satisfaction was rated a 5 on a 1 to 5 scale. Multiple copies of the completed intake form given to each patient for potential use in other departments.
Physician and Patient	English and Spanish speaking patients were queued to meet with the physician in a business as usual manner.	Physicians who had access to the electronic forms regardless of language spoken by the patient rated the clarity of the information on the electronic form higher than the hand written form. Also, physicians stated that the quantity of the information was greater and offered a more clear picture of the patient medical, family and social status. Physician satisfaction with the electronic form over the handwritten form was ranked higher because the electronic form was easier and faster to read. See appendix xx for sample of handwritten and electronic form.
Administration and Patient	Once the intake forms were completed (English and Spanish), they were handed to the front desk for administration, placed in the patient intake folder and placed in queue for the physician. The form is reviewed by the physician. It is generally not used beyond physician review for other purposes.	After the physician encounter patients were often asked to complete other forms very similar in content to the original intake form. Form redundancy is a major detractor to patient satisfaction and high cost component to administrative efficiency. No other forms have a language assistance component. The impact of this is obvious i.e. when a dietary requirement is needed before a test can be conducted and this requirement is not met on the day of the scheduled procedure because the instructions were not understandable by the non-English speaking patient.

Communication barriers are not limited to the interactions between the patient and physician but also include the patient's interactions with the physician supporting healthcare infrastructure.

Communication Barriers Impact

Patient - Physician Communication

For example,

1. The inability for physicians to understand a patient's need and thus increase the potential for medical errors and the associated higher cost of service.

Table 3. Summary of findings

Actor	Event	Outcome
English Speaking Patient	English speaking patients are offered option of traditional paper intake form or completing the form at kiosk with touch screen and drop down menu capabilities.	The Department of Urology serves an aged skewed population. As a general rule the younger the patient the more likely they were to opt for the electronic format. 80% of the patients offered the electronic option chose for to use that. Several patients commented that the electronic version was much faster to use and more consistent with a modern healthcare setting. Other inquired if the electronic form was transferable to other departments. For those patients that chose the electronic version patient satisfaction ranged on the scale of 4 or 5 with 5 being the highest on a 1 to 5 scale.
Spanish Speaking Patient	Spanish speaking patients are offered option of the traditional paper intake form or completing the form at kiosk with touch screen and drop down menu capabilities. The hand written intake form provided by the administration was not translated into Spanish, consequently each Spanish speaking patient opted for the electronic version of the form offered in their native language.	In each case at the electronic kiosk, translator services were incorporated to facilitate the completion of the intake form. Spanish speaking patients were afforded the opportunity to complete the intake in their language while the administration and physician were provided an English language version of the intake form. In each case customer satisfaction was rated a 5 on a 1 to 5 scale. Multiple copies of the completed intake form given to each patient for potential use in other departments.
Physician and Patient	English and Spanish speaking patients were queued to meet with the physician in a business as usual manner.	Physicians who had access to the electronic forms regardless of language spoken by the patient rated the clarity of the information on the electronic form higher than the hand written form. Also, physicians stated that the quantity of the information was greater and offered a more clear picture of the patient medical, family and social status. Physician satisfaction with the electronic form over the handwritten form was ranked higher because the electronic form was easier and faster to read. See appendix xx for sample of handwritten and electronic form.
Administration and Patient	Once the intake forms were completed (English and Spanish), they were handed to the front desk for administration, placed in the patient intake folder and placed in queue for the physician. The form is reviewed by the physician. It is generally not used beyond physician review for other purposes.	After the physician encounter patients were often asked to complete other forms very similar in content to the original intake form. Form redundancy is a major detractor to patient satisfaction and high cost component to administrative efficiency. No other forms have a language assistance component. The impact of this is obvious i.e. when a dietary requirements is needed before a test can be conducted and this requirement is not met on the day of the scheduled procedure because the instructions were not understandable by the non-English speaking patient.

2. Poor communications between the physician and patient extends the healthcare encounter and creates delays in physician access.

Patient - Administration Communication

For example,

1. The ability for the patient to follow with procedural or pharmacy instructions,
2. The ability for patients to provide or understand billing or insurance information, and
3. The ability to follow up with next steps in a treatment protocol which leads to higher cost of service

Using Technology to Reduce a Healthcare Disparity

This study represents a first step to understand the impact of using an electronic intake format for gathering patient information from both English speaking and non-English speaking (LEP) patients. Healthcare disparities plague the US healthcare system and language proficiency is one of these key barriers. Technology does have the potential to reduce this barrier effectively and efficiently so that superior care delivery might ensue. The proffered solution described in the preceding holds the key to potentially addressing this challenge.

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KEY TERMS AND DEFINITIONS

Cloud-Based Computing (or Cloud Computing): When computing resources such as software and hardware are delivered as a service over a network.

Healthcare Delivery: The network, structure and stakeholders involved in administering medical care to individuals.

Human Interpreter: Person who performs language translation.

Language Translation: The act of converting the meaning into a different language.

LEP-Limited English Proficiency: Individuals for whom English is not their native language and thus have difficulty communicating and understanding in English.

Meaningful Use: Federal government stipulation for technology solutions in healthcare.

Real-Time Translation: Translation that happens instantaneously at the point of action.

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Section 5

Health Information Systems

Chapter 15

Challenges and Implications of Health Literacy in Global Health Care

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ABSTRACT

This chapter explains the perspectives on health literacy, trends and issues with health literacy, and the challenges and implications of health literacy in global healthcare. Health literacy concerns the knowledge and competences of patient to meet the complex demands of health in modern healthcare. Providing effective patient information means acknowledging, understanding, and overcoming barriers to health literacy that physicians, health professionals, and patients might experience. Health literacy affects health behavior and the use of health services, thus affecting health outcomes and health costs in the healthcare organizations. The benefits of health literacy improvement include improved communication, greater adherence to treatment, greater ability to engage in self-care, improved health status, greater healthcare efficiency, and cost savings to the healthcare systems.

INTRODUCTION

The specific level of health literacy is required for patients to fully understand health information and services to make effective decisions about their health care, including decisions about screening and treatment (Koay, Schofield, & Jefford, 2012). Being able to employ a certain degree of control is recognized as a precondition for the active patient participation and is often discussed concerning health literacy (Nutbeam, 2008). Patients' perceived control over their care is indicated by their perceived ability to perform the self-care activities in the home environment, to interact effectively with health care providers, and to organize care at the right moment (Coulter, 2012). Older patients and patients who are less educated about their health care condition are more likely to have the lower health literacy, visit their health care provider more frequently, and perceive more difficulties in exerting control over their care than the highly educated younger patients (Dahlke, Curtis, Federman, & Wolf, 2014).

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This article aims to bridge the gap in the literature on the thorough literature consolidation of health literacy. The extensive literature of health literacy provides a contribution to practitioners and researchers by describing the challenges and implications of health literacy in order to promote the health literacy in global health care.

BACKGROUND

Health literacy is a complicated perspective that depends on the individuals' ability to communicate and the demands posed by society and health care system (Baker, 2006). Lack of specific skills and knowledge associates with health literacy has been shown to negatively affect the people's understanding and use of information provided by health professionals (Rubinelli, Schulz, & Nakamoto, 2009). Effective health care strategies can be used by health care providers to address the serious health care-related problem, including the effective health communication, development of health education materials, professional education, and development of health care community partnerships (Corrarino, 2013). Developing educational materials aimed at individuals with low health literacy, as well as training health care providers on how to effectively communicate with individuals with limited literacy, should be promoted (Ojinnaka et al., 2015). Lupattelli et al. (2014) indicated that clinicians should take time to inquire into their patients' ability to understand health information, perception, and beliefs regarding health literacy.

THEORY AND APPLICATIONS OF HEALTH LITERACY

This section emphasizes the perspectives on health literacy; trends and issues with health literacy; and the challenges and implications of health literacy in global health care.

Perspectives on Health Literacy

Health literacy encompasses several abilities including word recognition, reading comprehension, communication skills, and conceptual knowledge (Macek et al., 2010). The components of literacy include reading, writing, verbal communication, numeracy, and conceptual knowledge (Nielsen-Bohlman, Panzer, & Kindig, 2004). Federman et al. (2009) stated that memory and verbal communication fluency are strongly associated with health literacy. Effective communication among health professions is a necessary component of health care, as no single profession can adequately respond to the complexity of health problems that patients may possess (Barr, 2002).

While health literacy is a complex concept that includes many components, print prose and print document literacy are two essential health literacy skills that help patients understand the written health information (Baker, 2006). Written health information can be found in various areas of health, and includes medical instructions, medication information, disease information, admission forms, informed consent materials, and other examples (Hadden, 2015).

Trends and Issues With Health Literacy

The public health response should include seeking out the new strategies for health systems to promote the public's health literacy, while working with the educational system to better equip the younger generations with the health care-related knowledge and skills necessary to navigate health care (Parker, Wolf, & Kirsch, 2008). In the medical contexts, low health literacy is recognized as a barrier to the health care and treatment adherence, requiring that providers and health care community-based organizations adapt to become more accessible and user-friendly (Liechty, 2011). In the public health contexts, health literacy is recognized as an opportunity for education and empowerment, a capacity-building challenge to enable individuals to exercise more agency in their lives and better utilize the health information and services (Nutbeam, 2000). Public health literacy encompasses skills in evaluating public health information and the ability to apply it in ways that affect small groups and communities rather than individual's health alone (Freedman et al., 2009).

van der Heide et al. (2015) indicated that in chronic care, patients are expected to fulfill an active role in the care of their condition by fulfilling the care tasks in their home environment. This active patient role is considered as important for maintaining the best possible state of health (Coulter, 2012) and reducing the burden on health care (Cramm & Nieboer, 2012). Not all adults with chronic conditions are able to fulfill this role (Kawi, 2014), either because they are not interested or because they lack the knowledge (Swenson et al., 2004). Patients with higher health literacy are found to take a more active role with respect to their care (Fransen, von Wagner, & Essink-Bot, 2012) and to make less use of health care services than those with lower health literacy (Berkman, Sheridan, Donahue, Halpern, & Crotty, 2011).

An evaluation of government websites from a health literacy perspective has recognized the need for the improvement of readability, user-friendly content, and cultural tailoring (Neuhauser, Rothschild, & Rodriguez, 2007). Cultural competency and health literacy are directly related to health care (Ingram, 2012). Cultural competency is an ongoing process in which a health professional continuously strives to achieve the ability to effectively work within the cultural context of the patient and is a process where there is room for improvement (Campinha-Bacote, 2002). Incorporation of cultural competency into health care education for pharmacy, medical, and nursing students has proven to be effective (Durand, Abel, Silva, & Desilets, 2012) and should be continued in order to increase the awareness of future health professionals.

Challenges and Implications of Health Literacy in Global Health Care

Sentell et al. (2014) stated that primary care providers and facilities should consider health literacy at both community and individual levels. Providing advice and guidance to individuals regarding both their mental well-being and physical well-being improves the service users' self-esteem and increases their ability to manage their own health (Lennox, Bain, & Rey-Conde, 2007). Hemingway et al. (2015) indicated that people with a learning disability or serious mental illness significantly experience the complex health inequalities that cannot be only understood from the perspective of their condition. Health and social care staff providing services for people with a learning disability increasingly need the education and training in the physical health interventions (Manthorpe & Martineau, 2010).

Adults with inadequate health literacy skills have less ability to identify their medications (Kripalani et al., 2006). Regarding medication adherence, clinic efforts to improve the patient's access to the affordable medications include helping patients with filling out prescription assistance program paperwork, prescribing generic medications, providing samples, and encouraging effective patient education (Alton, March, Mallary, & Fiandt, 2015). Kairuz et al. (2015) stated that low health literacy has the important consequences for health status, medication adherence, and utilization of health services.

Low health literacy is expected to be associated with medication non-adherence (Ostini & Kairuz, 2014). Lower levels of health literacy are associated with a wide range of health-related outcomes, including higher mortality, worse general health, poor health care access, more hospitalizations, and greater use of emergency care, higher health care costs (Eichler, Wieser, & Brugger, 2009), greater difficulty participating in the shared decision making, and a worse medication adherence, and self-management in general (Easton, Entwistle, & Williams, 2010).

Poor health literacy is associated with poor physical health care and mental health care (Wolf, Gazmararian, & Baker, 2005), less use of flu vaccination (Scott, Gazmararian, Williams, & Baker, 2002), and increased mortality (Sudore et al., 2006). Public mental health efforts are needed to raise the caregiver's mental health literacy (Mendenhall & Frauenholtz, 2015). Mental health literacy is an important factor in the early detection and prompt treatment for the mental, emotional, and behavioral disorders among young people (Olsson & Kennedy, 2010). Poor mental health literacy is associated with the lower rates of help-seeking and service use, as well as societal stigma and discriminatory behavior (Evans-Lacko, Brohan, Mojtabai, & Thornicroft, 2012).

Dunn et al. (2009) indicated that tracking mental health literacy within populations is important as it has been shown to be related to the individual help-seeking as well as the provision of support for those with a mental disorder. Mental health disorders have detrimental effects on well-being, functioning, and development in adolescence (O'Connell, Boat, & Warner, 2009). A recent review of help-seeking for mental disorders considers lack of knowledge regarding mental health as the major obstacle preventing young people from seeking the health-related assistance (Gulliver, Griffiths, & Christensen, 2010).

Regarding mental health literacy, both public stigma and self-stigma have a broad range of negative ramifications for those with mental illness, remarkably social exclusion, and reduced treatment-seeking (Patel et al., 2010). Negative attitudes toward mental illness are commonly endorsed by adolescents (Reavley & Jorm, 2011). High levels of these stigmatizing attitudes among adolescents are associated with the reduced intentions to seek the professional assistance and a lower likelihood of viewing such health-related support as helpful (Yap, Reavley, & Jorm, 2013), and effectively influence the first aid actions toward the distressed peers (Yap & Jorm, 2011).

Numerous studies have emphasized the importance of an adequate level of health literacy to the disease management process (Cho, Lee, Arozullah, & Crittenden, 2008). The inadequate health literacy is a potentially modifiable determinant of poor health outcomes in people with chronic disease (DeWalt, Berkman, Sheridan, Lohr, & Pignone, 2004). Poor reading skills are associated with an increased use of emergency care, a decreased use of preventive services, and poor health maintenance (Easton et al., 2010). The connection between health literacy and health behavior is likely to be intermediated by knowledge and self-efficacy (Osborn, Paasche-Orlow, Bailey, & Wolf, 2011).

Among adults, low health literacy has been associated with poorer health status and poorer health outcomes, such as the lower medical adherence, lower awareness of medical condition, longer hospital stays, and greater use of the emergency department (Nielsen-Bohlman et al., 2004). Children of parents

with lower literacy skills are more likely to have the worse health outcomes (Sanders, Shaw, Guez, Baur, & Rudd, 2009). Low health literacy among parents has been found to be associated with the poor child's health outcomes (DeWalt, Dilling, Rosenthal, & Pignone, 2007).

FUTURE RESEARCH DIRECTIONS

The classification of the extensive literature in the domains of health literacy will provide the potential opportunities for future research. Health literacy is the degree to which individuals have the capacity to obtain, process, and understand the basic health information needed to make appropriate health decisions. Training in health literacy, the use of simple language, and the effective communication is essential for people working in health information and services toward improving the quality of care and reducing the medical error in the health care industry.

The effective communities of practice (CoPs) facilitate the social interactions and encourage the members' willingness to share knowledge and ideas in the workplace (Kasemsap, 2016a). Social media tools are open to anyone, whereas reaching the traditional media often requires a lot of money and a good network of media industry contacts (Kasemsap, 2016b). Total quality management (TQM) practices in quality performance has the potential to improve organizational performance (Kasemsap, 2015). Promoting health literacy in the health care industry through health care-related training program, CoPs, social media, and TQM activities will be the valuable topic for future research direction.

CONCLUSION

This article highlighted the perspectives on health literacy; trends and issues with health literacy; and the challenges and implications of health literacy in global health care. Health literacy is very important in the health care industry. Health literacy concerns the knowledge and skills of patient to meet the complex demands of health care perspectives in the health care industry. Providing effective patient information means acknowledging, understanding, and overcoming barriers to health literacy that physicians, health professionals, and patients might experience. Health literacy affects health behavior and the use of health services, thus affecting health outcomes and health costs in the health care organizations. The benefits of health literacy improvement include improved communication, greater adherence to treatment, greater ability to engage in self-care, improved health status, greater health care efficiency, and cost savings to the health care systems.

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KEY TERMS AND DEFINITIONS

Communication: The two-way process of reaching mutual understanding, in which participant not only exchange information, news, ideas, and feelings, but also create and share meaning.

Health Care: The act of taking the preventative or necessary medical procedures to improve a person's well-being.

Information: The data that is organized for a specific purpose and presented within a context that gives it meaning and relevance.

Knowledge: The understanding of a circumstance gained through experience.

Challenges and Implications of Health Literacy in Global Health Care

Literacy: The ability to read and write.

Patient: A person who is receiving medical care, or who is cared for by a physician or health professional, when necessary.

Skill: The ability acquired through the deliberate, systematic, and sustained effort to smoothly and adaptively execute the complex activities.

Understanding: The knowledge about a situation or about how something works.

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Chapter 16

Cyber Behaviors in Seeking Health Information

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ABSTRACT

This chapter discusses health information seeking (HIS) behavior in general and then collaborative HIS behavior in terms of the current status, the representative researchers and their work, and challenges and future directions. All aspects of collaborative HIS constitute a wide field, and thus, this paper focuses on the HIS social dimension and explores how collaborative HIS could contribute to promoting people's positive health behavior. Afterwards, collaborative information seeking systems are introduced, and future directions and conclusion are discussed.

INTRODUCTION

Warner and Procaccino (2004) defined health information seeking (HIS) as “the process of seeking information needed for personal decision-making related to health and medical issues.” HIS constitutes an important part of people's information seeking behavior. In analyzing a Pew Research Center survey, Kennedy and Funk (2015) reported that about 66% online adults show interests on health and medicine topics, while 37% of online adults claim that “health and medicine” is one of the topics they deem as most interesting. Kennedy and Funk (2015) also noted that research on measuring public understanding about science and technology usually relates science and technology to the health and medical domain.

Consider the following scenario in your ordinary daily life (Yuan & White, 2012). Shown in Figure 1.

In this scenario, people need to 1. Deal with a need of seeking information on headache and brain tumor, which could be a complex task for people with limited medical knowledge. 2. Overcome potential stress caused by knowing about others' stressful events (e.g. deaths). 3. Share information with others who have similar concerns. Each of these three items is explained in further detail below.

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Figure 1.

Scenario: You have been bothered by a headache for a while. Your primary doctor suggested that you take a series of tests, but the results revealed nothing serious. One of your friends died of a brain tumor several years ago. You are worried about your own situation and would like to explore the issue in more detail. Specifically, you want to learn more about the types of headache, the corresponding symptoms, the causes, and the remedies for each type. You want to find websites with useful information and share your findings with others by posting as many Web links as you feel are necessary to adequately cover the topic on a social networking site such as Facebook.

Task: Please find as many Web links as you feel are necessary to adequately cover the topic and you believe can be useful to people in a similar situation. Copy and paste the Web links to the answer sheet. In the answer sheet, please answer each question. Also, create a sequence of Web links, comprising all links you selected or some sub-set, arranged so as to be useful to others.

1. In completing complex tasks, people need guidance to go through the required steps towards completing the tasks, instead of a simple ranked list (Joachims et al., 1997). The information foraging theory developed by Pirolli and Card (1999) provided a theoretical foundation for this situation. This theory indicated that information seekers rely on cues left by previous visitors to identify *patches* of information, and then use them to solve their information problems. Building on the previous findings and the information foraging theory, in a HIS context, Yuan and White (2012) studied the impact of domain knowledge on information seeking behavior and found that expert-generated sequences of web pages are more useful than those of novice users.
2. According to Folkman (1984), stress is “a relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and as endangering his or her well-being.” Studying information behavior models, Wilson (1997) reported that “stress arises in many situations that are considerably less than life-threatening but may endanger one’s “well-being” or, perhaps, self-image, in other ways.” Wilson also argued that stress arose in HIS because “the emotional impact of life-threatening diseases or operations is very obvious.” Current research indicates that people’s awareness and stress level are increased when they are provided information about stressful events associated with other people’s lives (Hampton et al., 2015; Smith and Rose, 2011).
3. How to design a system that can help users learn, understand and use during the information seeking process has been challenging. Twidale et al. (1997) suggested that “a truly user-centred system must acknowledge and support collaborative interactions between all users.” They proved that collaboration can actually help improve users’ learning and understanding of the systems. A well designed system should be able to help people get needed information and share it with those who have the same information need. People who are seeking the same or related information may probably also benefit from collaboration by division of labor.

Yuan & Dumas (2012) reviewed the recent literature in the field of information science and human computer interaction, and proposed Collaborative Information Seeking (CIS) as one of the promising directions. CIS was defined as “a research area about studying how people work in collaborative groups for information seeking, gathering and sharing, and also about how to build systems for supporting such activities.” (Yuan & Dumas, 2012). Collaboration may be an advantageous process for individuals faced with a task, as Grey (1989) identifies it: “a process through which parties who see different aspects of a

problem can constructively explore their differences and search for solutions that go beyond their own limited vision of what is possible". Karunakaran et al. (2013) proposed that collaborative information behavior involved three phases, including problem formulation, collaborative information seeking, and information use.

The field of CIS has been covered in main international conferences such as the ACM International Conference on Information and Knowledge Management (CIKM), the annual European Conference on Information Retrieval (ECIR), the ACM Special Interest Group on Information Retrieval (SIGIR), the ACM Conference on Computer-Supported Cooperative Work and Social Computing (CSCW), the ACM SIGCHI conference on Human Factors in Computing Systems (SIGCHI), the ACM SIGIR Conference on Human Information Interaction and Retrieval (CHIIR), and the Annual Meeting of the Association for Information Science and Technology (ASIST). Relevant journals are Journal of Information Processing and Management (IP&M) and the Journal of the Association for Information Science and Technology (JASIST). A special issue of IEEE Computer in 2014 was also dedicated to CIS. Finally, a related book has been released (Hansen et al., 2015).

This paper discusses HIS behavior in general, and then followed with collaborative HIS behavior in terms of the current status, the representative researchers and their work, challenges and future directions. All aspects of collaborative HIS constitute a wide field and thus, this paper focuses on the HIS social dimension and explores how collaborative HIS could contribute to promoting people's positive health behavior. Afterwards, collaborative information seeking systems are introduced, and future directions and conclusion are discussed.

BACKGROUND

Research has shown that HIS behavior varies depending on user's information needs and situations. People tend to use different strategies and resources to look for various types of information to satisfy their information needs. Johnson and Meischke (1991) reported that when searching about cancer, people tried to find factual information on how to prevent, detect and treat cancer. This study indicated that people may also look for information to help them emotionally cope with their health problems. In a research on HIS behavior of medical experts versus novice users, Yuan & White (2012) found that medical experts utilized different seeking strategies and selected different information resources than those of novice users; and medical experts selected more relevant and useful URLs than novice users. Warner and Procaccino (2004) indicated that people's HIS process may involve multiple channels, including formal ones (e.g. physicians and other health professionals, health organizations, librarians, and media), informal channels (e.g. friends and relatives), and hybrid channels (e.g. formal and informal Internet health resources, and interactive sites including online chat groups, facebook, and twitter).

Researchers have studied factors affecting people's HIS behavior. These factors include technology use and social media (Smith and Rose, 2011), age (Connell and Crawford, 1988; Watkins et al., 2014), gender (Connell and Crawford, 1988; Warner & Procaccino, 2004), motivation and emotion (Kassulke et al., 1993; Wilson, 1997).

Connell and Crawford (1988) proved that women believed they collected more health information than men from different sources. They related this finding to the mother nature of women: they are care-givers and "lay health care providers". This finding was confirmed by research on a national cancer information service (BACUP) by Slevin et al. (1988), in which women contributed 80% use of the service. Connell

and Crawford (1988) also found that age plays a critical role in the amount of health information urban residents received from a variety of sources. Specifically, older men received much fewer information than younger men; and older women received slightly fewer information than younger women. In terms of an exploratory study of online HIS behavior in Hong Kong, Yan (2010) found that digital divide is obvious based on age and education. To address the information need of older adults and to balance the gap between their knowledge on health need and recent technologies, it could be helpful to design appropriate mobile apps for older adults. Watkins et al. (2014) found that it is important to help older adults change their health behavior in a positive way, such as increasing their daily fruit and vegetable intake by supporting their search for useful information with touch devices like Apple iPads. They generated 14 usability heuristics for older adults and iPad apps and further conducted a heuristic evaluation study to identify the existing usability issues of the current iPad apps.

It has been debated whether the use of technologies negatively affected or positively promoted people's health behavior in general. Hampton et al. (2015) examined whether the use of social media, mobile phones and Internet can potentially lead to higher levels of stress. Results indicated that (1) use of Internet and social media does not lead to higher levels of stress. In fact, women who use social media frequently perceived lower levels of stress; (2) in a situation that people are aware of other people suffering stressful events, their own stress increases. This situation is called "cost of caring." In particular, in comparison to men, women are more sensitive to the stressful events of their closest friends and family (Hampton et al., 2015). Social interaction is an important factor to be considered in this "cost of caring" situation. Thus, we must take into account the social dimension in HIS process. Radecki and Jaccard (1995) demonstrated that user perception of a friend's knowledge has an impact on their perception of their own knowledge. The importance of social dimension in HIS behavior has also been addressed by other researchers in the field. Kassulke et al. (1993) noted that emotional barriers, defined as "a construct consisting of questions relating to an inability to make decisions about health and to take advantage of existing health services", could dramatically limit people's access to health services. The information seeking behavior model of Wilson (1997) pointed out the relation between emotion, motivation and effectiveness of information seeking processes, and the critical role of social interaction in people's HIS behavior.

There exist evidence to support the claim that the social dimension of HIS behavior demands more research on collaborative HIS behavior. For example, the cost of caring situation (Smith and Rose, 2011), in which the link between the level of stress to HIS behavior was considered by taking into account the social dimension in HIS. Yuan & White (2012) compared the usefulness and effectiveness of search trails (the sequence of webpages in the order of usefulness) generated by medical experts and novice users, and found that the trails of experts were more effective and useful than those of novice users. In their study, the task scenarios (mentioned in the Introduction) are about finding information for someone they know who was diagnosed with serious illness. The findings indicated that under such a "cost of caring" situation, people tended to go to trusted websites (e.g., www.nih.gov) to search for information, and they rely on opinions of experts. Results also indicated that domain experts used different strategies in selecting resources and structuring search trails than those of novice users. In a study relevant to information visualization and presentation techniques, Yuan et al. (2015) investigated how different information presentation styles affected consumers' preference and decision-making in purchasing product online. They found that consumers prefer some specific presentation styles in their purchase decision making in an opinion summarization task environment. These research efforts created opportunities to integrate or apply research in general HIS to the field of CIS.

In sum, research has been paying attention to the importance of incorporating collaboration in information seeking processes and designing information retrieval systems to satisfy people's health information needs. Next, CIS in health in general will be discussed, followed by system and user interface design of CIS systems.

COLLABORATIVE INFORMATION SEEKING IN HEALTH

Traditionally, information seeking is a solo activity, but with technology evolution, the ways people seek information changed. In many cases, people need to share information and/or learn from others. As Twidale and Nichols (1996) noted, "The use of library resources is often stereotyped as a solitary activity, with hardly any mention in the substantial library science and information retrieval literature of the social aspects of information systems." They believed users would more effectively learn and use information retrieval systems if such systems can support collaboration. Twidale et al. (1997) proposed that "a truly user-centred system must acknowledge and support collaborative interactions between users." Morris (2007) found that introducing support for collaborative search could improve the features of exploratory search, i.e., coverage, confidence, exposure, and productivity. These studies demonstrate the importance of considering collaboration in the information seeking process and system design/development.

Research revealed the importance of CIS in people's daily work. Based on a survey of academic researchers' collaborative information seeking behavior, Spence et al. (2005) found that researchers employed various tools (e.g. e-mail, phone, and video-conferencing) to collaborate during information seeking processes. In this study, researchers felt that they were motivated to collaborate in seeking information mainly because of their lack of expertise. More importantly, results indicated that CIS is generally successful and more useful than seeking information individually. In the health and medical domain, research on CIS process and its affecting factors have become increasingly important. In a study of patent office workers, Hansen and Järvelin (2005) reported that researchers should reframe the hypothesis that information retrieval performance is just individual-based. Within the context of hospital care, Gorman et al. (2000) studied how members of an intensive care team collaborated together to seek and share information. They discussed the importance of putting different information sources together to answer team members' questions. Based on examining the radiological request form in a study of intra-departmental coordination at a hospital, Symon et al. (1996) reported that the form used to schedule radiology examinations can only provide incomplete information. Thus a number of workarounds by the staff were needed in order to identify the needed information. This research concentrated on information needs and information records, as well as helping the medical staff find needed information. Reddy and Dourish (2002) investigated how work rhythms played the role in team members' CIS activities in an intensive care unit. Understanding work rhythms can enable team members know when information is needed. Subsequently, team members could collaborate with each other for needed information at appropriate timing. As Grudin (1994) pointed out, "Many expensive failures in developing and marketing software that is designed to support groups are not due to technical problems. They result from not understanding the unique demands this class of software imposes on developers and users." The above mentioned research made it possible to develop effective CIS systems by understanding such demands.

On the technical side, effort has been made to develop collaborative information systems (CIS) to better support interaction and collaboration during people's information seeking process. Some represen-

tative systems are introduced below. These systems were designed with different focus and approaches, including support for collaboration (1) at the user interface level (Twidale et al., 1995); (2) at the system-mediated level (Pickens et al., 2008); (3) on awareness (Morris & Horvitz, 2007; Shah, 2010); and (4) on communication (Krishnappa, 2005).

In terms of system design for collaboration, Twidale and Nichols (1996) claimed that a visualization of the search process that can be changed and communicated by the real users must be developed. The “Ariadne” system was developed by Twidale et al. (1995) for supporting the collaborative learning of database browsing techniques. In this system, a visualization of the search process was designed to “facilitate complex browsing processes in collaboration.” Such a visualization is composed of thumbnails of screens presented as play cards, representing *command-output* pairs. Each play card can be expanded to display the contents. Pickens et al. (2008) proposed a CIS system designed using algorithmic mediation for synchronous collaborative search and communication activities. In this system, people can search together to solve a common information problem. MUSE, a collaborative information seeking and retrieval prototype (Krishnappa, 2005) was designed with the focus on communication. After evaluating MUSE, Krishnappa suggested that the collaborative features (e.g. the chat function) improved collaboration between teams in the information seeking and retrieval process. In particular, they found that using the chat function enabled users to understand both the search process and the findings.

As one of the important features in the design of CIS systems, awareness has been considered from various perspectives. Schmidt (2002) suggested that awareness should be considered “not as a separate entity, but as someone’s being aware of some particular occurrence.” Morris and Horvitz (2007) developed a system called SearchTogether that incorporates awareness using various methods, including per-user query histories (it shows each team member’s screen name, photo, and queries in the “QueryAwareness” region); and display of page-specific metadata. Query awareness was identified as an important feature in collaborative searching by allowing team members to share their query terms and to learn various query formulation techniques from each other. Coagmento (Shah, 2010) is a system exploring awareness in various interface designs. The major difference between SearchTogether and Coagmento is that the former supports searching and sharing, but the latter also supports organizing and synthesizing information. Regarding awareness, besides query and results awareness, the latter also considered contextual and workspace awareness.

Challenges exist in the design and evaluation of CIS systems, and in health information system research in a broader context. After examining the publication of health information systems research (HISR) in 17 IS journals since 1985, Chiasson and Davidson (2004) claimed that “healthcare poses significant challenges to IS theory, but, by taking on these challenges, HISR researchers can contribute to this multidisciplinary field as well as expand the body of IS knowledge.” Furthermore, they suggested that the health care industry “poses important social challenges and intriguing research possibilities for researchers interested in the development and use of information systems and technologies.” Baeza-Yates & Pino (1997, 2006) took the initiative to formally evaluate Collaborative Information Retrieval proposing metrics to do so. The evaluation of Collaborative Information Retrieval/Seeking is still a challenging endeavor. Soulier et al. (2015) mention this occurs because there is a variety of confounding factors such as the multi-user context, the exploratory aspect of the search through multi-session search activities, the multiplicity of relevance factors, the individual vs. collective value of relevance, and the search interfaces supporting the collaborative interactions. A framework to evaluate CIS has been proposed by Antunes et al. (2012).

FUTURE RESEARCH DIRECTIONS

Collaborative Health Information Seeking is an area facing technical challenges common to CIS in general, as mentioned above, like the evaluation one. However, the area will greatly benefit from advances in social networks, since it presents many characteristics associated to them. It is yet to be investigated how people in the scenario mentioned in the Introduction can get a good result belonging to communities with varying degrees of knowledge on health-related subjects, using advanced systems either controlled by the community members or system-driven, accessed from any place at any time, using crowdsourcing, distributed search strategies and ontologies.

Generally speaking, future directions in CIS include, but not limited to the following aspects.

- It is important to comprehensively understand in which situations people need to collaboratively seek for health information, including topics of interest, level of detail, and stages of information seeking. Based on such understanding, how people interact and collaborate to satisfy their health information needs should be investigated, e.g., the relationship between tasks (including task complexity and task types), supporting techniques, and stages of information processes. Furthermore, CIS systems should be designed to respond to the findings of these investigations, in order to better serve people's HIS.
- With the development and use of mobile devices and applications, mobile health behavior is becoming an important research area. Kassab and Yuan (2012) found that searching for information is the main motivation for people to access the internet resources using mobile devices. Taking into account the importance of HIS (Kennedy and Funk, 2015) and the fact that 44% active users accessing Facebook using mobile devices (Dan, 2011), research on people's collaborative health information seeking using mobile devices would be an important area to grow. Meanwhile, the progress of speech recognition technology in a mobile environment creates opportunities to incorporate a spoken language interface to collaborative information seeking systems for the purpose of improving interaction and collaboration during people's HIS process. Previous findings (Begany, Sa, & Yuan, 2015; Yuan & Sa, 2016) on spoken language interface may be able to apply to the CIS interface.
- Research on how to apply methodologies and findings of health ICT (information and communication technologies) to collaborative information seeking would be a promising direction. Begany, Mirzaei and Yuan (2014) started a mobile diary study project to investigate health information behaviors of ICT users. They aim at understanding the use of ICTs (e.g. computers, laptops, tablets, smartphones, cellphones, and health wearables) for HIS and provide practical implications for the design of future health information systems, applications and devices (including health wearables).
- As Shah (2015) pointed out, it is meaningful to look at the different visualization methods of CIS interfaces, and find out which kind is useful for CIS users. Future research should also address the need of evaluation of CIS systems and setting up standards for such evaluation.

CONCLUSION

Seeking health information is an important component of Cyber behavior. CIS has become part of people's daily lives with the advancement of technologies, devices and tools provided in the digital society. CIS

became increasingly important because of the nature of the task, and the phenomenal change on the way people interact and share information through social networks. The development of technologies and social networks pose challenges and opportunities to researchers and practitioners interested in CIS to deeply explore relevant collaboration activities, and design and implement CIS systems to support such activities. More studies involving a large and diverse group of users should be conducted to find out real information needs in the situation requesting collaboration and sharing. System design and evaluation should take into account the complexity of tasks, the information needs and situations.

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KEY TERMS AND DEFINITIONS

Collaborative Health Information Seeking: People seek for health information collaboratively.

Collaborative Information Seeking System: An information system supporting collaboration and sharing among users during their information seeking processes.

Cost of Caring: People get stressful when they know of stressful events occurred in other people's lives.

Health Information Seeking (HIS) Behavior: Human information behavior related to seeking for health information to satisfy human information needs.

Health information Systems Research (HISR): The multidisciplinary research relevant to the design, construction and use of information systems and technologies in a healthcare setting.

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Chapter 17

Information Systems and Technology Projects in Healthcare Organizations

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ABSTRACT

Healthcare organizations must improve their business practices and internal procedures in order to meet the increasing demands of health professionals and the public in general for better information. Hospitals have adopted a patient-centered care approach and have invested massively in information systems and technology (IS/IT), in the hope that these investments will improve medical care and that they will meet patient demands. From the point of view of public service, the focus of healthcare system is the patient, and therefore any intervention should be based on their needs and expectations. It has become more and more important that investments in information systems and technology (IS/IT) support not only short-term objectives, but also long-term benefits, in order to provide a sustainable service for organizations, professionals, and users. The main objective of this research is to study how organizational maturity, enhanced by IS/IT investments and project management best practices, leads to successful projects in healthcare organizations.

INTRODUCTION

The challenges facing healthcare organizations require more comprehensive and integrated solutions and efficient resource management as a means of eliminating inefficiencies and of achieving promised benefits. In academic literature, information systems and technology (IS/IT) have been recognized as being an organizational capability that can lead to competitive advantage and better performance (Bharadwaj 2000; Kohli & Devaraj 2003). Organizations recognize project management as being a fundamental tool for the development of initiatives which lead to the implementation of the organizational strategies

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(Crawford, 2005; Hodgson, 2002). One way that the effectiveness of IS/IT project management capability has been assessed is through the use of maturity models, with the underlying assumption that higher levels of project management maturity imply a higher effectiveness of project management capability (Kwak & Ibbs 2002; Sonnekus & Labuschagne, 2004).

Our research focuses on the combination of the project management and maturity models approaches as a means of strengthening the final results of IS/IT projects in the healthcare sector. It is the authors' belief that this combination of approaches enhances not only the success of projects, but also the realization of the expected benefits. It is also important to emphasize that, by taking advantage of the specific features of each of these approaches, their structure will certainly increase the effectiveness of IS/IT projects in the health sector, by enhancing both the confidence of sponsors and investors, and also the achievement of the promise benefits.

The maturity models approach provides a framework which helps organizations increase their capability to deliver projects on schedule, within budget, and according to the desired technical performance (Levin & Skulmoski, 2000). Projects are temporary achievements that are used to solve various types of tasks of variable size, and are applicable in a very broad range of business sectors (Maylor, 2001). Project management coordinates skills and organizational knowledge and follows the progress of a set of pre-established activities in order to achieve objectives (Kronbichel, 2009). Many organizations fail to review whether the planned benefits of IS/IT projects have been achieved, or not, as they do not possess sufficient resources to undertake such a benefit review, and, moreover, they are constantly under pressure to deliver other projects (Bennington & Baccarini, 2004). Benefits management identifies goals and benefits by combining organizational changes and investments in IS/IT, and also by showing the way to achieve them (Gomes, Romão & Caldeira, 2013; Ward & Daniel, 2006).

BACKGROUND

Literature Review

Whilst there is general agreement that IS/IT does indeed contribute to adding business value, there is uncertainty as to how these contributions were really obtained (Melville, Kraemer & Gurbaxani, 2004; Devaraj & Kholi, 2003). Although many studies have focused on the consequences of IS/IT investments, fewer studies have examined factors which impact the capability of IS/IT (Devaraj & Kholi, 2003).

Project Management Institute (PMI) (2012) define project as a limited effort in time, which is undertaken to create a product, service or a result. The essence of project management is to support the implementation of these temporal initiatives under the framework of an organization's competitive strategy, in order to successfully deliver a particular outcome (Milosevic, 2003; Senhar & Dvir, 2007). Project management is thus a set of management activities which is required to ensure that projects which are defined, planned and monitored, go on to achieve agreed objectives and benefits (Devaraj & Kohli, 2003). Kerzner (2009) highlights the importance of project management in the planning and control of organizations' resources, helping to achieve, not only short-term goals, but also broader, temporal objectives.

It appears that determining whether a project is a success, or not, is far more complex. Success is perceived differently by the different stakeholders involved in the projects (Freeman & Beale, 1992). The differences in success criteria definition should reflect the different interests and points of view, which leads us to conclude that project success is a multidimensional criterion (Freeman & Beale, 1992; Pinto

& Mantel, 1990). Success criteria known as the 'iron triangle' have been criticized for their exclusive focus on the project management process, to the detriment of including the vision and goals of the different stakeholders (Baccarini, 1999; Bannerman, 2008).

This classic approach remains the most widely used measure of project success and its main value is in offering a simple, direct measure of performance of the project, but it neglects whether the deliverables fulfilled the objectives of the project (Bannerman, 2008).

The improvement in the success of projects results from increased maturity and organizational competence (Sergeant et al., 2010). Higher levels of maturity will, in most cases, lead to improved project outcomes (Nieto-Rodrigues & Evrard, 2004). Projects which have multiple stakeholders, with different perspectives about the purpose of the project, usually have different expectations as to what the project should achieve (Lim & Mohamed, 1999). Since the success of a project depends on the perceptions of a large number of stakeholders, "*absolute success*" probably never exists in project management, but only "*perceived success*" (Baker, Murphy & Fisher, 1988). In the academic literature, we found examples of projects that have successfully completed the criteria of the "iron triangle", but resulted in disappointing business experiences (Shenhar et al., 2005). On the other hand, initiatives that did not meet the constraints of cost and time later proved to be successful (Pinto & Slevin, 1988). The understanding of the concept of project success has evolved over recent decades, and a gradual understanding is now emerging that project success requires a broader and more comprehensive definition.

Aaltonen et al. (2008), state that the key issue in project management is managing the relationship between the project and its stakeholders. There is little evidence to suggest that process capability improvement result in improved project success, although a few studies are promising in this respect (Mullaly, 2006; Lee & Anderson, 2006).

Maturity models have become an important evaluation tool for measuring the internal and external capabilities of organizations. Maturity models describe the development of an entity over time (Klimko, 2001) and they represent a structured collection of elements which highlight the characteristics of effective processes at different stages of development (Pullen, 2007). The maturity models approach provides a theoretical framework for improving the business outcome of an organization, for assessing their strengths and weaknesses, and also for allowing comparisons with industry best practices and also by benchmarking with similar organizations (Ibbs & Kwak, 2000). Several studies focus on the recognition of the benefits of investment in project management skills in organizations and others have discussed the issue of the correlation between level of maturity and the performance of projects (Ibbs & Kwak, 2000; Ibbs & Reginato, 2002; Mullaly, 2006). In an IS/IT discipline, maturity is considered to be a measure for evaluating an organization's capabilities (Rosemann & Bruin, 2005). Measuring the maturity of organizations is a difficult and somewhat subjective task, as such an audit process focuses mainly on individuals' tasks (Andersen & Jessen, 2003). Working with different types of projects within an organization requires standard models, in order to deliver successful future projects repeatedly and as a means of improving the quality of future projects and of gaining knowledge and learning from past successes and mistakes. The assessment of maturity typically involves variations along five developmental stages (Jugdev & Thomas, 2002).

These assessment procedures help organizations to understand where they have been, where they are, and what processes they need to implement, in order to continue their implementation of management methodologies. The underlying assumption in the maturity models is that there is a relationship between higher levels of maturity and improved organizational performance (Ibbs & Kwak, 2000; Lee & Anderson, 2006) and that this enhances project success.

The Healthcare Sector

Today, healthcare organizations are increasingly focusing on the need for investment in IS/IT, with the goal of achieving the minimum level of benefits that these projects can attain. The study of the success or failure of these initiatives has become vitally important for the performance of these organizations (Rahimi & Vimarlund, 2007). Since the 1990's, the health sector has sought to improve its effectiveness and efficiency by adopting IS/IT to increase quality levels (Raghupathi & Tan, 1999). The use of IS/IT in health sector is recognized as being a major factor which has improved clinical practices and supportive care (McDonald et al., 1998). The use of these systems provides an important support for specialized services and it increases the efficiency, quality and safety of patient care, and also reduces medical errors (Low & Chen, 2012). It is not always investments in IS/IT that result in efficiency and effectiveness gains, and thus it becomes essential to evaluate the factors that limit performance, and to identify opportunities for enhancing their use.

IS/IT has the potential to dramatically change the way individuals or society see the healthcare sector, and also to provide tremendous opportunities for supporting professionals, and for improving effectiveness and efficiency in the health sector (Ammenwerth et al., 2006).

There is a growing consensus that organizational factors are far more critical for the successful implementation of IS/IT, than technical considerations (Markus et al., 2000). Achieving successful change is much easier if all stakeholders are committed, and the earlier this commitment is achieved, the smoother is the path to a successful outcome (Bradley, 2006).

We live in times where healthcare providers generate significant amounts of personal data about patients and the major obstacle to the management of this increasing volume of information is the difficulty, or inability, of sharing information across systems and between organizations (Grimson et al., 2000). Medical information needed for clinical decision making has increased dramatically, however the accessibility of health data is still poor, resulting in inappropriate decisions and sometimes in medical errors (Tierney, 2001).

The use of informatics tools has been developed to increase the accessibility and management of medical information (Bleich, Beckley & Horowitz, 1985), with the aim of supporting medical decision, of increasing the coordination between different health care providers, and of promoting the use of guidelines, thereby improving the global quality of care (Pringle, 1988; Shiffmann et al., 1999). However, in addition to providing new capabilities, new technologies also impact the technical, social, organizational, economic, cultural, and political dimensions of work in new and different ways (Anderson & Aydin, 1994).

Observations of new technology implementations have shown that a change in technology alters roles, strategies, and paths to failure (Sarter, Woods & Billings, 1997). In recognizing this, the Institute of Medicine of the USA recommends examining new technologies for avoiding threats to safety and redesigning them to prevent undesirable accidents (Kohn, Corrigan & Donaldson, 2000).

There is a widespread feeling that a significant proportion of initiatives in IS/IT healthcare have failed (Heeks & Davies, 1999). Studies have identified high failure rates in IS/IT projects in various sectors, including that of healthcare, particularly in hospitals (Kaplan & Harris-Salamone, 2009; Wears & Berg, 2005). The results of the implementation of IS/IT projects in healthcare have revealed a waste of financial resources in acquiring large sized systems, which are totally ineffective (Heeks, 2006). In various aspects, these implementations are different from other projects, in other industries. The key main differences were related to the environment, the diversity of systems and the devices that need to

work, together with the challenge of integration and interoperability which is required to meet the expectations of different stakeholder groups regarding that which constitutes project success (Abouzghara, 2011). Healthcare projects are a complex undertaking, which depend largely on the quality of existing information (Bose, 2003).

Proper training is a major determinant for success in the adoption of IS/IT by health professionals, and it has a great influence on the integration of technologies in clinical practice (Allen et al., 2000). The effectiveness of interventions aimed at the integration of IS/IT applications in the practices of health professionals tends to be influenced by several factors, which are related to individuals, professional groups, organizational and contextual characteristics, and the nature of the intervention per se (Grol et al., 2007; Aarts et al., 2004). One of the most critical factors recognized by the academic literature is resistance to change by healthcare professionals, particularly amongst doctors (Lapointe & Rivard, 2006; Phansalker et al., 2008).

The complexity of systems, together with organizational diversity and the volume of investment required, as well as failure in adopting IS/IT, is all largely justified by the way that IS/IT is implemented, and by the need to identify best practices and to act on a number of critical factors, in order to reduce the chance of failure (Olson & Zhao, 2007). Cooke-Davis & Arzymanow (2003) identify organizational culture as exerting a positive influence on the development of superior project management practices.

FUTURE RESEARCH DIRECTIONS

Healthcare organizations require interdisciplinary cooperation and coordination. It needs to be highlighted that insufficient communication and missing information are among the major issues that have contributed to unintentional injury caused by medical mismanagement (Lenz & Reichert, 2007).

IS/IT processes have the potential to significantly reduce the rate of these adverse events by providing relevant information in real time to all who need it (McDonald et al., 1984). An important challenge for the future is to seek for a *real clinical integration* of systems. Clinical integration between providers and hospitals has historically been a goal which is continually sought, but rarely achieved. It will become crucial that the design of future applications be integrated easier into existing systems, through open communication interface (Geissbuhler et al., 2001).

The *intersection of healthcare and social media* represents another promising field of IS/IT research. Anderson and Agarwal (2010) demonstrate that individuals are more willing to share personal healthcare information if they think that it could help others. Social media platforms could provide aggregation through the mechanisms of information filtering and knowledge synthesis (Kane et al., 2009).

Evidence-based medicine (EBM) is a form of medicine which aims to optimize decision-making by emphasizing the use of evidence from well-designed and well-conducted research. EBM produces quantitative research, especially from randomized controlled trials (RCTs). A randomized controlled trial (Chalmers et al., 1981) is a type of scientific experiment whereby those studied are randomly allocated one or other of the different treatments under study. EBM has been gaining increased attention among researchers (Carey, 2006) as a tool for addressing concerns about healthcare costs and quality.

Another emerging topic for knowledge discovery arises from the use of digital technology to enable new kinds of *mathematical healthcare modelling and simulations* (Lumpkin, 2007). Simulation models are distinguished from other types of conceptual models by the fact that they include simulated objects,

such as people, which correspond to real objects, one-to-one. Development of such a model requires creating a population of simulated individuals who all have experienced important events which occur in real life with real people, and who respond to interventions in the same way as real people (Schlessinger & Eddy, 2002).

Another research trend concerns the use of the combined knowledge about a person for predicting treatment response and this can thereby improve that person's health (Redekop & Mladsi, 2013). This concept of *personalized medicine* allows for an earlier and more precise diagnosis, cheaper and more effective treatments, and the minimization of side effects of treatment (Glaser et al. 2008). Personalized medicine uses genomic medicine to take advantage of a molecular understanding of disease, in order to optimize preventive health care strategies and drug therapies whilst people are still well, or at the earliest stages of disease (Ginsburg & Willard, 2009). Another term which has emerged in recent years is *personalized healthcare*, which extends the previous concept to address questions related to treatment monitoring and disease surveillance.

CONCLUSION

Although project management emerges as being one of the main approaches used by organizations, there is no strong evidence in the literature of the success of the implementation of any of the available approaches in the health sector. This study attempts to show that organizational maturity contributes to the success of a project, through the systematic application of project management best practices.

The combination of the project management and the organizational process maturity approaches provides a more efficient and useful framework for supporting decision-making. The approach proposed in this study tries to prove that it is easier to implement best practices in project management in organizations which have higher levels of organizational maturity, and that the correct combination between investments in IS/IT and management practices can also be a positive influence, leading to successful projects.

We have a strong conviction that higher levels of organizational maturity have a positive influence on the success of projects implemented by organizations particularly in cases where good project management practices are in evidence.

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KEY TERMS AND DEFINITIONS

Benefits Management: Benefits Management is an integral part of managing change and aims to increase the success of the measurable and significant benefits of investments in IS/IT for an organization.

Critical Success Factors: Critical success factors are elements which are vital for a project to be successful.

Maturity Models: A theoretical framework that helps organizations to increase their ability to deliver projects by assessing strengths and weaknesses, good sector practices and benchmarking with similar organizations.

Project Management: Project management is the application of processes, methods, knowledge, skills and experience to achieve the project objectives.

Project Management Success: Project management success is measured mostly against cost, time and quality.

Project Success: Project success is measured against the overall objectives of the project.

Project Success Criteria: Project success criteria are the standards by which the project will be judged at completion.

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Chapter 18

Peer-to-Peer Health-Related Online Support Groups

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ABSTRACT

In recent years, the internet has provided new opportunities for individuals living with health-related problems to communicate with each other via online support groups. These groups offer many unique advantages, such as convenience, anonymity, and access to a diverse range of group members. However, there are potential disadvantages to their use, for example, misleading information. Within such groups, patients may talk about a range of issues and provide support to one another, particularly informational and emotional support. Through self-disclosure and empathic communication, members may feel able to share personal stories as well as help others. While robust evidence for their effectiveness is lacking, there is much qualitative and cross-sectional evidence suggesting that participation in online support groups may be beneficial. However, there is an urgent need for randomized controlled trials of pure peer-to-peer online support interventions across both physical and mental health conditions.

INTRODUCTION

In recent years more and more individuals living with long-term conditions are turning to the internet for information, advice and support. In particular, there has been a rapid expansion of the number of online support groups (also known as ‘online support communities’) and this rise in popularity is arguably related to many of the unique characteristics inherent within this form of communication. Researchers have begun to examine the nature of online support groups (e.g., Wright & Bell, 2003), their role in the lives of those living with illness (e.g., Mo & Coulson, 2010) as well as the activities which are taking place online (e.g., Malik & Coulson, 2010). There is much qualitative and cross-sectional evidence (e.g., Coulson, 2005) describing their impact on individuals but as yet there are few well-designed studies which have clearly tested the effects of peer to peer online communication and support. This entry will consider the current state of knowledge with regards key aspects of this growing online phenomenon.

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BACKGROUND

Unique Characteristics of Online Support Communities

Online support groups present several unique communication characteristics, which can include anonymity, asynchronous text-based communication and the ability to transcend geographical and temporal barriers (White & Dorman, 2001; Joinson, 2003; Coulson & Knibb, 2007). These unique characteristics also give rise to a number of unique advantages and disadvantages for individuals choosing to seek support through the medium of online groups.

Potential Advantages

A number of studies (e.g., Ferguson, 1996; Buchanan & Coulson, 2007) have documented the potential advantages of online support groups over more traditional face-to-face sources of support (e.g., face-to-face support groups).

Access Support at Any Time

In contrast to a face-to-face group where members typically meet once a week or less frequently, online groups are available 24 hours a day, 7 days a week (Malik & Coulson, 2008) thereby providing opportunities for peer support at any time of the day or night. As a consequence, this introduces considerable flexibility for individuals in terms of when they wish to access support and this flexibility has been shown to be very helpful for those who have work, family or educational commitments (Coulson & Knibb, 2007).

Asynchronous Communication

The asynchronous nature of many online support groups means that there is no pressure or commitment to engage in real-time communication with other members (Coulson & Knibb, 2007). Instead, members can take their time to read messages and reflect upon their feelings while considering if and how to reply, allowing members to control their level of involvement in a way that is not possible with traditional face-to-face communication (Malik & Coulson, 2008). Indeed, it has been argued that asynchronous communication reduces the pressure associated with real-time communication thereby allowing participants time to carefully construct their messages before contributing to the group (Joinson, 2003).

Anonymity

Online support groups also offer a degree of anonymity that would not be possible in face-to-face communication. This may encourage certain individuals, particularly those patients who feel stigmatised because of their condition, to openly discuss their experiences without fear of a negative reaction.

Group Composition

Since participation in online support groups is not restricted by geographical, physical or spatial barriers, members can potentially access a larger and more heterogeneous mix of people with ease (White

& Dorman, 2001). This is likely to be of particular benefit to patients suffering from chronic health conditions, as these individuals, may experience difficulties attending a regular face-to-face meeting due to limitations arising from their condition such as problems with mobility or treatment side effects. The Internet thus offers a novel opportunity for individuals to communicate with similar others in the comfort of their own home.

The ability to reach people from geographically diverse locations also increases the chances of finding others with similar experiences (White & Dorman, 2001). This is particularly helpful for individuals with rare conditions who may be unable to locate people with the same problem in their geographical area. At the same time, due to their diversity, online support groups are advantageous because they can offer participants a wide variety of different perspectives, viewpoints and experiences on issues related to their condition (Wright, 1999; Wright, 2000). Walther and Boyd (2002) argue that for this reason online communication provides numerous opportunities for people with health concerns to seek support from 'weak tie' relationships. 'Weak ties' refer to relationships between people who might communicate on a regular basis but are not necessarily close. Prior to the advent of the Internet, weak tie networks typically incorporated neighbours, service providers or individuals known through other associations. However, the recent growth in the popularity of the Internet has led to a larger and more heterogeneous pool of individuals that could potentially develop into weak tie networks for people with health concerns.

Granovetter (1982) proposed that since weak ties provide access to a large pool of individuals with a range of different characteristics they are extremely useful sources of information. In addition, since weak tie relationships tend to exist outside of traditional social networks they provide a useful alternative for the discussion of taboo topics, which people may feel reluctant or uncomfortable discussing with their close relations. Online support groups, therefore, can potentially increase the chances of individuals forming weak tie relationships that offer access to diverse sources of information and advice that would not be available from close tie relationships. Furthermore, the absence of visual cues in the online environment and the opportunity to remain entirely anonymous may further facilitate the discussion of taboo or highly sensitive topics. Indeed, a frequently mentioned advantage of health-related online support groups is the perception that members attach less stigma to one's illness, thus removing the fear of being judged negatively (Walther & Boyd, 2001; Wright, 2000).

Adjunct Support

Online support groups can be a useful adjunct to support that is received through face-to-face support groups and other traditional sources (White & Dorman, 2001). There might be occasions when an individual is too ill to attend a face-to-face group, making online support particularly beneficial. Likewise, some individuals might have higher support needs than can be fulfilled by face-to-face groups, and online groups provide a way for them to receive additional support between face-to-face meetings.

Potential Disadvantages

Despite the many potential advantages of peer to peer online support groups, there exists a number of disadvantages (Finfgeld, 2000; White & Dorman, 2001), some of which appear to arise as a result of the computer-mediated nature of the communication.

Absence of Social Cues and Lack of Face-to-Face Contact

Within online support groups social cues including facial expressions, tone of voice or body language are not apparent and this can sometimes present unique challenges to group members (Coulson & Knibb, 2007). As a consequence, it is not uncommon for misunderstandings to arise when members misinterpret what has been posted by others, or feelings of awkwardness when members make incorrect assumptions about other members (Attard & Coulson, 2012). In order to compensate for these limitations, group members may employ emoticons or excessive punctuation in their communications (van Uden-Kraan, Drossaert, Taal, Lebrun et al., 2008a). In addition, the lack of physical proximity may potentially limit the extent to which a meaningful face-to-face relationship can develop between members as well as precluding the ability to offer a hug or touch someone (Coulson, 2013).

Anonymity

The anonymity inherent to the Internet could lead to deindividuation. Deindividuation is described by Festinger, Pepitone, and Newcomb (1952) as a state of lowered self-awareness where a person temporarily loses their individual sense of identity and becomes immersed into the identity of a larger group. Some authors argue that due to this deindividuation Internet behaviour will inevitably be characterised by increased instances of disinhibited communication such as aggressive and hostile exchanges often referred to as flaming.

Incorrect or Misleading Advice

In a number of studies, concerns have been identified by online support group members around the challenges of assessing the credibility and trustworthiness of information exchanged (Sillence, 2010). For example, it might be the case that some of the messages posted to an online support group may not in fact be from genuine patients living with a particular long-term condition. For example, it may be that an individual makes a series of postings to an online support group in order to advocate a specific treatment. In such a scenario, it may be that this individual is actually an employee of a drug company or some other organization who has a vested interest in the particular product being promoted (Coulson, 2013).

When an individual member within an online support group posts a message offering information or advice, it is not uncommon to see other members also replying to share their experiences and these responses may be helpful to the individual in terms of determining the credibility of the original information or advice. It has been argued that incorrect or misleading information may be more of a problem within online support groups with low levels of activity (Hwang et al., 2007), but broadly speaking it appears that the actual number of messages which contain incorrect or misleading information is low (Esquivel, Meric-Bernstam & Bernstam, 2006).

Delayed Feedback

Another disadvantage associated with online support groups is delayed feedback (Wright, 2002). Although participants can log in and post messages at virtually any time of day, in comparison to face-to-face groups there may be a considerable time lag before the individual receives a response from other participants.

Individual Differences in Online Support Group Use

Socio-Demographic and Psychosocial Characteristics

Empirical data from Internet user surveys suggests that individuals who seek health-related information and support online tend to be white, female, well-educated, of a younger age and in employment (Eysenbach, 2003; Im et al., 2007). There is some evidence to indicate that these factors are also associated with participation in online support groups (Owen et al., 2010). For example, in a recent survey of cancer sufferers, Im et al. (2007) found that patients accessing online groups were typically middle-aged, well-educated, female and middle class. Similarly, Hoybye et al. (2010) found that cancer patients participating in online support groups belonged to higher socioeconomic groups compared to non-participants. Another recent survey of Internet use among individuals with HIV/AIDS, also revealed that frequent users of online support groups were more likely to be female, younger and single when compared to infrequent or non-users of online support groups (Mo & Coulson, 2010).

The association between patient's demographic characteristics and health-related Internet use may reflect barriers to Internet access among certain groups of people. For instance, individuals who are educated and in employment, may be more likely to have easier access to Internet resources compared to those who are unemployed with a lower educational record of attainment. Shaw et al. (2006) examined whether demographic variables would predict participation in online support communities when barriers to Internet access were removed. A group of breast cancer patients were therefore provided with free Internet services, computer hardware and IT training. As hypothesised, the study found that demographic differences in participation were diminished. Nevertheless, the factors that predicted higher levels of participation were found to include having fewer breast cancer-related worries, a positive relationship with doctors and higher levels of social/family well-being. This implies that a range of psychosocial characteristics may influence participation in online groups.

However, there is comparatively little research specifically examining the relationship between patient's psychological characteristics and health-related Internet use, particularly the use of online support groups. Furthermore, the findings from the few studies (e.g., Fogel et al., 2002) that have addressed psychosocial factors are mixed. While some studies suggest that individuals turning to online groups report high levels of social support from offline relationships (Fogel et al., 2002), others have found that individuals seek online support when offline support is perceived as inadequate. For example, in a study comparing women with breast cancer who use the Internet for support and women with breast cancer who do not, Winefield et al. (2003) found that women using the Internet were significantly less satisfied with support from their family and were more psychologically distressed than non-users. Conversely, an Internet use survey conducted by Ybarra & Suman (2006) reported that those individuals who did not use the Internet for health-related purposes were more likely to report being unhappy or lonely. However, recent surveys by van Uden-Kraan et al. (2009) and Hoybye et al. (2010) found no relationship between psychological well-being and health-related Internet use among arthritis, cancer and fibromyalgia sufferers.

Since most studies employ cross-sectional designs it is difficult to determine causality. The exact nature of the relationship between social support, distress and participation in online support groups is therefore unclear.

Level of Interaction

To date, little is known about the reasons why some members become active contributors of online groups, while other members are less involved. There are however several ideas which have emerged in the literature. For example, Kollock (1999) proposes three key motives to explain why some individuals contribute to an online group. Firstly, anticipated reciprocity, where an individual is motivated to offer help and support in the expectation that they will also receive the same support and information when required. Secondly, for a sense of efficacy, where members will contribute useful information or support to the other members in the belief that they are having a valuable impact on the group, which may help to promote their own self-efficacy. Thirdly, to gain increased recognition and help build up a reputation within the online group.

Another approach for understanding participation in online group is through the 'uses and gratification' model (Blumler & Katz, 1974). The basic premise of the model is that people are motivated to use mass communication in order to gratify a range of needs or goals. Thus, when considering level of participation in online groups, the theory would suggest that members are motivated to be passive or active participants depending on which activity offers the best means of meeting their needs. For example, an individual who wishes to obtain information whilst also maintaining anonymity, may find gratification in 'lurking' (Nonnecke & Preece, 2000). In comparison, individuals who wish to connect with other participants and develop new friendships will be motivated to take a more active role in the online group. Although the theory offers a useful way for examining participation in online groups, it has not yet been extensively applied to understand participation.

Posting Messages or 'Lurking'

Individuals who access online groups but do not participate are referred to as 'lurkers'. Lurking describes the act of 'reading messages posted by others on electronic spaces, without also posting one's own messages or in any way signalling one's vicarious observation' (Walther & Boyd, 2002, p168). It is estimated that 'lurkers' make up the largest group of individuals using online groups (Burnett, 2000).

Despite the prevalence of lurking, little is known about the online experiences of 'lurkers' and their motives for visiting online groups. This is in part due to the difficulty of identifying and accessing the views of individuals who choose to remain entirely anonymous. In an attempt to redress this, Preece, Nonnecke and Andrews (2004) surveyed 219 'lurkers' from 375 MSN bulletin boards to explore their reasons for not posting. The most frequently selected reason for lurking was 'just reading/browsing is enough' followed by 'still learning about the group', 'shy about posting', 'nothing to offer' and 'no requirement to post.' It was observed that many individuals lurked while familiarising themselves with the dynamics and norms of the group. Others commented that by not posting their views they felt they were being helpful (e.g., not pretending to be an expert).

Attention has also focussed on investigating differences between the attitudes of 'lurkers' and posters. Research findings indicate that posters perceive a greater sense of group membership in comparison to 'lurkers', who appear to be less positive about the benefits of group participation (Nonnecke, Andrews & Preece, 2006; Okleshen & Grossbart, 1998; Preece, Nonnecke & Andrews, 2004). It has been suggested that this might arise from the fact that members who do not actively participate in online discussions will often feel like distant outsiders who are simply observing a separate group of people interacting.

Some authors (e.g., Walther & Boyd, 2002) argue that individuals reading messages within health-related support groups are, on the contrary, likely to feel empathy with the stories they read due to their shared experiences. As a result, these 'lurkers' may perceive a stronger sense of membership and connection to the group (Preece, 1999). Walther and Boyd (2002) propose that patients lurking in online support groups will also derive similar benefits to that of active participants. They argue that since patients can obtain information, support and validation of their feelings of stigma through reading other people's messages and without having to contribute anything themselves, lurking may be as beneficial as active participation. Lurking can also function as a helpful way for patients to find answers to frequently asked questions without overloading the group with a repetition of earlier queries.

However, there remains a scarcity of empirical work exploring the phenomenon of lurking in the context of health-related support groups. Recently, van Uden-Kraan et al. (2008b) investigated self-reported differences in the benefits associated with participation between 'lurkers' and posters in various online patient support groups. Results indicated that both 'lurkers' and posters gained a range of benefits from the online groups including feeling better informed, enhanced self-esteem, feeling more confident with physicians, and improved acceptance of the disease. Thus, offering support for Walther and Boyd's argument. However, in line with findings from other types of online groups, the study found that 'lurkers' were significantly less satisfied with the online group compared to posters and had poorer social and mental well-being. This suggests that although individuals can benefit from reading messages, individuals who lurk may be less satisfied with their online experiences than active participants and have poorer psychological well-being.

The Nature of Online Communication

What Do Members of Online Support Groups Discuss?

Research which has considered what members talk about within online support groups has provided either a broad overview of discussion areas, such as symptoms, diagnoses, treatments and medications (Finn, 1999; Haker, Laubler & Rossler, 2005; Mursch & Behnke-Mursch, 2003; Perron, 2002; van Uden-Kraan et al., 2008a) or a richer insight into the specific health-related issues. A number of broad, recurring themes emerge from these studies. First, they demonstrate the importance of being able to communicate with others who can understand them and have been through similar experiences. Second, they demonstrate how people benefit from having a safe environment where they can vent and express their true feelings without the risk of hurting others or damaging social relationships. Third, they highlight the frustrations caused by misconceptions about what each illness is and how it affects sufferers. Fourth, the information, social support and advice shared within these groups can have an important impact on members by helping them to feel less alone and develop more effective coping strategies to overcome the issues unique to each illness.

Understanding the Therapeutic Processes Involved in Online Support Group Communication

There is a growing body of research which has attempted to understand the potential therapeutic processes at play within online support groups. These include: self-help mechanisms, social support and self-disclosure.

1. **Self-Help Mechanisms:** A small number of research studies have shown that online support groups can provide many of the therapeutic exchanges that occur in face-to-face self-help and support groups (Finn & Lavitt, 1994; Finn, 1999; Haker et al., 2005; Perron, 2002; Salem, Bogat, & Reid, 1997; Schielein, Schmid, Dobmeier, & Spiesl, 2008; van Uden-kraan et al., 2008a; Weinberg, Uken, Schmale, & Adamek, 1995). For example, Weinberg et al. (1995) investigated the presence of therapeutic factors in an online support group for women with breast cancer. The study was guided by a range of factors which are thought to influence the process of change and recovery among patients in group therapy – universality, altruism, instillation of hope, imparting information, catharsis, group cohesiveness, interpersonal learning, imitative behaviour, developing social skills, existential factors and the corrective recapitulation of the primary family experience. Results revealed that women perceived the instillation of hope, group cohesion, and universality to be the most prevalent therapeutic factors. These factors were also moderately correlated with the perceived helpfulness of the group. Perron (2002) coined the term ‘self-help mechanisms’ to describe the parts of messages that facilitate the development of supportive or helping relationships among members of a group. Their analysis of communication in an online community for caregivers of people with a mental illness found that similar to face-to-face groups, members of the online group employed a range of self-help mechanisms. Specifically, self-disclosure and the provision of information or advice were found to be a central focus of many of the messages posted to the online group. Similar findings have been observed in studies examining self-help mechanisms within other illness support groups, for example, infertility (Malik & Coulson, 2010).
2. **Social Support:** A larger number of studies (e.g., Braithwaite et al., 1999; Coulson, Buchanan & Aubeeluck, 2007) have focussed on examining the type and nature of social support exchanged within online groups. Some of these studies employed content analyses as a means of quantifying the prominence of different categories of social support (e.g., Coulson, Buchanan, & Aubeeluck, 2007). One study analysed messages posted to an online disability support group for the presence of 5 categories of social support – informational, emotional, network, esteem and tangible aid (Braithwaite et al., 1999). Of the 5 categories it was observed that messages exchanging emotional support, followed by informational support were most prominent, whilst tangible assistance was the least common category. The primary focus of these support messages appeared to relate to life functions affected by disability. For instance, informational support typically involved sharing advice and suggestions to help members tend to their self-care and house-keeping needs, while network support aimed to reduce limitations on mobility and access to others. In an analysis of messages posted to an Irritable Bowel Syndrome bulletin board, Coulson (2005) also noted that tangible assistance was the least visible category of social support, while the exchange of information concerned with symptom interpretation, illness management and interactions with health-care providers were the most common forms of support. Overall, research suggests that informational and emotional support appear to be the most prominent exchanges in health-related online support groups. Alongside the prevalence of emotional and informational support, a number of authors also identify features of online support that appear to be relatively unique to this format. For example, humor, personal narratives/journals and poetry have all been found to play an important role in supportive exchanges taking place in various online groups (Braithwaite et al., 1999; Hwang et al., 2010; White & Dorman, 2001). Indeed, Braithwaite et al. (1999) found that many members of a disability community joked about their own problems as a method of conveying empathy and in some instances used poetry to express emotional support.

3. **Self-Disclosure:** Along the development of strong interpersonal relationships, evidence suggests that Internet behaviour is also characterised by high levels of self-disclosure. Self-disclosure can be defined as the act of revealing personal information to others. Computer-mediated discussions are thought to contain higher levels of disclosure compared to face-to-face discussions. This phenomenon is also apparent within online support groups (Barak & Gluck-Ofri, 2007). One factor that might explain the high levels of self-disclosure observed in these online groups is the anonymity associated with computer-mediated environments. Online support groups provide individuals with the opportunity to keep their identities entirely anonymous, this may encourage certain individuals to disclose information that they may otherwise feel uncomfortable discussing with others due to the possibility of a negative reaction. As Caplan and Turner (2007) point out, the anonymity offered by these groups may help to 'establish a safe and secure environment in which participants are willing to discuss deeply personal and upsetting matters' (p. 989). Tichon and Shapiro (2003) argue that self-disclosure plays an important role in the elicitation and provision of support. In their examination of messages posted to a group listserv for siblings of people with special needs and learning difficulties, self-disclosure was used in three distinct ways. Firstly, self-disclosure was used by participants to elicit support and start a relationship with other members, for example members would often share concerns and problems with the group to generate a discussion about ways to cope with their problems. Second, self-disclosure was used by support providers to demonstrate that successful coping is possible through disclosing similar experiences where they had successfully coped. Finally, self-disclosure was used to share social companionship with other members.
4. **Psychosocial Benefits of Participation:** To date, there has been a lack of outcome research (Eysenbach et al., 2004) evaluating the efficacy of health-related online support groups. Most quantitative studies in the literature focus on professionally developed online support groups or comprehensive computer support programmes. Comprehensive support programmes typically incorporate a wide array of interactive features including question and answer functions, decision-making and problem-solving aids, encyclopedia reference materials and individually tailored behaviour change support. Two of the most extensively researched comprehensive computer support systems for chronic health conditions are the Comprehensive Health Enhancement Support System (CHESS) and ComputerLink. The basic format of these interventions have been tailored to meet the needs of individuals suffering from various health conditions such as Breast cancer, Prostate cancer, Alzheimer's disease, Asthma and HIV and AIDS, and for patients from different socio-demographic backgrounds. Randomised controlled trials and observational studies assessing the impact of these computer systems indicate that usage may be associated with a variety of positive outcomes including improved emotional well-being and quality of life, more efficient use of health care systems and improved ability to cope (e.g., Gustafson et al., 2005; Gustafson et al., 2008). In addition, a number of studies note that the communication features of the support systems appeared to be the most heavily accessed functions (Gustafson et al., 1994). This suggests that participants may particularly value and benefit from computer support interventions that offer the opportunity to interact with other patients. While these studies show that computer-mediated patient support interventions can have beneficial effects for individuals, they tell us very little about the effectiveness of the millions of "natural" online support groups found on the Internet. Most studies evaluate complex interventions with a range of different components making it difficult to distinguish the stand alone effect of online communication and peer-to-peer support. However, in a systematic review of the effects of health-related online groups, Eysenbach et al. (2004) found only six studies

that evaluated pure peer-to-peer online communication. Most of these studies contained relatively small samples sizes and no comparison group, thus limiting the generalisability of the findings. The review therefore concluded that there was a lack of robust evidence for the psychological and health benefits of peer-to-peer online groups. Despite this, there is a growing body of qualitative literature which suggests that use of an online support groups can be associated with a range of positive psychosocial benefits for patients, particularly in the context of self-management behaviours (Allen et al., 2016).

5. **Empowerment:** More recent evidence suggests that participation in online support groups can have an empowering effect on patients suffering from physical and mental health problems (e.g., van Uden-Kraan et al., 2008c). The term empowerment describes a process through which people gain greater mastery and control over decisions and actions affecting their lives. In the context of health care, empowerment can reflect an increased confidence in one's ability to manage their condition, the ability to access appropriate health information and greater control over health-related decision-making and interactions with healthcare providers. The exact nature of patient empowerment however is complex; various factors can have an empowering effect including a patient's skills and knowledge, trust, locus of control and a reduction in feelings of hopelessness, isolation and oppression (van Uden-Kraan et al., 2008c). Different patients may also have different experiences and perspectives regarding empowerment. Furthermore, empowerment not only reflects an individual's sense of control and efficacy but can also occur at the group and community level. There is also a distinction between empowering processes (i.e. the process through which individuals take control of their life) and empowering outcomes (i.e. the psychosocial consequences of empowerment). The majority of research documenting empowerment in online support groups has focused on exploring the empowering processes that take place in messages exchanged between participants (Finn, 1999; Perron, 2002; Sharf, 1997). For instance, in a discourse analysis of communication in an online breast cancer mailing list, Sharf (1997) reports that the online group allowed women to express feelings of grief and depression surrounding their experience of breast cancer whilst simultaneously offering a unique source of information and emotional support. This not only resulted in enhanced decision-making but also helped the women meet new challenges associated with breast cancer and transform their feelings of negativity into optimism.

CONCLUSION

Relatively little work has been conducted to examine the extent to which the empowering processes that occur online lead to empowering outcomes. Some qualitative studies have addressed this issue through exploring empowerment from the perspective of the patient. Buchanan and Coulson (2007) found that dentally anxious individuals accessing an online support group felt that the guidance, encouragement and shared experience offered by the online community empowered them to try to conquer their own fears. The support available from the group also led to a growth in confidence about disclosing dental anxiety to dental professionals. In another study, van Uden-Kraan et al. (2008c) asked participants using online breast cancer, arthritis and fibromyalgia support groups about the full range of both empowering and disempowering processes that occur online. Results revealed that empowering processes included emotional support, information exchange, recognition, sharing experiences and helping others. These

processes appeared to bring about a number of empowering outcomes namely feeling better informed, a greater sense of confidence about their treatment and interactions with health care professionals, improved acceptance of the disease, increased optimism and self-esteem and greater social well-being.

FUTURE RESEARCH DIRECTIONS

Over the past decade there has been a rapid growth in the number of studies which have considered peer-to-peer health-related online support groups. Despite this, there has been a notable lack of well-conducted randomized-controlled trials therefore there is an urgent need to redress this situation, particularly in the context of long-term physical health conditions. Beyond this, however, there is a need to more fully understand predictors of engagement with online support groups, factors impacting on levels of engagement as well as their linkage with relevant clinical outcomes. More broadly, if we are to fully understand and realize the potential of peer-to-peer health-related online support groups then a multi-disciplinary research perspective must be adopted.

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KEY TERMS AND DEFINITIONS

Deindividuation: When a person has a lower sense of self-awareness and ‘loses’ themselves within a larger group.

Lurking: When an individual does not actively post messages to a discussion forum but rather passively reads messages.

Online Support Group: A collection of individuals who come together online to engage in mutual support in the context of health and illness.

Self-Help Mechanisms: The therapeutic processes that may help oneself to address a challenge, crisis or difficult.

Social Support: The perception and actuality that one is cared for, has resources available from others and is part of a support network.

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Chapter 19

Software Evaluation From the Perspective of Patients and Healthcare Professionals

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ABSTRACT

Healthcare software evaluation is a complex process. Specifically, in the health information systems, focusing on the patients' health and on the healthcare professionals' motivation is particularly important. Doctors, nurses, and other healthcare professionals use software that indirectly affects the patients. Does software improve the patients' health, their satisfaction, or the healthcare professionals' commitment/job satisfaction? How can the impact of an information system be measured from the perspective of the patients, the doctors, the nurses, or the supporting staff? Some relevant efforts have been made in the last years to measure healthcare software impact. Nevertheless, the decision to extend a study to different fields may lead to many difficulties as far as its conclusions are concerned. By identifying the research questions and the most relevant works, as well as indicating the open research issue, this chapter is a revision of the literature on the subject. This work may be expected to be useful to all those wishing to contribute by their research in this field.

INTRODUCTION

Healthcare software evaluation is a complex process. Specifically, in the health information systems, focusing on the patients' health and on the healthcare professionals' motivation is particularly important.

Doctors, nurses and other healthcare professionals use software that indirectly affects the patients. Does software improve the patients' health, their satisfaction, or the healthcare professionals' commitment/job satisfaction? How can the impact of an information system be measured from the perspective of the patients, the doctors, the nurses or the supporting staff? Some relevant efforts have been made

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in the last years to measure healthcare software impact. Nevertheless, the decision to extend a study to different fields may lead to many difficulties as far as its conclusions are concerned. By identifying the research questions and the most relevant works, as well as indicating the open research issue, this article is a revision of the literature on the subject. This work may be expected to be useful to all those wishing to contribute by their research in this field. The article provides a historical perspective of the field, followed by the main research works, their goals, instruments and key results. A thorough discussion of the results, advances and challenges will also be developed, finishing the manuscript with fruitful research directions.

It is believed that this article will be of great value for those who need a solid insight in the field and want to contribute for advances in the research questions identified.

The next section introduces the concepts related with the evaluation of the software, patients' satisfaction evaluation, and the healthcare professionals' satisfaction. The following section presents the dimensions of evaluation, tools and approaches used, ending with a discussion of issues and challenges of the assessment of patients' and healthcare professionals' satisfaction. Solutions and recommendations are preceding the discussion of future and emerging trends. Finally, the last section provides discussion of the overall coverage of the chapter and concluding remarks.

BACKGROUND

According to the World Health Organization (World Health Organization, n.d.), e-health can be defined as the providing of services and resources per electronic means either for health professionals, health consumers or for health systems management. Software plays in this way a central role in the healthcare systems because it can interact with the patients or doctors, or being embedded software in medical instrumentation, and other healthcare-oriented life-critical systems. Software is becoming more pervasive in all facets of medical device design and development. As transitions from hardware to software controls occur, there is a growing need for formalized software assurance processes (Cooper & Pauley, 2006).

The use of the modern information technology in health offers tremendous opportunities: 1) to reduce clinical errors, e.g., medication errors, diagnostic errors; 2) to support health care professionals, e.g., availability of timely, up-to-date patient information; 3) to increase the efficiency of care, e.g., less waiting times for patients; 4) or even to improve the quality of patient care (Elske Ammenwerth, Gräber, Herrmann, Bürkle, & König, 2003)(Walker et al., 2005). According to Alalwany (2010), e-health supports disease allows people to better manage their own health and provides more accessible and consistent healthcare services, besides improving the efficiency of healthcare systems. Despite the opportunities, e-health presents some challenges namely considering that modern information technology systems are costly (Drouin, Hediger, & Henke, 2008)(Deloitte Touche Tohmatsu Limited, 2015) and that their failures may cause negative effects on both patients and staff. Adopting e-health applications is also highly complex. Finally, the privacy and security concerns in e-health applications are other key challenges. Therefore, a rigorous evaluation of IT in health care is recommended (Brender et al., 2013) and of great importance for decision makers and users (Kaplan & Shaw, 2004). Evaluation is likewise of some importance considering the high rate of failed IT projects in public sector where 35 percent of IT government projects have been classified as total failures, and 50 percent as partial failures (Heeks, 2006).

As for evaluation it can be defined as the decisive assessment of defined objects, based on a set of criteria, to solve a given problem (Elske Ammenwerth et al., 2003). It is challenging evaluating software

in health. The complexity and difficulty lie in the challenges faced at the intersection of three areas all well-known for their complexity (Hamid & Sarmad, 2010): healthcare services, information systems, and evaluation methodologies. Table 1 sums up the challenges encountered at the intersection of healthcare services, information systems and evaluation methodologies (Alalwany, 2010).

Ammenwerth *et al.* (2003) identify the typical problems in evaluation of IT in health care considering the complexity of the evaluation object, the evaluation project, and the motivation to perform evaluation.

E-health evaluation involved many stakeholders, the most important of them being the users (Gustafson & Wyatt, 2004). Therefore, assessing e-health from the users' perspective should address all the key factors that influence the users' acceptance of the new adopted technologies including the risks and benefits associated with the design and implementation of the e-health initiative in specific contexts. Two types of users, direct and indirect users, may be distinguished. In the first domain, patients that use e-health applications and health care professionals that use healthcare software will be considered. In the second domain, indirect users are the patients that do not use directly the applications but are indirectly affected by the use of the systems in, among other examples, hospitals, home healthcare, or health centers. Therefore, it is important direct and indirect evaluations, which is why the next section will focus on the evaluation, dimensions to evaluate and tools and techniques.

EVALUTION, DIMENSIONS, TOOLS AND APPROACHES

Evaluation can occur at different phases of a software project: prior to the implementation of the e-health software, during and after the implementation. When evaluate at the pré-implementation, the main reason stands for maintain accountability for expenditure of resources and/or evaluation for decision-making. At the implementation, the rationale for doing evaluation is to assess the user's reaction to system or service and/or evaluation for decision making. Finally, at the post implementation, the intention is for performance evaluation and/or the impact evaluation to assess the overall social and technical impact of the system on users and organizations and/or usability and acceptability evaluations. Alawany (2010) proposes an evaluation roadmap for e-health evaluation with the main elements: 1) the rationale of e-

Table 1. Challenges encountered at the intersection of healthcare services, information systems and evaluation technologies (Alalwany, 2010)

The Research Field	The Challenges Encountered
Healthcare services	• Healthcare services are characterized by having many stakeholders who are working in different disciplines and pursuing different goals. • Healthcare services are dictated by complex regulations. • The medical knowledge is an enormous and dynamic field. • The main aspects of medical knowledge require an interactive environment to be transferred or practiced.
Information Systems	• The multiple perspectives involved. • The difficulties of quantifying benefits. • The nature of information systems investments is changing both in terms of technological capability and the benefits they can deliver, as well as in terms of diffusion in most aspects of society. • Consider the social and technical context of use.
Evaluation Methodologies	• The limited experience of using methods. • The unfamiliarity with evaluation techniques. • The difficulty in interpreting results.

health evaluation; 2) the time frames of evaluation; 3) the stakeholders; 4) the criteria; 5) the methods of e-health evaluation; 6) dealing with the ethical issues; 7) determination of how to interpret and present the evaluation outcomes.

Taking into consideration the current state of knowledge on this question, assessment by the users, either patients or healthcare professionals, occurs at a post implementation level. Hence, the focus of the present article is to focus on the post-implementation evaluation of the satisfaction of the patients and health professionals. It is therefore essential to determine which dimensions are evaluated and what instruments are used.

What Really Matters for Patients?

What really matters for patients is the starting point in order to determine what should be evaluate when considering a software evaluation. One can consider the perspective from either the tele-healthcare, the software engineering or the healthcare institutions. The analysis of these perspectives may help to understand what must be performed by software in order to meet, or even increase, patients' satisfaction, either directly or indirectly.

Regarding the patients' satisfaction (Williams, May, & Esmail, 2001), the aspects of satisfaction measured by existing studies in tele-healthcare are: 1) professional-patient interaction; 2) patient's experience/feeling; 3) overall satisfaction; 4) technical aspects; 5) preferences for telemedicine or face-to-face consultation; 6) convenience; 7) administrative aspects; and 8) physical environment.

From the software engineering perspective, the approaches to measure the usability of a software using questionnaires as the Computer System Usability Questionnaire (CSUQ) and the Post-Study System Usability Questionnaire (PSSUQ) (Lewis, 1995) the aspects measured are: 1) the overall system usability (OVERALL); 2) the system usability (SYSUSE); 3) the quality of the information (INFOQUAL); 4) the quality of the interface (INTERQUAL).

Existing instruments to measure patients' satisfaction at healthcare institutions such as the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) (National Quality Forum, 2013) or the Patient Satisfaction Questionnaire Short Form (PSQ-18) (Marshall & Hays, 1994) use both similar and different dimensions. The Centers for Medicare & Medicaid Services (CMS), along with the Agency for Healthcare Research and Quality (AHRQ), developed the HCAHPS Survey, also known as Hospital CAHPS®, to provide a standardized survey instrument and data collection methodology for measuring patients' perspectives on hospital care. HCAHPS has composite measures, individual items, and global items. Composite measures are communication with nurses, communication with doctors, responsiveness of hospital staff, pain management, communication about medicines, discharge information, and care transition. Individual items concern the cleanliness and the quietness of hospital environment. Finally, global items relate with the overall hospital rating and whether the patient would recommend the hospital. PSQ-18, in its turn, presents separate scores for each of seven different subscales: 1) general satisfaction; 2) technical quality; 3) interpersonal manner; 4) communication; 5) financial aspects; 6) time spent with doctor; 7) and accessibility and convenience.

Cornwell & Robert (2011) in the study of "*What matters to patients'?*", found consistency both across conditions and in relation to the various sectors. Generic themes were:

- Good information provision;
- Having confidence in health professionals;

- Awareness and understanding of specific health condition;
- The right treatment from the right staff at the right time;
- Continuity of care;
- Being treated as a person;
- Partnership with professionals.

Table 2 lists the ten most and least important items for the patients identified Scotland's survey. The findings of the survey broadly support the argument that a generic framework of 'what matters' to patients could be applied across conditions and sectors.

Main Approaches Used for Patients' Satisfaction Assessment

Knowing the key dimensions of patients' satisfaction, as well as the methods used for their assessment, is of great importance.

Regarding e-health (Williams et al., 2001) the majority of studies are descriptive, regarding one service only, some comparing telemedicine services with standard healthcare using the same sample of patients. Only 20% of the studies included an independent control group against which telemedicine was compared. The research was mainly quantitative, with some studies including at least some qualitative component. Tables 3 sums up the methods used for the assessment from the perspective of the healthcare organizations.

Assess Health Care Professional Satisfaction

Doctors and nurses are the main users of software health applications. Studies consider these users as software users but don't measure the possible relation between the use of the applications and the impact on job satisfaction. The only existing job satisfaction scale specifically aimed at community nurses defined was Ellenbecker's Home Healthcare Nurses' Job Satisfaction (HHNJS) scale. The 2001 edition was composed of eight subscales (21 items, 5-point Likert scale): general feeling of overall job satisfac-

Table 2. Scotland's Patient Experience Programme: Patient Priorities for Inpatient Care ((Reeves & Bruster, 2009), from 2,213 patients)

10 Most Important Items	10 Least Important Items
• A clean ward • Staff cleaning their hands before touching patients • Being treated quickly in an emergency • Getting the best treatment for my condition • Doctors knowing enough about my condition and treatment • Clear explanations about what will happen during an operation or procedure • Being told the risks and benefits of any treatment in a way I can understand • Clear explanations of my condition or treatment • Being treated with dignity and respect • Being told how my operation or procedure has gone in a way I can understand	• Being given help to eat my meals when I need it • Being given accurate information about ward routines • Not having to wait around in hospital once I have been told I can go home • Being given help to arrange transport home • Having a choice about which hospital I go to • Not having to pay too much to make phone calls • My religious beliefs being respected • Being able to watch television without having to pay for it • Being able to get an interpreter • Having access to food when I am hungry (not just at mealtimes)

Table 3. Methods including tools/surveys for the assessment of patients' satisfaction. Adapted from (Williams et al., 2001).

Author, year	Methods (incl. Tools/Surveys)
(Boyd, 2007)	• Postal questionnaire consisting of 82 statements using a 5-point scale. 54 of the statements were based on core items from the 2006 inpatient survey, 12 from the question bank for the inpatient surveys and 16 were created at the request of the DH. • Cognitive interviews with 8 ethnically diverse volunteers with recent experience of inpatient stays in England were conducted to test the questionnaire.
(Bridges, Flatley, & Meyer, 2010)	• Systematic review of worldwide grey and published literature written in English between January 1999 and June 2008 identified from databases: CINAHL, Medline, British Nursing Index, EMBASE Psychiatry, International Bibliography of the Social Sciences, PsychINFO, and AgeInfo. • 42 primary studies and 1 systematic review met the inclusion criteria.
(Coulter, 2006)	• Expert opinion
(Davies, 2005)	• Qualitative interviews with senior health professionals and managers and a review of the literature
(The NHS Confederation, 2010)	• Seven organisational case studies

tion, interaction, stress, professionalism, task requirements, autonomy, organizational policy and quality of care delivered. Nine subscales were presented in the 2005 (Ellenbecker & Byleckie, 2005) edition (32 items, 5-point Likert scale): autonomy/independence, professional growth, group cohesion/peers, group cohesion/physician, characteristics of the organization, stress/work load, autonomy/flexibility in work scheduling, autonomy/control of work activities and salary/benefits/perception of opportunities elsewhere. So far, no scale to assess doctors' professional satisfaction has been known.

Users' Acceptance

According to (Ullah, Fiedler, & Wac, 2012), the most important determinants for successful e-health implementations are shown in Table 4. As can be seen, user acceptance is the most important factor for any healthcare service implementation

Technology acceptance model was designed to be used in the context of Information Systems for the purpose of predicting information technology acceptance and usage in the work environment. The final conceptualization of TAM model (Davis, 1989) includes two core constructs which are defined as follows: 1) perceived usefulness, i.e., "the degree to which a person believes that using a particular system would enhance his or her job performance", 2) perceived ease of use: "the degree to which a person believes that using a particular system would be free of effort". TAM therefore identifies two

Table 4. Determinants for successful e-Heath implementation (Ullah et al., 2012)

Determinants	Ingluence in Implementation (%)
User acceptance	37%
Technology deployment factors	29%
Leaving behind the organization	13%
Policy and Legislation	11%
Financing factors	10%

factors: the perceived ease of use (PEOU) and perceived usefulness (PU) that determine individuals' attitude (ATT), which influences individuals' behavioural intention. The Technology Acceptance Model (TAM) is one technology acceptance theory that can be used to understand perceived barriers and benefits of using technology in health care settings. TAM can help predict acceptance of health information technology among users. The systematic review by Holden & Karsh (2010) shows over twenty studies that applied TAM to health care settings by presenting the views of physicians and non-physicians, among which nurses, pharmacists, and patients. The study found that TAM can forecast accurately the portion of Health IT users that are accepting the system. In 2000, Venkatesh and Davis (Venkatesh & Davis, 2000) developed TAM2 in order to capture the social influence (SN) that influences individuals to positively or negatively accept such IT. In 2003, Venkatesh et al. formulated a new model called the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003) that was extended in 2012 to UTAUT2 (Venkatesh, Viswanath and Thong, James Y. L. and Xu, 2012). UTAUT introduces three constructs, which are the main determinants of intention to use an information technology. These are defined as performance expectancy, effort expectancy and social influence. UTAUT2 incorporates three constructs into UTAUT: hedonic motivation, price value, and habit. Compared to UTAUT, the extensions proposed in UTAUT2 produced a substantial improvement in the variance explained in behavioral intention and technology use.

Existing Studies to Assess the Impact of Software in the Patients and Healthcare Professionals

A nursing record system is the record of care planned and/or given to individual patients/clients by qualified nurses or other caregivers under the direction of a qualified nurse (Currell & Urquhart, 2003). The goal of the study was to assess the effects of nursing record systems on nursing practice and patient outcomes. Eight trials involving 1497 people were included. In three studies of client held records, there were no overall positive or negative effects, although some administrative benefits through fewer missing notes were suggested. A paediatric pain management sheet study showed a positive effect on the children's pain intensity. A computerised nursing care planning study showed a negative effect on documented nursing care planning, although two other computerised nursing information studies showed an increase in recording but no change in patient outcomes. Care planning took longer with these computerised systems, but the numbers of patients and nurses included in these studies was small. A controlled before-and-after study of two paper nursing record systems showed improvement in meeting documentation standards. No evidence was found of effects on practice attributable to changes in record systems. The number of studies on this topic, albeit of poor methodological quality, indicates that this is an important area of concern for nursing practice (Currell & Urquhart, 2003). However, none of the studies produced results that could be interpreted as evidence of a change in practice that resulted from a change of record system. The studies indicate that nurses believe that there is a link between their clinical practice and the nursing record, beyond its obvious use as a note keeping system. The client held records studies suggest altered and improved relationships between clients and health professionals, and the pain management study sought to demonstrate a direct effect on patient care.

Currell, Urquhart, Wainwright, & Lewis (2010) developed a study to assess the effects of telemedicine as an alternative to face-to-face patient care. Establishing systems for patient care using telecommunications technologies is feasible, but there is little evidence of clinical benefits. The studies provided variable and inconclusive results for other outcomes such as psychological measures, and no analyzable data about

the cost effectiveness of telemedicine systems. The review demonstrates the need for further research and the fact that it is feasible to carry out randomized trials of telemedicine applications. Policy makers should be cautious about recommending increased use and investment in unevaluated technologies.

Sinha & Shetty (2015) show the relevance of the attitude of users, namely doctors, in the impact of health information technology. Health information technology (HIT) equips healthcare professionals with the required information and tools for making quality decisions in patient care, but it is always advisable to assess their attitude before its actual implementation. A cross-sectional survey was carried out among 140 doctors of an Ayurvedic center of Southern India. A validated questionnaire consisting of 18 questions based on a 5-point Likert scale was administered to the participants after receiving their due consent. About 75–80% of the respondents concurred that the HIT application, such as electronic health record, has the potentials to reduce the duplication of documentation work, is easy and has an instant processing and real-time access to patient information. They also felt the need of such application to report the patient data to local and national health institutions. A total of 85% of them mentioned that these applications can make the collection and accessibility of patient data much easier compared with paper-based records, whereas 87.4% of them claimed telemedicine as a platform for multidisciplinary collaborative research and patient care. Even though most of the respondents agreed about the role of HIT in improving the quality of health care, there were many who held no opinion about HIT, including privacy and security of patient data. The need of proper awareness and training program is identified to make them aware about the HIT and its application in patient care, education and research.

Main Approaches Used for Professionals' Satisfaction Assessment

The types of study designs are (Currell & Urquhart, 2003) (Williams et al., 2001)(E Ammenwerth & Keizer, 2005; E. Ammenwerth et al., 2004; Brender et al., 2013): 1) randomized controlled trials; 2) controlled clinical trials; 3) interrupted time series analyses; 4) and controlled before and after studies.

Issues, Controversies, Problems

Studies indicate that many of the main barriers to healthcare information systems (specifically referencing electronic health records) are not technical, but other issues including stakeholder issues such as risk tolerance, physicians' resistance related to time concerns, fears about privacy, the number of sellers vendors on the marketplace and their transience (Walker et al., 2005). Each of the aforementioned barriers is rooted in the associated vested issues in health technologies held by stakeholders. Stahl and Shaw (2011) indicate that success with health information systems needs to bring together various stakeholders and their work practices. Ultimately, Patient Centered Care (PCC) success is determined by the quality of the interactions between patients and clinicians (Epstein, Fiscella, Lesser, & Stange, 2010). A fundamental objective of the PCC model is therefore to integrate information technology applications and infrastructures in every link of the care chain in the belief that Web portals, shared patient records, electronic consultation systems, and online data access for patients facilitate relationships between professionals and patients by providing sufficient information, patient engagement and mutual feedback (Vikkelsø, 2010). In this context, assessing the impact of the e-health software in patients and healthcare professionals is critical. Despite a large amount of published evaluation studies, many authors report problems during evaluation, such as (E Ammenwerth & Keizer, 2005):

- Unclear, conflicting or changing evaluation goals during the study;
- Large efforts needed for the preparation and execution of the study;
- Complex and sometimes contradictory results;
- Dependence of the evaluation results on the motivation and expectation of the users;
- Uncertainty as to whether results can be generalized to other environments.

Reviews of patient satisfaction research in health care highlight several methodological problems (Williams et al., 2001), including the use of short quantitative questionnaires, lack of standardization, and confounding due to a range of social psychological biases, including self-selection bias, social desirability response bias, and acquiescent replies. Answers to patient satisfaction surveys conducted at healthcare delivery sites are undoubtedly influenced to some degree by the patient's concerns about the impact that any negative feedback may have on the services that are available to them. The results of patient satisfaction studies are often influenced by the method of data collection. Other factors that influenced patient satisfaction included the choice of response format for rating satisfaction, order of placement of satisfaction items within the overall questionnaire, and the distinction between open-ended and closed or dichotomous questions. These findings suggest that "patient satisfaction" is influenced, at least in part, by the nature of the methodology used to measure it.

SOLUTIONS AND RECOMMENDATIONS

E-health software satisfaction assessment is difficult, time consuming and resource demanding. Existing approaches are designed for a very specific scenario, so the existing results are difficult to generalize and do not allow a comparison between software applications. One possible solution is the development of a global validated tool and method for each sectorial health service allowing in this way the benchmarking of the applications. A validated instrument and their application method leading to a unique scale of satisfaction impact assessment could be used in decision-making and impact estimation of a commercial e-health product, the development of new products, and as the backbone of regulatory work. Finally, as stated in this work, these instruments must encompass a holistic approach for measuring the satisfaction either of the patients or of the healthcare professionals.

FUTURE RESEARCH DIRECTIONS

Due to the importance of the evaluation of the software from the perspective of patients and healthcare professionals many fruitful research directions exist and the academic and non-academic community is invited to develop efforts for contributions in the field. This work shows the need to develop standard and holistic tools and methods to perform this assessment at least at the health service level. It also, shows the need of tools and methods easy and faster to apply. The heavy investments in e-health request the existence of an impact scale in the patients and professionals that would allow the comparison between software applications. Moreover, the presented studies are time consumer, requiring a lot of availability either of the research teams either of the patients and health professionals. The existing instruments

neither take into account many dimensions of patients' satisfaction nor consider jobs satisfaction in its equation. Finally, there's a lack of tools and methods to perform satisfaction assessment prior to the implementation of the e-health software and during the implementation.

CONCLUSION

The paper provides a thorough discussion about the relevance of the evaluation of the software from the perspective of the patient and healthcare professionals. It holistically presents the concept of satisfaction of the patients and the professionals, with dimensions and methods both measured. It demonstrates the need to develop new efforts in this research area due to the existing fragilities. The paper may be a helpful tool for those who need a solid support from where to start or to continue their work.

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KEY TERMS AND DEFINITIONS

E-Health: According to the World Health Organization (World Health Organization, n.d.), e-health is: “the transfer of health resources and health care by electronic means. It encompasses three main areas: 1) the delivery of health information, for health professionals and health consumers, through the Internet and telecommunications; 2) the use of the power the power of IT and e-commerce to improve public health services, e.g. through the education and training of health workers; 3) the use of e-commerce and e-business practices in health systems management”.

Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS): A standardized survey instrument and data collection methodology for measuring patients’ perspectives on hospital care. The HCAHPS survey contains 21 patient perspectives on care and patient rating items that encompass nine key topics: communication with doctors, communication with nurses, responsiveness of hospital staff, pain management, communication about medicines, discharge information, cleanliness of the hospital environment, quietness of the hospital environment, and transition of care. The survey also includes four screener questions and seven demographic items, which are used for adjusting the mix of patients across hospitals and for analytical purposes. The survey is 32 questions in length (National Quality Forum, 2013).

Organizational Commitment: Organizational commitment refers to the extent to which the employees of an organization see themselves as belonging to the organization (or parts of it) and feel attached to it (Meyer, Kam, Goldenberg, & Bremner, 2013; van Dick & Ullrich, 2013).

Patient Satisfaction Questionnaire Short Form (PSQ-18): PSQ-18, Likert scale questionnaire proposes seven dimensions of patient satisfaction directed toward their healthcare professionals. These are 1) general satisfaction, 2) technical quality, 3) interpersonal manner, 4) communication, 5) financial

aspects, 6) time spent with doctor, and 7) accessibility and convenience. Each domain is tested through different related questions, which is of substantial benefit when one aims to identify a particular area to improve on. The general satisfaction has strong correlation with the other domains and thus it is important to improve in all (Marshall & Hays, 1994).

Software Quality: The “capability of software product to satisfy stated and implied needs under specified conditions” (“ISO/IEC 25010:2011 Systems and software engineering -- Systems and software Quality Requirements and Evaluation (SQuaRE) -- System and software quality models,” 2011) and as “the degree to which a software product meets established requirements; however, quality depends upon the degree to which those established requirements accurately represent stakeholder needs, wants, and expectations” (*IEEE P730™/D8 Draft Standard for Software Quality Assurance Processes*, 2012).

Usability: Usability relates with the concept of ease of use and the ability to use a product for its intended purpose (Bevan, 1995).

User Acceptance: For technology to improve productivity in organizations first users’ must accept the technology and use it. Models explaining the factors and predicting user intention for using technology are of great importance for health information systems development (Venkatesh et al., 2003).

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Chapter 20

Technology Design and Routes for Tool Appropriation in Medical Practices

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ABSTRACT

This chapter aims to analyze the extent to which medical practitioners incorporate the use of digital technologies into their practices. In this process, it is recognized that significant developments of technologies not only transform ways in which people interact and access to information to make decisions related to individual and social functioning but also influence and demand changes in professional practices. Nowadays, it is common that patients consult online information during their medical treatments. How do medical doctors develop an expertise in the use of digital technologies to fully incorporate them into their regular practices? The authors discuss the process in which medical practitioners get involved to transform an artifact (webpage, catheter, stent, etc.) into an instrument to treat a particular patient's health problem. To this end, they focus on the development of the practitioners' cognitive schemata to analyze and describe the main phases associated with the practitioner appropriation of the tool.

INTRODUCTION

Nowadays it is recognized that the developments and use of digital technologies are changing the way in which people communicate, get access to a variety of information, solve problems, and discuss solutions. These technologies open up novel avenues for people to share practical and specialized knowledge from a variety of domains, and interest or goals. Tools can be physical or virtual artifacts and they influence

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human cognition and act as mediators between the phenomenological and conceptual world (Santos-Trigo, et al. 2016). In health areas, experts or professionals such as physicians, nurses or physiotherapists rely on social media (YouTube channels, blogs, wikis, or specialized webs) to share knowledge and practical experiences. Similarly, patients look for information on diseases and health advice and they often interact, via Internet, with experts to monitor their health and to interpret lab results. An important feature of the Web or an online platform is that it allows the participation of experts and users with a variety of experience or knowledge to build a source of accumulated knowledge in constant scrutiny. Denecke (2015) identifies three main groups as users of medical social media with different aims and purposes: patients, healthcare professionals and researchers. Thus, through the medical web, patients interact with health professionals and other patients to get information on diseases, treatments, prevention or ways for operating tools for diseases. Healthcare professionals interact with other colleagues and patients to discuss latest results or to identify and share experiences and best practices. Researchers interact with other researchers to discuss treatment results and information on treatment outcomes and information of disease development and progression. How is a medical web system constructed? What criteria are used to select the information to be included in the online system? ¿How do patients process and use the information they consult? Available medical data in online platforms might vary and increase in volume and themes, then data visualization becomes important for physicians and patients to overview and interpret changes in health status. Likewise, physical tools designed by engineers and other professionals (magnetic resonance imaging, catheters, etc.) are also transforming medical practices such as surgeries and disease detection and treatments. Thus, it is important to analyze the extent to which users of both physical and virtual artifacts get engaged in activities to transform those artifacts into an instrument to solve problems. To this end, we focus on the importance for users to develop cognitive schemata that shape their appropriation of the tool affordances in problem solving environments (Santos-Trigo, et al, 2015).

The design and use of technological artifacts in medical practices involve the participation of several experts' communities including engineers, scientists, and medical doctors. Thus, to delve into what happens to artifacts (designed by engineers) when they enter into medical practices implies not only to uncover what engineering and medical practices entail, but also to address how both agendas could converge or incorporate common goals. Regarding the engineering as a discipline, the National Research Council (NRC) (2009) pointed out its problem solving approach to design and create human-made products under certain conditions or constraints. Some of those constraints involve taking into account principles that encompass science and scientific laws, budget restrictions, available materials, sustainability, ergonomics, and ethical issues.

Progress in science and engineering goes hand in hand, science advances often depend on tools developed by engineers and reciprocally scientific knowledge guides and permeates engineering designs. Nowadays, it is not unusual to find engineers working with medical doctors and researchers in the design of artifacts that aim to improve human health.

Engineering design is a purposeful activity bound by specifications and constraints and an eminently collaborative enterprise. It involves an interactive process in which the design is tested and modified and it often offers several solutions to a particular problem (NRC, 2009). In general, the design and the construction of artifacts are tasks that require an expertise in science of materials, control, ergonomics and biomedicine. And there is set of standards that any medical artifact needs to fulfill in order to be used within the medical community. However, as Béguin (2003) pointed out the design of artifacts does not finish when the tool or object fulfills material and technical requirements; it should include how

users transform the artifact into an instrument. Then, how does the medical community develop the needed expertise to use those artifacts efficiently in medical practice? This question becomes important to identify and delve into a research area that examines ways in which medical doctors transform and artifact (physical device) into an instrument to solve problems. Then, what information and actions are important to characterize the process to transform an artifact into an instrument? Hadolt, Hörbst & Müller-Rockstroh (2012) cited a four-phase model (Hahn, 2004) that includes appropriation, objectification, incorporation, and conversion activities. The authors stress that the incorporation of artifacts into practices depends on social, cultural, and economic conditions.

It is important to analyze the extent to which medical doctors construct cognitive schemata that explain what we called their appropriation process of an artifact. In this process, it is recognized that tools shape and are shaped by the users' actions. Trouche (2004) pointed out the importance of considering the instrument as an extension of the body that becomes an organ formed by the artifact itself and by a psychological part that helps the user to mobilize the artifact to carry out activities and solve problems. Béguin (2003) emphasizes the difference between an artifact and an instrument or a problem-solving tool. The latter is made up by the artifact and the user's social and private cognitive schemata. The artifact characteristics that include ergonomics and constraints and the cognitive schemata developed by the user during the activities are important for the transformation of the artifact into a problem-solving tool or instrument to solve problems.

Artigue (2002) pointed out that users need to get involved in an appropriation process to transform an artifact or physical device into an instrument for specific use. This process leads users to gradually construct personal schemata or to appropriate pre-existing social schemata to appreciate its potentialities and use them in problem solving situations. Thus, relations between users and objects are shaped by ways in which a community of practice acts in problem solving environments. Trouche (2004) also mentioned that the development of the user's psychological component could be categorized in terms of three related functions: A *pragmatic* function where the subject achieves a particular goal, a *heuristic* function in which the subject visualizes and pursues an action plan; and an *epistemic* function where the subject comprehends and makes sense of what is being achieved.

BACKGROUND AND RATIONALE

Delving into the ways that medical doctors develop an expertise in the use of artifacts in their practice implies examining not only what activities they engaged in order to develop such expertise; but also reflecting on common issues that permeate or characterize two fields: the engineering design and medical practice. In this context, we stress the interdependence between scientific principles that support the design of tools and those activities involved in using those tools in problem solving environments.

Throughout the chapter, it is recognized that performances and advances of humankind go hand in hand with developments and use of technology. Thus, the use of tools not only influence cultural and science developments (Trouche, 2004); but also some tools facilitate the maintenance of physical wellness and humans comfort. Koszalka et al. (2014) pointed out that the use of technology goes beyond developing an expertise in its practice, it also includes that subjects develop a set of abilities for accessing relevant medical information, constructing an effective communication among colleagues and patients, and supporting the subjects participation in virtual practices environments. Thus, the use of tools has

been shaping the developments and practices in medicine and in all disciplines. As a consequence, tasks in the design field and ways in which users appropriate the tools become relevant not only to incorporate the tools in different practicing domains, but also to provide feedback to improve the tools design.

Are there common principles that characterize the design and development of particular tools? How do engineers design artifacts? How are designed technologies or tools used in medical practices? To what extent does the design process influence or shape ways in which medical doctors use the tool in their practices? The discussion of these questions provides basis to comprehend and frame ways in which medical doctors develop an expertise in the use of the tools. In a broader context, the relation between science and technology is a theme that should be examined from diverse angles or perspectives. In terms of goals and methods, engineering design, as an area of study, can be compared with processes involved in scientific developments, both processes rely on or are conceptualized as problem solving approaches (Santos-Trigo, 2010).

Trouche (2004) pointed out there are cultural biases or differences between Western and Eastern cultures regarding the value of physical and manual work vs. cognitive or intellectual work. While Eastern cultures recognize a dialectic interaction between mind and body, the West tends to privilege intellectual or mind activities over physical or manual activities. Recently, science and technology communities recognize that scientific inquiry or science development, technology, engineering, and mathematics are fields in constant interaction and play an important role in society developments. Trouche cites a Francis Bacon' passage that seems to recognize the importance of both intellectual and manual activities: "Human hand and intelligence, alone, are powerless: what gives them power are tools and assistants provided by culture" (p. 283). That is, both science and engineering or technology activities are fields that depend on each other and as a consequence, multidisciplinary approaches that incorporate principles and methods from several realms seem essential to identify, frame, and solve society problems. In particular, information regarding how scientific and technology developments influence not only the building of disciplinary knowledge or practices; but also the users' appropriation process of those developments becomes an important component of the academic agenda. Similarly, Ritella and Hakkarainen (2012) pointed out that in order to fully understand the role of artifacts in disciplinary practices, it is important to think of them as cognitive prostheses that enhance and expand human creativity and ways to solve practical problems.

DESIGN AND USERS CHALLENGES

Béguin (2003) underlines that the design of an artifact, factory, or a vehicle is both an individual and collective process based on two principles: a) *differentiation* in which tasks involved in the design are distributed among the team members and b) *interdependence* that recognizes the need to ask for the participation of several specialists to work on a product or artifact. Likewise, the NRC (2009) states that engineering design demands that engineers work in collaboration with teams and clients. That is, the design process can be conceptualized as an ongoing activity in which the designers' plans and knowledge are key to achieve the task; but also during the same process some unexpected goals and challenges need to be attended or addressed. Indeed, although there is no formula to characterize the interactive process involved in engineering design, it is accepted that one initial step is the identification of a problem that eventually needs to be explicitly formulated. This problem becomes a platform to generate ideas and actions to solve it. Next, is the evaluation of potential solutions in which models and prototypes are constructed and evaluated in terms of the extent to which the solutions meet standards and constraints;

an optimization process. A salient feature of engineering design activities is that goals and actions take place within a set of specifications and constraints and involve the consideration of multiple solutions. Thus, important steps that characterize the engineering tasks design include: the identification of the problem and objectives, the definition of goals and constraints, the search and gathering of key information, the identification of possible design solutions, contrasting and analyzing the pertinence of solutions, building and implementing the design, testing and evaluating such design and repeating all steps as necessary (NRC, 2009, p. 83).

It is observed that the aforementioned design process steps do not include, at least explicitly, the importance of taking into account the appropriation process in which users engage in order to use “efficiently” the product generated by the design. Thus, the challenge of communities involved in artifact designs is to extend the design process to include information regarding the subject’s appropriation process of the artifact. That is, the interactive cycle that characterizes the process of designing artifacts should also include information regarding how the artifact becomes a tool for the client or user. In addition, feedback provided by users to designers plays an important role in improving and designing new artifacts. In the appropriation process of artifacts, the analysis of experts’ behaviors and actions shown through dialogue-conducting strategies play a crucial role for subjects to transform an artifact into an instrument to solve problems (Folcher, 2003).

SCOPE OF THE ARTICLE: A FOCUS ON ARTIFACT APPROPRIATION

The analysis of the process involved in the subjects’ appropriation of tools requires the documenting of ways in which a community of practices (Perkins, 2009) behaves in problem solving environments. In this context, it becomes important to analyze and document group or subjects’ interactions within a community formed by expert such as cardiologists, mechanical and biomedical engineers, technicians, and nurses during the process of transforming a particular artifact into a problem-solving tool. The user’s tool appropriation in medical practice often takes place within a community of practice formed by experts and specialists including anesthesiologists, nurses, medical experts, technicians, etc. where novices doctors participate gradually in several activities that involve the coordination of physical skills required while inserting of a catheter or stent and the corresponding interpretation information available through monitor displays.

There are different frameworks to delve into the subjects’ appropriation process of particular tool; however, recently a *bricolage* perspective that involves relying on more than one framework has been used to explain how a particular community develops knowledge and expertise in problem solving activities. For example, the construct *community of practice* was originally developed as a learning theory that fosters self-empowerment and professional development and it has evolved to become a framework for improving organization’s competitiveness (Li, et al. 2009). In this context, a community of practice framework can be extended to explicitly take into account theoretical constructs used in cognition and artifact studies (Verillon & Rabardel, 1995). These studies explicitly recognize and address the importance for subjects to transform a technological artifact into a problem-solving tool. Key in this approach is the recognition that the subject’s appropriation of tools for problem solving activities involves an adaption and transformation of the artifact known as an instrumentation process and the development of cognitive schemata or instrumentalization process. Those schemata are explained in terms of subjects’ cognitive systems associated with the use of artifacts (Rabardel, 1995). Ritella and Hakkarainen (2012)

relied on these two concepts, instrumentation and instrumentalization to explain a dialectic relationship or mutual shaping between people and tools during the appropriation process. Cognitive behaviors are expressed by subjects' use of language and explicit use of strategies to coordinate information provided during the use of the tool. In addition, the artifact appropriation process takes place through subjects' legitimate peripheral participation in an ongoing social practice. Lave (1991) recognizes that an active participation as member of a community of practice shapes new members' identities and help them internalize community values and actions. Thus, as a part of a community of practice the subject develop and internalize knowledge to become a member of that community.

SOLUTIONS, RESULTS, AND REFLECTION

Currently, many research projects emphasize the importance of formulating and approaching scientific and technological problems through the convergence and collaboration of multiple disciplines. For example, Stewart (2011) introduces what he calls the sixth revolution in biology, the first five include: the microscope, classification of living creatures, the theory of evolution, the discovery of the gene, and the structure of DNA, in which he proposes to wide the scope of ways of thinking of the discipline to include mathematical approaches as the sixth revolution to frame and work on biological problems. "Mathematics provides a new point of view, addressing not just the ingredients for life, but the processes that use those ingredients" (p. 18). Similarly, a task of designing artifacts requires the participation of experts to develop both the technical and ergonomic components, but also to incorporate information regarding how an artifact is used in actual practices. Recently, in the USA there is an increasing interest for medical school reform that includes the use of technologies to help enhance and standardize the medical curriculum. For instance, scholars in medical educations recognize the importance to carry out multi and interdisciplinary studies to analyze ways to incorporate educational technologies in medical curricula (Koszalka, Epling, and Reece-Barnes, 2014). In particular, it becomes relevant to characterize medical doctors' cognitive and metacognitive behaviors that appear during their processes of appropriation of technological tools. That characterization includes the subject's development of schemata, mental models, and a language to communicate and eventually carry out the community's goal. Figuerola (2014) reviewed different studies that focused on individual's tools appropriation in several fields including the use of digital tools in mathematical practices. In addition, she examined medical practices involving the use several artifacts to introduce catheters or stents where newcomers' doctors were guided to develop an expertise in those practices. In her analysis, she found that during the subjects' appropriation process of artifacts there are goals to meet at different stages that are monitored within the community. The stages involve initial recognition of a community, direct involvement in particular actions or routine activities, and the management of time to carry out and regulate the development of the activities (Dousay, Igoche and Branch, 2014). Thus, research results consistently show that there are three crucial phases to distinguish the subject processes to develop an expertise in the use of artifacts.

Initial familiarization within the community's goals and carrying out peripheral activities. At this stage, the medical doctor, who is developing an expertise to use a tool, gets engaged into a set of routine tasks that includes checking proper disposition of the surgery equipment, functioning of the auxiliary equipment and in general terms he/she observes the role played by each team member during the entire process of using a particular tool (catheter, for instance). In addition, the subject carries out pragmatic and routine tasks to help other team members and listen to others and to observe actions that medical

expert exhibit during the entire process of using the tool. It is important to mention that the expert continuously calls the attention of the team members to pinpoint critical events that occur during the use of the tool. At this stage, they develop cognitive skills to initially visualize the complexity involved in using the tool to carry out some particular tasks and recognize the need to work and interact with others (Lavigne and Mouza, 2013).

Gradual use of the tool. At this stage, the subject is gradually asked to participate into a series of tasks that includes the actual use of the artifact, in particular stages of the surgery involving the initial introduction of a catheter or stent and moving the artifact to detect a particular spot that needs attention. In general terms, the subject begins to develop and show a heuristic approach to take decisions that define and anticipate actions related to the use of the device. For example, it is evident that in this phase, that even when the subject receives some explicit guidance to carry out particular tasks, the expert scaffolding activities to direct such guidance eventually get reduced or faded. Van Merriënboer, and de Bruin (2014) emphasize that people develop an expertise or learn something by being engaged directly in activities of doing, exploring, observing others, solving problems, analyzing information, repeating, etc. Subjects not only gradually get involved in tasks but it is evident the complexity of the tasks they participate increase gradually within the community.

Full participation that involves the subject's response to new events that appear during the actual use of the tool. In this phase, there is evidence that the subject has developed strategies and skills that help him/her to not only carry out all procedures to use the main artifact and auxiliary instruments; but also he/she exhibit a full coordination of emerging information displayed during the intervention process. That is, at this stage, the expert role is reduced to basically monitor the subject behavior and actions. It is important to observe that in addition to the subject full control of the process of using the tool, the subject shows a clear physical coordination between his/her hand and the manipulation of the artifact. That is, the artifact becomes and extension of his/her hand. Hahn (2004) mentions that as a result of an appropriation, understood this as the process by which objects change (not materially), the object or artifact is no longer what it used to be; but it becomes and extension of the subject's body and cognition.

Figuerola (2014) asked 52 practicing physicians working on different areas in public and private institutions about their experiences in the use of several medical artifacts and about how they developed the skills and knowledge to incorporate them in their professional practices. The questionnaire included 9 statements addressing issues regarding the importance of theoretical knowledge and the artifact; the role of observing experts and gradually being involved in artifact use; the development of a specialized language to understand and explain decisions that emerge during the use of a particular artifact; and effective coordination between visual, hand movement, monitor information and the use of the artifact, and the recognition of patterns involved in actual practice and patient status. Figure 1 and 2 show frequency, percentages, and a bar graph of the answers that the 52 participants gave to two statements.

FUTURE RESEARCH DIRECTIONS

In this contribution we present a research area that deals with the importance of extending the process of designing and producing medical artifacts to include or take into account information regarding the transformation of an artifact into an instrument or problem solving tool. That is, it has been argued that the design of an artifact should not only involve the contribution of experts in several fields addressing technical or material issues; it should also include the participation of research groups that explicitly focus

Figure 1. Relation between experts and residents in medical practices

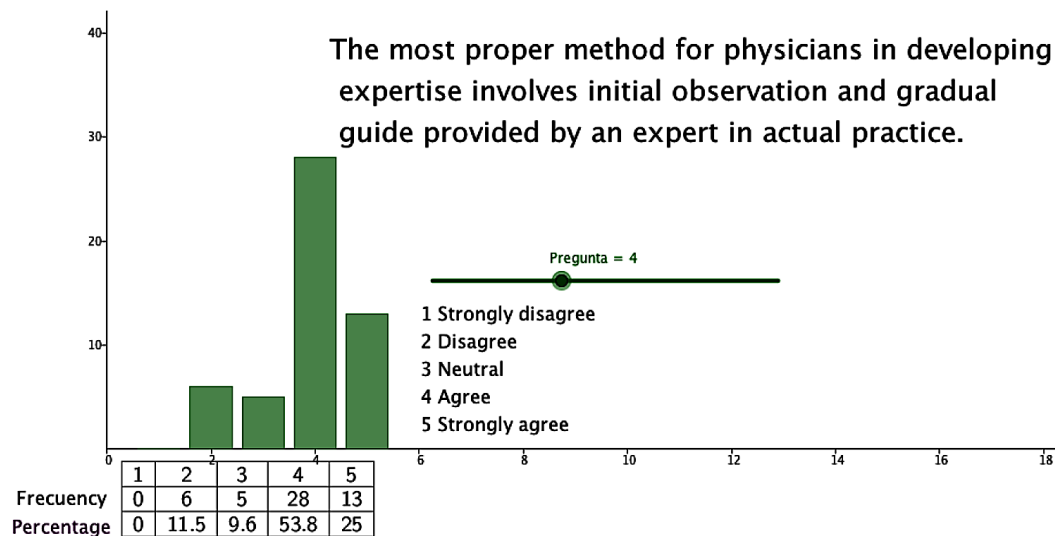
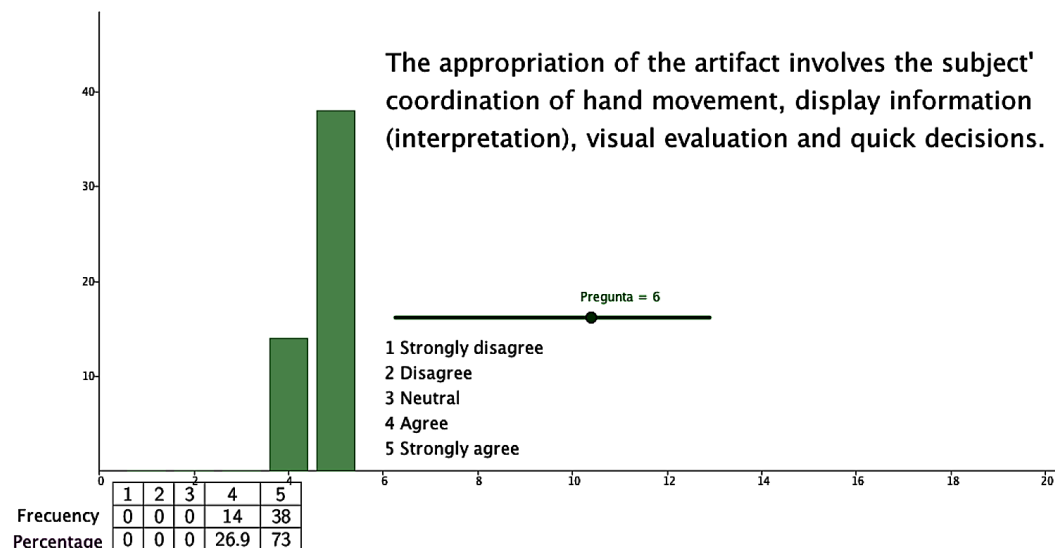


Figure 2. The coordination cognitive and body movements



on the analysis of what the subjects' process of tool appropriation entails. The initial review provides a rational to focus on analyzing cognitive behaviors that users exhibit during their appropriation process of the artifact. A challenge that emerges in this perspective is to develop the language and communication strategies to productively interact and communicate among the members of those diverse communities. Schoenfeld (2011) proposes three constructs to explain in detail what problem solvers do on a moment-by-moment basis while engaging in a problem solving process: the problem solver's resources, goals, and orientations. He suggests that these constructs offers practitioners, and problem solvers in different

domains tools for reflecting on their practicing decisions. In his book, he uses the constructs to analyse and predict the behaviours of mathematics and science teachers and a medical doctor. It is also important to recognize that artifacts are developed within a cultural context where communities of practices reside and work, then what happens when the artifacts or products are used in environments that not necessarily reflect those cultural values? This could be a research question that designers and practicing communities should frame and pursue. In this context, the analysis of the subjects' appropriation process of the artifact should also include information regarding cultural values and traditions associated with environments where the device will be used. Finally, it is important to examine extant frameworks that are used to analyze ways in which subjects transform an artifact into an instrument and discuss the extent to which a *bricolage* perspective can be used to identify basis to characterize what is common in the subject's process of appropriation of different types of artifacts and what elements depend on the use of a particular device.

CONCLUSION

This contribution provides important information for both medical communities and biomedical engineers to discuss the process and ways to guide novice doctors to fully learn the use of the tool, and to improve the design of the tool. The distinction between an artefact and an instrument or tool is key to comprehend how the subject, a medical doctor in this case, develops knowledge about the artifact itself, its uses to transform such artifact into an instrument or problem solving tool. In particular, it became important to foster a full collaboration between both communities in designing and developing an expertise in using artifacts in medical practices. That is, it becomes important to consider users in the design of an artifact and also to involve them in the process by which users transform the artifact into an instrument. Design-in-use captures the idea that design and use is a continuous process that never ends. In addition, thinking of users' appropriation process of artifacts as an essential component of the artifact design implies to take into account information regarding how that appropriation takes place and could be achieved and monitored. This consideration or integration could be of benefit for both communities, engineering and medical communities, in terms of addressing and solving users' appropriation issues through a continual collaboration.

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KEY TERMS AND DEFINITIONS

Artifact: A material or physical object designed to sustain and improve human activities.

Catheter: A medical artifact that is inserted in a patient body to treat a disease or to perform a surgical operation.

Cognitive Scheme: The subject's internalisation of actions to use the tool in practice and to anticipate and respond to emerging actions and to comprehend what the user is doing with the tool.

Community of Practice: A group of people or special interest group involved in activities to promote individual and collective learning. Problem solving activities are key in learning communities.

Engineering Design: A goal oriented activity to create and design human-made products under constraint such as nature and science principles, time, money, sustainability, materials and ergonomics.

Instrument or Tool: An Artifact becomes a tool or an instrument when its user develops cognitive schemata to incorporate them into its social or discipline practices.

Stent: A medical artifact that is inserted into a natural conduit in a patient body to prevent or to treat a disease.

Tool Appropriation: The process by which the user transforms an artifact into an instrument. Thus, the tool or instrument becomes a user's functional organ formed by an artifact and a psychological component.

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Chapter 21

Trends in Health Care Information Technology and Informatics

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ABSTRACT

It was not until 1994 that the United States healthcare industry established information systems capable of handling a universal delivery system. The healthcare industry has been one of the unhurried organizations to embrace the computer revolution in regards to patient care. Healthcare comprises of the use and management of a profusion of information that must be collected, managed, reviewed, processed, and mined. Technology changes rapidly and maintaining the status quo in healthcare actually means falling behind, and health organizations cannot afford to do that in a technology-driven world. This chapter investigates the trends in healthcare information technology and informatics. The chapter will consist of the following sections: background; issues, controversies, and problems; solutions and recommendations; future research directions; and finally the conclusion. This will enhance the field of health information and technology and its influences on all aspects of health organizations and society in general.

INTRODUCTION

It was not until 1994 that the United States (U.S.) health care industry established information systems capable of handling a universal delivery system. These Information Technology Systems (ITS) operated along enterprise and system boundaries in the Health Care Delivery System (HDS). ITS have become fragmented by the proprietary business benefits of large vendors that want to control patient information (Accenture, 2001). Practical tools, especially computers, continue to be created and rapidly placed in industry with the ability of organizations to accept, accommodate, and even embrace technology

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moving at a varied pace (McHaney, n.d.). The health care industry has been one of the unhurried organizations to embrace the computer revolution in regards to patient care. Health organizations have been using computers for years in business departments. Health care comprises the use and management of a profusion of information that must be collected, managed, reviewed, processed, and mined (McHaney, n.d.). Technology changes rapidly and maintaining the status quo in health care actually means falling behind; and health organizations cannot afford to do that in a technology-driven world (Rutsky, 1999).

The implications facing health organizations are driven by the substantial pressure to implement Health Information Technology (HIT) systems that have “certified” Electronic Health Records (EHRs) applications and that fulfill the federal government’s definition of “meaningful use” or risk significant financial penalties in the near future (Ford, Menachemi, Huerta, & Yu, 2010). To offset this pressure and cost, every hospital in the U.S. is eligible for a minimum of \$2 million incentive with larger hospitals eligible for more funds to purchase and incorporate EHRs (Bau, 2011). With this in mind, health organizations such as larger hospitals located in urban areas, and teaching hospitals are implementing EHRs at a quicker rate (Jha et al, 2009). In 2014, research found approximately 38 percent possibly eligible hospitals achieved meaningful EHR implementation by the end of 2012 (Diana et al, 2014). The Health Information Technology for Economic and Clinical Health Act (HITECH) of 2009 is driving fundamental market and industry changes that health organizations need to be strategically poised to deal with and implement. This chapter investigated the trends in health care information technology and informatics related to patient care. The chapter will consist of the following sections: background; issues controversies, and problems; solutions and recommendation; and future research directions in health care.

BACKGROUND

Health care expenditures have amplified melodramatically during the past 50 years, mutually in total terms and as a share of Gross Domestic Product (GDP) (Center for Medicare and Medicaid Services [CMS], n.d.). Expenditures in the U.S. health care segment computed over \$2.7 trillion in 2011, increasing from up the \$698.3 billion expended in 1980, increasing by a factor of 3.9. Health care expenditures in 2011 attributed for 17.9 percent of GDP, resulting in doubling of the shares from 1980 (CMS, n.d.). These expenditures have led to Quality Management for Health Care System to make available a structure to aid health organizations in communicating, monitoring, and incessantly advancing the whole HDS (James, n.d.). The vision for the Center for Medicare & Medicaid Services (CMS) Quality Strategy is to optimize health outcomes by leading clinical quality improvement and health system transformation. This has resulted in and gives indication back to the very suggestion that a systematized system to achieve high quality care can be a front-runner to lowering health care costs (James, n.d.).

The Patient Protection and Affordable Care Act (PPACA) entails 10 separate legislative Titles, with more than a few major goals. As it relates to quality, the goal is to increase health-care value, quality, and efficiency, while dropping lavish expenditures and creating the health-care system more accountable to a varied patient population (Rosenbaum, 2011). Also, the Act invests in the development of a multi-payer National Quality Strategy to create multi-payer quality and efficiency procedures to stimulate worth procuring, better safety, and all-embracing health information across public and private insurers (Public Law 111-148, 2010). In the long run, this will build on the HITECH Act, which was ratified into law in 2009 as measure of the American Recovery and Reinvestment Act (ARRA) (Public Law 111-5, 2009).

Trends in Health Care Information Technology and Informatics Issues, Controversies, Problems

Today's digital technology plays a significant role, permitting the storage and rapid retrieval of patient records and other important information. At the same time, patients expect their sensitive personal information to be handled appropriately, to ensure accuracy and confidentiality (Hall, 2014). Privacy and security is a humongous concern for a hospital's network infrastructure. Implementing security systems to prevent data breaches and leaks, keep Patient Health Information (PHI) secure, and managing the secure transmission of electronic medical record data are all major issues in the industry. Management must continue addressing ethical and legal issues with regard to control of information. In multifaceted health care organizations, management is realizing efficiency goals assist with meeting more intricate goals (Prior, 2006).

Due to the economic crisis of 2008, the American Recovery and Reinvestment Act (ARRA) of 2009 directed nearly \$150 billion in new funds to the health care industry. According to Health care IT News (2015), it included \$87 million for Medicaid, \$24.7 billion to subsidize private health insurance for people who lose or have lost their jobs, \$19.2 billion for health information technology, and \$10 billion for the National Institutes of Health (NIH). Also, the Act provided \$650 million to support prevention and wellness activities targeting obesity, smoking, and other risk factors for chronic diseases. Subsequently, it obligated \$500 million for health professions training programs to include \$300 million for revitalizing the National Health Service Corps (NHSC) (Health care IT News, 2015). This will allow promoting the foundation for performance reporting on a system-wide source so that patients can more readily get information about their own health care and how their health-care providers perform.

ARRA funding was designated to modernize the health care system by promoting and expanding the adoption of HIT. The federal government stated achieving this goal would reduce its health costs by more than \$12 billion over the next 10 years (Sandlot Solutions, 2014). ARRA targeted funds at implementing a national infrastructure for health information technology. ARRA allocates \$19.2 billion to increase the federal coordination of that effort and the use of electronic health records (Portfolio Media, Inc., 2009). Politicians are still arguing over its efficacy. Opposition continues to state that say the stimulus was too big or too small and the government should have allocated those billions of dollars more prudently (Gura, 2014).

According to Blumenthal (2010), the HITECH Act of 2009 is an attempt to improve the performance of health care systems through the use of technology, such as EHR's. The HITECH Act is focused on health organizations using certified EHRs. The HITECH Act was touted to expand the federal government ability to establish a national electronic patient records system by 2014 (APA Practice Organization, 2014). This allows the Department of Health and Human Services (HHS) to have the authority to institute programs for improving health care quality, safety and efficiency through the advancement of HIT (HealthIT.gov, 2014). The HITECH Act provides for enforcement and penalties for violation of privacy and security standards, including permitting enforcement through state attorneys general (APA Practice Organization, 2014).

Patient implications include reduced cost and better quality of care. The HITECH Act of 2009 supports health care quality improvement and cost reductions. This falls in line with the PPACA. An example is the required functions of EHRs being aligned "to requirements for emerging models of health care delivery improvement, including "patient-centered medical homes," a term for health care providers who emphasize partnerships between patients, their physicians, and Accountable Care Organizations" (Bau,

2011, p 1). The Act has the ability to involve patients and health consumers in their own self-care, even rallying entire communities into more patient self-awareness. In addition, PPACA has come up with a Duals MediPlan, where only some regions and specific states have the luxury to take advantage of these benefits. The Dual-Medi services provide in-home care and other services that Medicare and any other plan will not cover (Senior Quote, 2014).

The PPACA launched the Institute for Comparative Clinical Effectiveness Research to support the type of research essential to identifying the most appropriate and efficient means of delivering health care for diverse patient populations (Public Law 111-148, 2010). All the way through, these ingenuities foster improved quality and materials that underline hard work to accumulate statistics about health and health-care inequalities. This permits the country to enhance measure advancement, for the populace as a total and subpopulations with prominent possibility for reduced health consequences (Rosenbaum, 2011). Quantities of health care assistances are mandated by either federal law, state law, or both. Between the federal government and the states, there are in the neighborhood of 2,000 health insurance mandates (Bihari, 2014).

According to Dingley, Daugherty, Derieg, & Pershing (2008) effective communication among health care professionals is challenging due to a number of interrelated dynamics:

- Health care is difficult and volatile, with professionals from an assortment of disciplines involved in providing care at various times, often dispersed over several locations, creating spatial gaps with limited opportunities for regular synchronous interaction (Zwarenstein & Reeves, 2002).
- Health care providers often have their own disciplinary view of what the patient needs, with each provider arranging the activities in which they act independently (Zwarenstein & Reeves, 2002).
- Health organizations have traditionally had a hierarchical organizational structure, with substantial power distances between physicians and other health care professionals. This commonly leads to a culture of inhibition and restraint in communication, rather than a sense of open, safe communication (psychological safety).
- Differences in education and training among occupations in the health care field often result in different communication styles and methods that further complicate the scenario and render communications ineffective.
- Teamwork and effective communication are crucial for safe patient care; however, the educational curricula for most health care professions focus primarily on individual technical skills, neglecting teamwork and communication skills.

Table 1 is factors that lead to the requirement to implement health-authorities interconnection infrastructure. Furthermore, these factors may be seen as the targets that are and will be accomplished (Lampsas, Vidalis, Papanikolaou, & Vagelatos, 2002).

SOLUTIONS AND RECOMMENDATIONS

Technology in the form of software and hardware has given the health care industry the opportunity to transform services. Regulations and technologies have given patients control over their care and the autonomy to choose innovative physicians able to deliver personal service. Continuous adherence to

Table 1. Benefits of using information and communication technologies in the health care sector. from Implementation and Integration of Regional Health care Data Networks in the Hellenic National Health Service, by Lampsas, Vidalis, Papanikolaou, & Vagelatos (2002)

Health Care Players	Benefits
Administration Units	• Policy development and decision-making are strongly supported by effective and on-time information gathering and distribution. • Easier adaptation to eEurope challenges. • Supply control; better budget monitoring. • Overall improvement in the way citizens are served.
Hospitals	• Increased efficiency in communication between hospitals, administration units, social security services, careers, physicians, and citizens. • Personnel familiarization with information technologies through Internet-access operations. • Patient-record traffic support. • Reinforcement of the need to build health care information systems (HCISs) and local networks in hospitals. • Utilization of the developed Intranets. • Better information services for the citizens. • Advanced telematics services (i.e. telemedicine applications in difficult-to-reach regions).
Health Care Personnel	• Meets the increased need for telecommunications not only for medical, but also for compensation reasons. • Participation in care chains and relevant coordination. • Physicians' collaboration. • Patients' history data retrieval. • Continuing education services; familiarization with new technologies through special training programs. • Interaction with patients to provide advice or prescriptions.
Citizens	• Use of the Internet for health-related information retrieval. • Information and communication technologies will increase interest in citizens' health-issues management. • Creation of the appropriate infrastructure for future provision of special health services for specific population groups (eg, in-house services for older people or patients with long-lasting attendance and nursing needs).

government requirements and insurance carrier demands requires software, hardware, and related components to ensure success. Health care organizations need to safeguard patient information with secure storage of all compliance-related documentation. This includes ensuring the ability to control access, add, or modify records from patient information to billing and reconciliation of data. Health Insurance Portability and Accountability Act (HIPA) and ARRA affect the various health care organizations.

Prohibiting the disclosure of records without the written consent of the individuals is essential unless one of the twelve disclosure exceptions listed in the Act applies. The Privacy Act of 1974 created the System of Records Notices (SORNs). This moved onto the Privacy Impact Assessments (PIAs), the "E-Government Act of 2002 that required government agencies to assess the impact on privacy for systems that collect personally identifiable information in PIAs" (U.S. Department of Health & Human Services [HHS], n.d., para 6.). Prohibiting the disclosure of records without the written consent of the individuals is essential unless one of the twelve disclosure exceptions listed in the PPACA applies. There needs to be a thorough look at integrated health care systems and installation of computer networks by health organizations.

It is mandatory on Information Technology (IT) to meet provider demand for more modern and efficient communication technologies, while maintaining patient privacy and complying with security and regulatory requirements," as concluded by the team of researchers (Ponemon Institute, 2014). Overpoweringly, respondents of the Ponemon Institute study agree that substantial time is wasted and it is

now up to hospitals to embrace technology by coming up with appropriate and compliant approaches. Table 2 summarizes the annual productivity and economic impact of inefficiency in communication and collaboration.

Ponemon Institute (2014) study found three areas of opportunity that can be improved with communication and collaboration:

- **Patient Admission:** Admitting one patient takes about 51 minutes, which an average of 33 minutes (65 percent) is wasted due to inefficient communications. This translates into an annual loss of about \$728,000 per U.S. hospital.
- **Emergency Response Coordination:** Coordinating an emergency response team takes an average of 93 minutes per patient. Of this time, an average of 40 minutes (43 percent) is wasted due to inefficient communications. This equates to an annual loss of more than \$265,000 per U.S. hospital.
- **Patient Transfer:** Transferring a patient to another facility or home care/hospice takes about 56 minutes, if all approvals are given in a timely manner, which an average of 35 minutes (63 percent) is wasted due to inefficient communications. The total annual cost of this waste is about \$754,000 per U.S. hospital (p. 2).

FUTURE RESEARCH DIRECTIONS

At the national level, most nations must reconsider their e-health strategies, according to the new trends and requirements, to adopt the developed standards, and introduce certification procedures for use of all Information Technology and Communication (ITC) applications in health care (Mihalas, 2014). Potential medical applications in public health and in the “ever-lasting health care reform” determined the creation or development of ITC compartments. The ITC elaborates or develops national/regional strategies for implementation of IT in health care/medical activities (Mihalas, 2014). In European countries, the old trend in biomedical/health informatics was to analyze the courses presented to the students for medical students/computer science students or future Health care Informatics Professionals (HIPs) (Mihalas& Lungeanu, 1997). The new trend is numerous European countries introducing doctoral level degrees in

Table 2. Economic impact for the U.S. health care industry resulting from Communications Inefficiencies Sector from The Imprivata Report on the Economic Impact of Inefficient Communications in Health care, by Ponemon Institute (2014 p. 3).

Workflows	Extrapolated Annual Cost of Inefficient Time per Hospital	Number of Registered Hospitals ²	Extrapolated Annual Impact for the Industry (U.S. \$ Billions)
Patient Admissions	\$727,957	6.409	\$4.67
Emergency Response	\$265,254	6.409	\$1.70
Patient Transfers	\$753,755	6.409	\$4.83
Total	\$1,746,966	6.409	\$11.20

¹United States Bureau of Labor Statistics, Occupational Employment Statistics May 2012.

²American Hospital Association May 2014 Update on the number of registered U.S. hospitals

medical informatics. This includes a universal approach to medical informatics courses and specialized medical/health informatics schools being at both undergraduate and master levels (Hasman, Mantas, & Zarubina, 2014). Continually, IT applications refer to 'big data', which is the enormous amount of data collected that requires applicable infrastructure such as cloud computing, as an impression on countless ITC applications in health care. This includes the national health care plans and strategies (Shimrat, 2009).

During research studies mobile devices were shown to improve communication between doctors and nurses on inpatient wards (Ozdalga, Ozdalga, & Ahuja, 2012). A study by Wallace, Clark, and White (2012) of medical school health care providers and students revealed that over 80 percent of those who responded described using mobile devices to communicate with colleagues about patient care via e-mail, telephone, and text messages. According to Mickan, Tilson, Atherton, et al. (2013), doctors have reported that the use of a mobile device for retrieving information from drug databases led to more efficient decision-making and patient care. They discovered that mobile devices have the ability to increase quality of patient documentation through fewer errors, more complete records, rapid access to new information, and improved workflow patterns (Mickan, Tilson, Atherton, et al. 2013).

There should be further research on smart devices and their capabilities in communication, assessing, and documenting patient information. It is important to look at the future and the use of medical or health care systems applications becoming more useful in the prevention and management of chronic health conditions, such as diabetes, obesity, and heart diseases. Electronic health applications are electronic tools that utilize information technology to store, manage and share health information (Tang, Ash, Bates, Overhage, & Sands, 2006). One of the most widely known electronic health applications is EHRs, which is an official health record that is digitized for patients to be shared across multiple health care organizations. Mobile device hardware and applications should continue getting better and more user friendly, bringing additional and enhanced benefits to clinical practice (Mickan, Tilson, Atherton, et al. 2013).

CONCLUSION

This chapter investigated the trends in health care information technology and informatics related to patient care. The chapter consisted of the following sections: background; issues controversies, and problems; solutions and recommendation; and future research directions in health care. The term smart devices will be used interchangeably with mobile devices such as smart phones, tablets and iPads; each commonly used by the general public which includes health care providers. Not all health care providers are eager to adopt mobile devices even though they have the potential to increase access to point-of-care tools that has been proven to support better clinical decision-making and improved patient outcomes (Divali, Camosso-Stefinovic, & Baker, 2013).

Information and time management has been the most frequent uses for mobile devices. Popular information management applications, such as Evernote and Notability, allow users to write or dictate notes, record audio, store photographs, and organize material into categories within a searchable electronic database (O'Neill, Holmer, Greenberg, & Meara, 2013). This allows for better documentation of patient records. Research has indicated that mobile devices improve the completeness and accuracy of patient documentation (Payne, Wharrad, & Watts, 2012). Mobile devices were judged higher than documentation using paper records (Mickan, Tilson, Atherton, et al. 2013). Ultimately, their study found a significant increase in the average rate of electronic prescribing, from 52 percent to 64 percent ($P = 0.03$) with the use of mobile devices (Mickan, Tilson, Atherton, et al. 2013).

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KEY TERMS AND DEFINITIONS

American Recovery and Reinvestment Act (ARRA): Had three immediate goals: to create new jobs and save existing ones, to spur economic activity and invest in long-term growth and to foster more accountability and transparency in government spending (Blumenthal, 2010).

Clinical Effectiveness: Application of interventions which have been presented to be effective to appropriate patients to improve patients' outcomes and value for the use of resources (National Institutes of Health, Health & Human Services, 2014).

Gross Domestic Product (GDP): Represents the monetary value of all goods and services produced within a nation's geographic borders over a specified period of time.

Health Information for Economic and Clinical Health (HITEACH) Act of 2009: Requires certified Electronic Health Records (EHR's). This requires providers to commit continued use of EHR technology over a period of years. There are no measurable thresholds and programmatic timelines (Joseph, Sow, Furukawa, Posnack, & Chaffee, 2014). However, the certification process for EHR vendors has reduced provider uncertainty by establishing an unbiased validation service to ensure that certain functionality is available. Providers have to meet certain criteria of "meaningful use". To an extent that has put the market and not the federal government in determining the vendors that will meet the provider needs with the financial incentives (Joseph, et al., 2014).

Health Insurance Portability and Accountability Act (HIPA): Act created by the U.S Congress in 1996 that amends both the Employee Retirement Income Security Act (ERISA) and the Public Health Service Act (PHSA) in an effort to protect individuals covered by health insurance and to set standards for the storage and privacy of personal medical data.

Patient Protection and Affordable Care Act (PPACA): The health care interrelated portions of the Health Care and Education Reconciliation Act of 2010 and the Student Aid and Fiscal Responsibility Act were also affirmed into law end to end with the PPACA. These Acts seek to overhaul the current healthcare system. "ObamaCare" H.R. 3590, or Affordable Care Act (ACA) for short turned out to be the largest renovation to healthcare reform since Medicare/Medicaid which was signed into law in 1965(Obamacare Facts, n. d.).

Privacy Act of 1974: This act "protects records that can be retrieved by personal identifiers such as a name, social security number, or other identifying number or symbol" (HHS, n. d.).

System of Records Notices (SORNs): "Required health organizations to create and maintain SORNs. "A system of records consists of any item, collection, or grouping of information about an individual, where those records can be retrieved by the name of the individual or by some other type of identifier unique to the individual" (HHS, n. d.).

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Chapter 22

User Resistance to Health Information Technology

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ABSTRACT

The use of information technology (IT) in healthcare to improve outcomes is now a global phenomenon. If effectively implemented and efficiently leveraged, these technologies will greatly lower healthcare costs, improve safety, and elevate the quality of health. Nevertheless, health IT implementation and adoption continues to meet challenges. Reports show that physicians, nurses, and other healthcare professionals continue to resist health IT. Researchers have proposed models to explain this notion, and till date, there still is a lack of an overarching paradigm to view the concept. Resistance is a complex phenomenon that defies simple explanation and analysis. It requires well-accepted theories or paradigms encompassing the full range of variables associated with it. Understanding and mitigating user resistance is a great step toward improving sector-wide adoption. In this chapter, the authors survey extant theories of resistance and provide a paradigmatic lens for leveraging this knowledge to practical solutions in health IT adoption.

INTRODUCTION

The vision to use information technology (IT) in healthcare to improve outcomes has been adopted by many a nation, including, the United States. If effectively implemented and efficiently leveraged, these technologies will greatly lower healthcare costs, improve safety concerns, and elevate the quality of healthcare (Blumenthal & Tavenner, 2010). No doubt, several industrialized nations are making significant investments in healthcare costing a substantial portion of their national gross domestic product (OECD, 2011). Recently, these investments have been in the area of health IT. Socio-economic factors such as aging population, increasing need for better healthcare, and rising health care costs have pressured governments to consider controlling costs while improving care (Romanow, Cho, & Straub, 2012).

Nevertheless, health IT implementation and adoption has met with its fair share of challenges. Reports show that physicians, nurses and other healthcare professionals continue to resist the use of technology within healthcare (Laumer et al., 2016; Dinev et al., 2016; Petrakaki et al., 2016). Researchers have

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proposed models to explain the *how* and *why* of user resistance to IT, and till date, there still is a lack of an overarching paradigm through which to examine this phenomenon. Hirschheim and Newman (1988) noted that resistance is a complex phenomenon which defies simple explanation and analysis; thereby requiring well-accepted theories or paradigms encompassing the full range of variables associated with an individual user's resistance of IT (Martinko, Henry & Zmud, 1996). If not for anything else, governments and the healthcare sector need a return on investment on these systems that have been implemented. Understanding and mitigating user resistance is a clear step forward in improving sector-wide adoption.

This paper surveys extant literature on resistance, synthesizes its theories, and provide a paradigmatic lens for leveraging this knowledge in the practice of healthcare IT implementation. It is hoped that this study will not only increase theory-based understanding of the subject, but that it will provide managerial guidance for change managers and project leaders who live the effects of user resistance in practice. The rest of this paper is structured thus: a methodological as well as contextual background of the paper is set forth, the theories of resistance are then synthesized and analyzed, and the implications of the study are discussed.

BACKGROUND

In order to delimit the scope of this research, to synthesize and to analyze extant literature, we use Cooper's (1988) taxonomy of literature reviews. This model (Cooper, 1988) proposes a taxonomy of reviews based on six categories, namely: the focus, goal, perspective, coverage, organization, and audience of the literature. Given the objective of this study, the literature was reviewed with varying emphases based on Cooper's taxonomy. To achieve this, the review focused on different theories and models of resistance, and highlight the unique perspectives that these theories offer about the phenomenon. First, we discuss a contextual background in the United States healthcare reform that has triggered nation-wide organizational change leading to resistance.

The Meaningful Use Reform and Change

On July 13, 2010, the United States administration rolled out a five-year transition plan for the U.S. healthcare industry to move from paper health records system to electronic health records. Over a ten-year period, the U.S. government plans to invest about \$70 billion to help the healthcare sector in this transition process (DHHS Press Release, 2010). This governmental mandate has been named, the Meaningful Use policy. It is arguably the greatest organizational change trigger in the U.S. healthcare system to date. Summarily, this reform program set the standards for health IT definitions, guidelines, and implementation.

The introduction of HIT into the healthcare industry has been associated with distinctive changes. Lorenzi et al. (2000) describes possible changes that typify healthcare organizational change namely:

- Operational changes. These affect the way the ongoing operations of the business are carried out, such as the automation of a particular area.
- Strategic changes. These occur in the strategic business direction, e.g., moving from an inpatient to outpatient focus.

- Cultural changes. These affect the basic organizational philosophies by which the business is conducted, e.g. implementing continuous quality improvement system in a clinical environment.
- Political changes. These involve staffing that occur primarily for political reasons of various types, e.g. those that occur at top patronage job levels in government agencies.

THEORIES AND CONCEPTUALIZATIONS OF RESISTANCE TO IT IN RESEARCH

User resistance to information technology is defined as a user's insistence to not use new IT. It is seen as a user's attempt to minimize his or her outputs while attempting to maximize and increase others' inputs (Joshi, 1991). This resistance, according to Markus, (1983) may range from subtler manifestations of resistance as passivity, misuse, low levels of use, and lack of use to harmful use (Marakas and Hornik, 1996; Martinko et al., 1996; Selander and Henfridsson, 2012). Marakas and Hornik (1996) discuss a form of resistance in which behaviors take "the form of overt cooperation and acceptance of the proposed system combined with covert resistance and likely sabotage of the implementation effort" (p. 208). Lapointe and Rivard (2005), on the other hand, mention the more overt side of resistance with scenarios where users "delivered an ultimatum, demanding that the system be withdrawn" (p. 477). In this study, resistance refers to covert or overt behaviors that oppose change towards the use of- or avoidance of an information system manifested as reactance, distrust, scrutiny or inertia (Ngafeeson, 2013).

The Interaction Theory

Markus's (1983) pioneering research in user resistance to information systems (IS) is arguably the departure point for most IS resistance research. Her seminal work basically responded to the question as to *why* people resist IS. Three types of theories are proposed: first, people are said to resist technology because of internal factors inherent in those who resist or their organizations. Second, resistance stems from external factors emerging from the introduced system. Lastly, resistance may also stem from the interaction of both internal and external factors. Markus termed the latter, the "interaction theory." While the theory of the interaction between the subject of resistance and the object of resistance was not entirely new, Markus's work discusses this theory within an IT context.

Arguing from a group level and organizational level perspective, Markus (1983) demonstrates the importance of the interaction theory in understanding user resistance to information technology. Markus established a model which showed the interplay of power within the organization following the implementation of a new system. According to Markus, the interaction of an individual's characteristics with the specific system design features and the organizational context will determine user resistance. Markus then describes and evaluates these sets theories based on the underlying assumptions and tests them with data from a case study. Results showed that the interaction theory was a superior theory for explaining resistance for implementers than just from the technology or from the individual/organizational perspective.

Markus contends that the interaction theory is important in analyzing, diagnosing and finding solutions to organizational resistance to change introduced by information technology. This conceptualization, however, is limited in two significant ways: it views resistance from purely a political sense, and is likely to be more applicable for systems that are implemented across departments (Joshi, 1991).

The Equity Implementation Model (EIM)

Another significant theoretical model, the equity implementation model (EIM), was posited by Joshi (1991). Derived from the equity theory, the EIM attempted to explain resistance to change from a fairness perspective. The EIM proposes that individuals attempt to evaluate most changes. The changes considered as favorable are generally welcomed, while those considered as unfavorable are likely to be resisted. In a similar way, the equity theory suggests that in an exchange relationship, individuals are constantly concerned about inputs, outputs and fairness of the given exchange. Hence, individuals are continuously comparing themselves with referent others and peers to assess if net gains are same. When these persons, therefore, experience a net loss in equity, the equity theory suggests that the people are likely to become distressed. This distress caused by inequity then leads the concerned individual to resist the change by lowering his or her inputs while trying to minimize the outputs of others. Building on the equity theory, Joshi (1991) proposed a three-level analysis of equity namely: a comparison of self with self, a comparison of self with employer, and a comparison of self with co-workers. According to the EIM, users will resist use, if inequity was perceived at any of these three levels, following the introduction of a new system.

In summary, EIM postulates that people analyze equity at three major levels, namely: at *self*, *organizational*, and *peer* levels. At level one (*self*) equity evaluation, individuals compare their inputs with outputs and calculate their net gains. If the new system brings with it net gains in equity such as less tension and better working conditions, the individual is more likely to embrace the change. On the contrary, if the system brings the individual a net loss in equity such as loss of seniority or increased workload, then the individual is likely to oppose change. At the second level of equity (*organizational*) evaluation, an individual compares equity net gains, in much the same way as at the first level: only this time, the individual compares their personal net gains to that of the organization. If the net gains are positive, change is welcome; but if the individual perceives that the organization's net gains are more than theirs, resistance is likely to result. A third level of analysis (*peer* level) is also proposed in which an individual compares their net gains with those of their peers and referent others after the introduction of the new system. Here, the user asks questions like: "Does the new system treat each user equitably? Or, does it increase others' equity while lowering those of others?" If the assessment is that personal equity is increased, change is received; otherwise, it is resisted.

A possible critique for using the EIM as a stand-alone model for explaining resistance is that inputs and outputs are difficult to name and measure. This is especially so because these inputs and outputs could be tangible as well as intangible—the measure of which might be as challenging as impossible. As Joshi (1991), himself, states: "the nature of changes may also make it difficult for users to make objective assessment." This suggests that, a need for a model that would be sensitive to other types of changes is a welcome necessity.

The Attributional Model of Reactions to IT (AMRIT)

Martinko, Henry and Zmud (1996) begin their theory-building process on the premise that, hitherto, there had not been any "well accepted theory or paradigm encompassing the full range of variables associated with an individual user's resistance of IT" (p. 313). Drawing from extant research in social psychology and organizational behavior, Martinko et al. (1996) proposed an attributional model to explain IT

resistance (AMRIT). Based on previous literature that utilized the attribution theory and learned helplessness, Martinko and associates develop a model that they suggest could serve as a “basis for a more comprehensive theory” of worker resistance to the introduction of new technology in the workplace. According to the attribution theory, an individual’s behaviors are a function of his or her beliefs about the possible outcomes. More specifically, it looks at the perceptions of what causes these outcomes. The AMRIT posits that individuals’ attributions are informed by their experience with successes and failures. It suggests that individuals interpret their behaviors in terms of the causes. Consequently, their behaviors in the future are constructed from the expectancy that comes from these attributions. In other words, success or failure with prior implementation of a technology may cause implementers to develop certain attributions to why this happened. These attributions then create certain expectations with regard to the technology’s efficacy, leading to behaviors or feelings about the system that can be either negative or positive. Like many of the other models before this one, the Martinko et al.’s (1996) model shed more light on the nature of IS user resistance; however, this conceptualization ended at a purely conceptual level.

The Lapointe and Rivard (2005) Model (L-R)

Lapointe and Rivard (2005) examined group resistance dynamics at three levels namely: pre-implementation, during implementation, and post-implementation of an IS. The L-R model was developed to explain a multilevel dimension of resistance to IT implementation; arguing from the perspective that previous models had only looked at resistance at one level of the organization instead of examining different levels of the organization. Building on existing research, the L-R model, has proven to be an important model for a closer examination and extension. In summary, the L-R framework posited that resistance to an information system results from perceived threats which in turn evolve from a complex interplay of political and interpersonal/group factors resulting from people’s interaction with an IS. Lapointe and Rivard (2005) termed these “interaction effects”, initial conditions. Simply put, when an individual or an organization interact with a newly installed technology in the workplace, resistance targeting either the technology itself, the advocates of the technology or the significance of the technology may result. The L-R model also posited that resistance to information technology is mediated through *perceived threats*. The L-R model serves as a generic process model that provides a good departure point for more empirical investigation. For one thing, the L-R model incorporates previous frameworks and deals with user resistance from a multilevel and process perspective.

The Status Quo Bias Theory

The status quo bias perspective was proposed by Kim and Kankanhalli (2009). It is one of the few theoretical models of resistance to information technology that has been proposed and empirically tested. Kim and Kankanhalli (2009) contended that people resist an information system due to their desire to stay in their current state or *status quo*. In other words, people exhibit a bias towards maintaining their “old habits” when confronted with the choice of change (see Hsieh, 2015).

In the context of technology-enabled change, therefore, the *status quo* bias perspective holds that people may resist the implementation of new technology, for the sole purpose that they are comfortable with the current state. Because of this desire to maintain the *status quo*, they judge the decision to change

as a cost associated with this change, rather than the benefits thereof. By testing their model within the context of a new enterprise system, Kim and Kankanhalli (2009), found that the cost of switching to a new system from an old one caused user resistance. The attempt to empirically test user resistance of IS was probably the hallmark of Kim and Kankanhalli's (2009) work.

IT Conflict-Resistance Theory (IT-CRT)

Situating their research within a pre-implementation context, Meissonier and Houzé (2010) propose the IT conflict-resistance theory and use the framework as a basis for a two-year action research project. The research suggests that pre-implementation resistance to IT could be used as a gauge to assess possible post-implementation concerns. Resistance in this sense, therefore, is seen as positive tool for technology acceptance in the post-implementation phase.

Like previous works, Meissonier and Houzé (2010) highlighted socio-political factors as well as task-oriented factors as salient determinants of conflict and resistance. However, being an action research in itself, the conceptual model proposed, suggests a more heuristic and practical approach to the topic than a testable concept.

Cynicism Theory

Selander and Henfridsson (2012) conceptualized *cynicism* as resistance. Building on the Lapointe and Rivard (2005) process framework, Selander and Henfridsson (2012) propose three dimensions of user cynicism as the precursors of resistance. They argue that cynicism is a remote form of resistance that is not mediated through *perceived threats*, but is rather manifested as a form of *passive resistance*. They also suggest that cynicism, being a passive resistance in itself, could escalate to other forms of resistance. The three dimensions of cynicism conceptualized were *cognitive distance*, *negative affect*, and *seeing through espoused claims*. *Cognitive distancing* here refers to the way employees of an organization alienate themselves from the management's policies and stance. *Negative affect* on the other hand is defined to involve negative emotions towards managerial behavior including defeatism, betrayal, and disillusionment. *Seeing through espoused claims* supposes that the employee possesses knowledge of how things could better be done and is aware of managerial inconsistencies and repudiates these assertions.

In sum, Selander and Henfridsson (2012) contend that these three dimensions of user cynicism constitute a form of *passive resistance*. Using this framework, they built upon the Lapointe and Rivard (2005) framework. Their work however deferred from the Lapointe and Rivard model in that it completely ignored *perceived threats* as mediator between *initial conditions* and *resistance*. Like other models before it, it remained at a purely conceptual level: suggesting three antecedents of user resistance, but going no further.

Alternative Theories of Resistance

The following section discusses theories that either have been used to explain user resistance, but have not been leveraged in IS literature, or theories that inform our knowledge of user resistance, albeit not fully. Some of these theories include: the technology acceptance model, the psychological reactance theory, and the cognitive dissonance theory.

The Technology Acceptance Model (TAM)

TAM has been used to predict user acceptance of technology in different IS studies (Venkatesh & Davis, 2000; Mathieson, 1991). TAM is based in the *theory of reasoned action* (Fishbein & Ajzen, 1975) and is now widely regarded as the standard model for examining *technology acceptance*. Because of the failure by employees to accept and use technology, organizations as well as technology vendors see *user acceptance* of technology as crucial to organizational survival. The TAM in its simplest form suggested that *perceived usefulness* and *perceived ease of use* would predict *user acceptance* of an information technology. In other words, Davis (1989) posited that the acceptance or rejection of a technology is a function of how individuals perceived that the technology would be either useful or how easy it could be to use the given technology.

The Psychological Reactance Theory (PRT)

Another alternative explanation of resistance is the PRT. Brehm's PRT is one of the most widely accepted resistance theories in social psychology. It has also been widely used to explain resistance and persuasion—its antithesis. PRT is built around the notion of “free behaviors” and “freedoms” It assumes a “conservative stance on people's desire for change” (Brehm & Brehm, 1981, p. 25). The PRT is based on the assumption that individuals generally believe that they have specific *behavioral freedoms*. When these freedoms are threatened, individuals are aroused by the motivation to reassert their freedoms. The *psychological reactance theory* assumes that people's behaviors are motivated by the desire to protect their “freedom” to carry out a particular behavior in a particular context. This “protection” of freedoms is then manifested as resistant behaviors.

The Cognitive Dissonance Theory (CDT)

This theory holds that, “when an individual holds two or more elements of knowledge that are relevant to each other but inconsistent with one another, a state of discomfort is created” (Harmon-Jones et al., 2010). The resulting discomforting state is called *dissonance*. Because dissonance originates from the conflicting views or beliefs about one's self, the term *cognitive dissonance* is used to collectively describe the concept (Festinger, 1957; p. 9). According to the dissonance theory, this inconsistency or “lack-of-fit” of cognitions motivates the individual to be involved in a psychological effort to reduce the inconsistency between the cognitions. It is this effort to reduce inconsistency that leads to *resistance*.

According to the *cognitive dissonance theory*, user resistance can be conceptualized as follows. When an individual's intention or action to reduce inconsistency is to rationalize or support his present state of cognition: such that “new knowledge” is considered as dissonant with the individual's present cognition, the consequent behavior can be described as resistance. Simply put, resistance is an implicit or explicit intention that results to a behavior that opposes change towards a particular “new” attitude or behavior. Notwithstanding, the CDT has shortcomings. Harmon-Jones and Harmon-Jones (2002) argued that Festinger's (1957) theory stopped short of explaining *why* individuals do not like to be in a state of cognitive inconsistency.

IMPLICATIONS AND FUTURE RESEARCH

This study examined user resistance to information systems from several theoretical angles within the wider context organizational change. The claims and assumptions of relevant extant theories and models were specifically discussed. The results of the synthesis of resistance to information technology literature can be summarized as follows:

- Resistance is a complex phenomenon: requiring different theorizations for a more comprehensive understanding.
- Resistance attitudes should be studied from an unbiased perspective: that is, not regarding resistance as either positive or negative; rather, letting the context define its nature.
- Resistance attitudes may last through pre-implementation, implementation, and post-implementation phases of an information system.
- Resistance behaviors could originate from a single individual as well as groups of individuals.
- Resistance is a result of the dynamic interaction between people, technology and the processes and procedures within an organizational environment.

In general, this research showed that there is a lack of an overarching paradigm of user resistance to information systems in spite of the burgeoning alternative theoretical explanations of user resistance to IT that have been proposed. Second, there is a noticeable lack of empirical investigations. Most of the research so far has been dominated by case studies, action research and other qualitative methodologies. Consequently, many of the proposed models are yet to be validated. Third, not many studies have specifically looked into user resistance in the context of health information technology. Lastly, with the several theories and perspectives already proposed, there still is a lack of a comprehensive theoretical framework that can be tested.

Theoretical and Practical Implications of Research

This work offers implications and contributions to theory. First, the study extends the body of literature by combining social psychological theories, information systems theories and a policy framework to explain the concept of resistance. It broadens our understanding about user resistance by introducing social psychological theories that are often not leveraged in information systems to explain resistance. As has been argued by other researchers before, resistance needs to be addressed from a more comprehensive theoretical standpoint. Future research can incorporate these theoretical perspectives to better understand resistance to IT.

The study also has implications for practice. In a healthcare environment fraught with technology-induced organizational change, change managers' understanding of the importance of resistance is critical. Knowles and Linn (2004, p. 9) have suggested that understanding resistance, would shed light about the role of persuasion—its antithesis. Persuasion is seen as a very important antidote to resistance. Persuasion skills are expected, if not required of change managers' portfolio of abilities. This study provides change managers with empirically tested knowledge for decision-making.

Overall, this study points to the critical role of organizational support in the change management process. Management would need to provide sensitization, guidance, training and opportunity for em-

ployee feedback before, during and after the implementation of a new system. Just as some researchers have recommended, top management support in organization-wide implementation is critical (DeLone, 1988). Reducing threats and mitigating resistance will clearly require the need for management support.

Suggestions for Future Research

Future research could use this study as an important departure point to answer some important questions: (1.) Do specific *threats* lead to specific dimensions of user resistance? (2.) Are there more types of perceived threats that are salient to IT user resistance? (3.) Are there any other theories that can inform our knowledge on possible *initial conditions* yet to be uncovered? These are some areas in which future research could take. Additionally, finding which type of *threats* and *initial conditions* contribute to resistance during the different stages of implementation could be particularly insightful. For example, if individual factors were found to be particularly associated with user resistance during the pre-implementation phase, then, change management programs could be designed to target causative initial conditions.

CONCLUSION

The introduction of electronic health records into the United States healthcare system is expected to increase legibility, reduce medical errors, shrink costs and boost the overall quality of healthcare. Early field reports about this transition reveal that healthcare professionals including physicians and nurses are resisting the full use of these systems. This study proposed key theories from social psychology, and information systems to provide a multi-perspective look at the concept of resistance to information technology. These theories, together, explain and expound on resistance in a way that can increase our understanding. The application of these findings has the potential to improve the chances of successful IT implementation within the healthcare industry in particular.

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KEY TERMS AND DEFINITIONS

Cognitive Dissonance Theory: The theory suggests that when there exists a “lack of fit” of cognitions, a state of discomfort called *dissonance* is aroused, triggering a reaction to reduce it.

Cynicism Theory: Proposes a passive form of resistance that is not manifested through perceived threats.

User Resistance to Health Information Technology

Interaction Theory: Proposed by Markus (1983), it proposes that IT resistance stems from the interaction between people, the technology in question, and the environment surrounding the technology.

IT User Resistance: The overt or covert attitude or behavior towards an IT system resulting in avoidance, underuse or outright nonuse of an IT system.

Meaningful Use: The U.S. government mandate of 2010 requiring an eligible provider to use certified technology to meet specified government benchmark outcomes.

Psychological Reactance Theory: This theory posits that when individual freedoms are threatened, and uncomfortable emotional state is created that necessitates a return to “normal”, which may manifest as resistance.

Status Quo Bias Theory: Posits that, people, who are comfortable with the current state of affairs, may resist the change that will ensue following the implementation of a new system.

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Section 6

Medical Education, Ethics, and Law

Chapter 23

Comprehensive E-Learning Appraisal System

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ABSTRACT

The healthcare sector in the 21st century presents a big technological development. All fields of medicine are deepening their knowledge, which increases the volume of material that must be handled by professionals in each specialty. This large volume of material should be taken into account by health professionals, because it contributes to a better quality of care. The traditional way of teaching has been face-to-face classes; however, with rising technologies, virtual training via computers and virtual teachers are being implemented in some institutions. This change in the way of teaching also leads to changes in how to assess the knowledge gained through this method of learning. The aim of this chapter is to provide a small analysis of online training courses for health professionals, and deepen into an appraisal system developed to integrate different complementary variables, and how they can be implemented as a method addressed to assess online courses in a more comprehensive way.

INTRODUCTION

The healthcare sector in the XXI century presents a big technological development that covers a broad knowledge. All fields of medicine are deepening their knowledge, which increases the volume of material that must be handled by professionals in each specialty. This large volume of material should be taken into account by health professionals, because it contributes to a better quality of care

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The mode of transmission of this knowledge to professionals is usually through training courses in their own work areas (internal instruction) or outside the centers (external instruction). New technologies have entered the world of education, leading to changes in the way people teach and learn. The traditional way of teaching has been face-to-face classes; however, with rising technologies, virtual training via computers and virtual teachers are being implemented in some institutions. This change in the way of teaching also leads to changes in how to assess the knowledge gained through this method of learning.

The aim of this paper is to provide a small analysis of online training courses for health professionals, and deepen into an appraisal system developed to integrate different complementary variables, and how they can be implemented as a method addressed to assess online courses in a more comprehensive way.

BACKGROUND

Health Training

Health training is a complex field; several areas of knowledge and practice make necessary an update in instructional and teaching methodologies (Schoonheim, 2014; Frenk, 2010; Horton, 2010).

There are many examples of instructional needs in the field of health. Many medical specialties (e.g. primary care, surgery, or oncology) require continuous training and up-to-date of professionals to provide the best patient care. Doctors, nurses, and technicians, all of them attend courses or educational programs in order to improve their knowledge or skills in each specialty.

One example is Evidence Based Medicine (EBM). It is based on the principle that medical decision making is achieved by integrating the best available evidence with clinical expertise and patient values. When teaching EBM it should integrate core knowledge with clinical practical activities. This will lead to taught EBM with a variety of modes: lectures, tutorials, online, problem based or self-directed learning (Straus 2011; Del Mar, 2004).

Not only the health areas but also the professionals in medical specialties have troubles with their instruction/training. General practitioners (GPs) struggle with several barriers to the use of EBM related to insufficient knowledge and skills. They also find barriers related to their practice and patient population such as lack of time, patient-related factors or a lack of available evidence (Mayer1999; Zwolsman 2013; Te Pas 2013).

Standalone teaching improves student knowledge, but not skills, attitudes or behavior in EBM. Non randomized clinical trials indicated that integrating teaching of EBM with clinical activities (blended learning) was associated with improvements across all four domains: knowledge, skills, attitudes and behavior (Coomarasamy 2004). In the results of randomized controlled trials, the authors concluded that any form of teaching, including lecture, tutorial, self-directed, online, problem-based, multidisciplinary, was associated with an increase in EBM competency (Ilic 2014).

A comprehensive meta-analysis recently conducted by Teachers College (Columbia University) (Means 2013), indicated that students in online classrooms had moderately better performances than those receiving instruction in traditional classrooms (Milic 2016).

In the Ilic's study students's perceptions were positive about using the BL approach in teaching and learning about EBM (Ilic 2015). They developed a three-step approach (i) self-directed learning through online multimedia presentations, (ii) discussion and activities in class, and (iii) application in practice. This method was positively received by students. Students involved in the BL approach found the content

was useful, engaging and well-targeted to their level of competency and suggested that blended learning could be strengthened by introducing a journal club to small group activities early in the curriculum, providing an opportunity to learn in a group environment. This could be similar to the “forums” created on e-learning platforms to debate issues or questions about different fields of knowledge.

Some other studies appreciate that e-learning alone will increase EBM knowledge but it is not effective in increasing EBM skills and changing EBM behavior. They recommended a blended learning course, because BL includes different learning or instructional methods, different delivery methods, different scheduling and different levels of guidance (Pankin 2012). An intensive blended learning course on EBM for GP trainers enables an increase in knowledge and skills that remains after four months. However, attitude and behavior towards EBM show no differences before and after the intervention (Te Pas 2015).

Training Methods

The classical training methods consist in classroom lectures with students and teachers together. Lecture is a simple and fast method to present the vast issues addressed to a high number of learners. Some disadvantages of this method are long periods of time, inactiveness or absence of the students, or fast forgetting of the subject. When students have control over the learning methodology, it is called a “learner-centered” model of teaching. The role of the teachers in this context is to facilitate knowledge acquisition (Bahner 2012; Ruiz 2006; Boulos 2006; Koops 2011; Cook 2010).

Traditional learning must be stepped at a specific time and place and is considered essential in building a sense of community. New technologies have grown in educational world, driving to changes in teaching methods (Kemp 2014; Conole 2008).

E-Learning refers to the educational system in which teachers and students are separated by physical distance, but the technology allows them to learn together: it is the online way of knowledge. This system has its own limitations: there is no human interaction and communication regarding to a face to face classroom (Thiele 2003; Twomey, 2004). Online education is growing rapidly, providing new and useful instructional elements in different professional fields (Slotnick, 2000; Cook 2008; Hugenholtz 2008; Zolfaghari 2007). It can not only improve suitability and effectiveness for individualized and collaborative learning, but also it can provide up-to-date information through the use of interactive multimedia (Choules 2007; Cook 2007; Yu 2006; Peng 2014; Wu 2010; Moreira 2015).

E-courses are becoming more popular because of the didactical advantages they offer, such as the possibility to adapt them to individual learning styles (Nilsson 2012) as well as the possibility to repeat courses (Sun 2008; Ellaway 2008). The logistic benefits, such as learning at any convenient time or anywhere in whatever place and using different devices, are also important advantages of e-learning (Wutoh 2004; Curran 2006; Choules 2007).

Blended education or blended learning (BL) combines two or more modalities that use other teaching methods than online courses (e-Learning), in addition to the traditional classroom lessons (Anderson 2005). Teaching styles are based on the concept that individuals differ with respect to what mode of study is most effective for them. Results of some trials show that students prefer an integrated learning methodology with different learning styles, and they are supporting the use of the BL approach (Pashler 2008; Grasl 2012; Lehmann 2013; Ilic 2015).

The *hybrid* instructional model is a blend of conventional face-to-face instruction and Web-based distance learning: a mix of both classroom face-to-face meetings and distance learning. Blended learning utilizes the best online tools to support a teacher led classroom. In blended learning scenarios, “face

time” between students and teachers is not replaced by online course delivery. Hybrid learning focuses less on the technology and more on the most effective way to deliver a course to learners. In hybrid learning, a significant portion of the course takes place online. Blended and hybrid learning both will be very effective because of the synergy that is created between different ways of studying.

Online and face-to-face traditional formats have their own respective strengths and weaknesses. Neither is better: they are complementary. This confirms the benefit of BL, which includes a combination of face-to-face and online learning methodologies integrated into a single course (Osguthorpe 2003; Garrison 2008). Research has suggested that well organized online classrooms are as effective and of comparable quality as traditional classrooms (Zebrack 2005; Cook 2008; Aggarwal 2011).

The main advantage of web-based education is its flexibility, allowing students to access content from several locations, at any time. It encourages self-management learning, with the ability to exchange links to related information (Baldwin 2001; Fieschi 2002; Harden 2002; Lewin 2009).

Appraisal Systems

The usual appraisal systems for official teaching and training are often based on objective tests checking knowledge acquisition, attendance control, delivery of practical works to improve clinical skills, and participation in classes, tutorials or seminars. Tests are mainly used as a way to assess students because there is evidence that they stimulate learning by increasing retention of the information (Roediger 2006; McDaniel 2007).

Evaluation methods of online courses should collect the objectives sought in each course or training. These objectives for online distance learning are represented by five areas:

1. Incorporation of learning principles and strategies.
2. Inclusion of real problems.
3. Inclusion of decision-making, or problem solving.
4. Inclusion of practice in evaluating viewpoints.
5. Development of interactive activities which drive to discussion and critical thinking.

To develop the methodology of on-line instruction, traditional appraisal systems may not be suitable, and some of them lose their objectivity. New assessment methods should be implemented, showing in a comprehensive manner and as objectively as possible, the development of students in the subject taught and their work progress (Casebeer 2004; Weston 2008; Freire 2012).

The Comprehensive Appraisal System of La Ribera University Hospital

La Ribera University Hospital (Alzira, Spain) periodically implements training courses for healthcare professionals assigned to the corresponding Department, and addressed to all employees that integrate this Department.

It has been delivered online training courses for several years in the health field, based on the Campus Ribera, a corporate virtual platform implemented in our Department of Health, which has allowed the organization, to evaluate the methodology and performance of these courses (Monroy Anton 2011,

2013). In this field we have developed what we call the “*Comprehensive e-Learning Appraisal System*” (CeLAS), which aims to categorize and score each of the elements of learning/instruction, resulting in a final assessment for students very close to objectivity and fairness.

These training courses are developed electronically through the corporate platform *Campus Ribera* using a Moodle platform. Campus Ribera started in 2009 as a learning platform that allows optimizing the traditional training process by using online learning methods (Izquierdo et al, 2014). This virtual platform is managed from the institution, and teachers (tutors) are qualified professionals of the Department of Health.

After several years of developing different types of courses, the final assessment to obtain credits or certificates was very heterogeneous because the test systems were different: only the connection to the course, meet a minimum number of input records online, make some assessment test, some drafting work, etc. None of them were perfect and contrast the existence of groups of students more interested and participatory compared to other more passive groups. Thus, the ultimate goal of the courses is distorted because the training of some professionals would not be that expected and motivation to achieve these courses would only be addressed to obtain certificates for merely passing the course.

To standardize somehow this deficiency and improve the quality of the course and the training of students it is designed a system of evaluation to attack different parts and elements, weighting each one according to the relative importance that teachers would give them, and resulting in a final note or score. We have called this system: “*Comprehensive e-Learning Appraisal System*” (CeLAS).

CeLAS was initially implemented in a blended course entitled “*Approach to the toxicity of treatments with external radiotherapy*”. It lasted 6 weeks, with a workload of 25 hours (mixed classroom and on-line) and it was accredited by the National Education Commission of Spain with 3.6 credits. They were accepted for the course seven students, based on the best ratio student/teacher parameters previously analyzed for our blended courses (Monroy Antón 2013).

Assessment Method

Three areas of training (blocks or sections) were proposed, with a system of weighted score for each one of a total of 100 points as it is displayed in Figure 1):

Area/Block I: Assessment of knowledge, representing 70% of the total score.

Area/Block II: Assessment of participation, representing 15% of the total score.

Area/Block III: Assessment of practices, representing 15% of the total score.

Figure 1. Areas of training



Final Course Certificate

For the final course certificate, students must achieve the following objectives:

1. Exceed 50% of the total points of the final evaluation.
2. Not obtain a score of zero in any of the three aforementioned evaluation blocks.

Methodology of Evaluation of Each Block

Evaluation of Block I

Assuming a total of 70 points which were obtained by performing knowledge test corresponding to each of the different thematic units (T.U.) of the course, and a final overall evaluation test (as it is shown in Figure 2).

Evaluation of Block II

Weighted with a total of 15 points. They were obtained by the participations of students in specific forums for each thematic unit. These entries were evaluated according to the type of response issued by the students (Figure 3):

- 0 points = not answered;
- 1 = unsatisfactory;
- 2 = satisfactory;
- 3 = above expectations.

Figure 2. Evaluation of knowledge

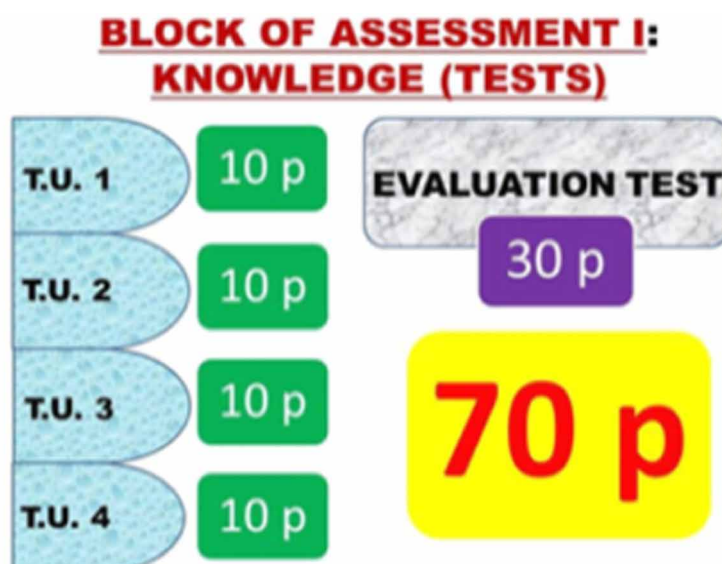
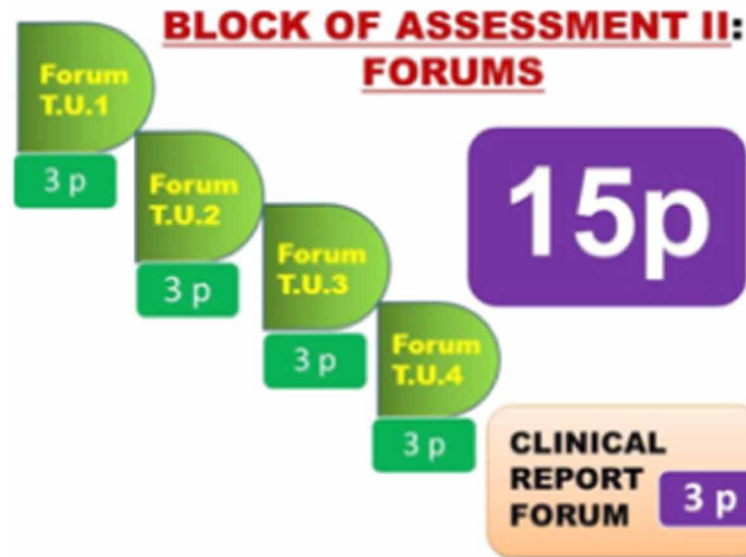


Figure 3. Evaluation of participation (forums)



The final grade of the evaluation block result of the sum of average scores in all forums, with a maximum possible score of 15 points.

For the evaluation of forums, students must meet minimum requirements:

- It was mandatory to answer the specific forum “*Case Report*”. In the case that there was no participation in this forum, the rating would be zero in the entire block.
- To obtain the score greater than zero in at least three of the four forums on thematic units.

Evaluation of Block III

Weighted with a total of 15 points. Related to works proposed by teachers and delivered by students by electronic means, and a test with questions about the practical issues discussed during the course. The grading of the work was as follows (Figure 3):

0 points = not answered;
1 = unsatisfactory;
2 = satisfactory;
3 = above expectations.

The final score of the block assessment result of the sum of average scores for all jobs, the maximum possible score was 15 points.

For these scores, minimum requirements had to be met:

- The fulfillment of the test of practice was mandatory.
- Achieving greater than zero score in at least three of the four papers offered in the thematic units.

Students' Work Monitoring

To guide students on their progress throughout the course and the scores on each of the blocks and tasks, Moodle offers the possibility of gathering information through the *Gradebook* which monitors student's activities. The *Gradebook* in Campus Ribera allows tutors to organize and manage information about the students in online courses. For example, by displaying the scores obtained through objective tests or grading the delivery of assignments or forum participation. It also enables the aggregation of the different assessment sources in order to get a final grade.

FUTURE RESEARCH DIRECTIONS

The Global World leads to the use of new technologies for most of our daily activities. One of them is education. Training systems via e-Learning are gradually imposing traditional education methods, allowing long distances formation of large population. However, this ability to communicate and learn knowledge should be assessed as objectively as possible, combining performance parameters and elements, so we must investigate in the development of new evaluation systems.

Recent studies suggest that a combination of face to face training with online instruction based on e-learning methods is more flexible than other methods (Garrison 2004).

The online learning paradigm offers valuable tools that could supplement or replace aspects of the traditional lecture-and-textbook-based approach to teaching and learning (Glazer, 2012).

Blended learning attempts to create an optimal learning environment by combining a variety of learning approaches (lecture, tutorial, online, problem-based and clinical) to deal with different learning styles and requirements. Some trials have evaluated the effectiveness of the BL model in medicine (Grasl 2012; Lehmann 2013; Masie 2002).

The asynchronous ability to exchange information, cost-saving, personalized learning, increased accessibility, ease of distribution and updating content are some examples of the advantages offered by the online classrooms. Studies and literature reviews show that technology based learning improves student knowledge acquisition which requires abstract conceptualization and reflective observation, but adversely affects student ability to obtain knowledge requiring concrete experience (Hui 2007).

The meta-analysis performed by Liu (2016) concludes that blended learning has a large consistent positive effect on knowledge acquisition compared with other modalities (pure e-learning, face-to-face, or no intervention) and may be more effective than other ways of learning. They concluded that blended learning was very effective and educationally useful in health professions. Possible explanations could be:

1. Compared with traditional learning, blended learning allows students to review electronic materials as often as necessary. It likely enhances learning performance (Wu 2010).
2. Compared with e-learning, blended learning learners are less likely to experience feelings of isolation or reduced interest in the subject matter (Hara 2000; Maki 2000).

Analyzing each unit of the toxicity course, acquired knowledge of study matter improved the previous level that brought the students before the end of the teaching of these subjects. This was observed con-

ducting tests before the study of the issues of each thematic unit and after teaching the same knowledge. The difference between the scores before and after training in other studies, led to increased knowledge scores in participants (Unal 2005; Koch 2005; Woo 2000).

Tests are considered the standard and principal ways of assessment for several courses. The implementation of a medical program with tests is developed in order to stimulate learning: after an initial contact with the learning material, being tested increases information retention more than reviewing that material again. Also the number of tests increases the effect of this system (Larsen 2008, 2009; Kerdijk 2013; Wood 2009; Karpicke 2008). Some institutions have created platforms that employ test-enhanced methodologies to teach learning materials (Taveira 2014).

The activities that can help learners to apply knowledge from the courses are exercises, quizzes, self-assessment test; but also discussion cases, forums interactivity or many others. These are the items that the faculty of courses should evaluate.

Prospective trial conducted with third year medical undergraduate students attending the Faculty of Medicine of the University of Belgrade (Milic 2016) compared two methods of education: blended learning and traditional on-site. Students were asked to choose their learning method at the beginning of their course. The evaluation system was identical for both learning modalities:

1. Course activities throughout the year,
2. Written knowledge test,
3. Final exam.

On a similar way, Larson reported no significant differences among three education delivery methods (on-site, online, and blended learning) as measured by exam scores and final grades. The study concluded that online and blended methods are at least equivalent to the face-to-face one (Larson 2009).

As we can see, most work on evaluation of online courses use multichoice test, as used by us. A simple way is to establish a classification or numerical evaluation of knowledge. However, increasingly we turn to complete this evaluation with other activities, which should complement the results of the test.

Systematic or comprehensive appraisal is not common practice. Other ways for monitoring courses are observing participation and satisfaction. Appraisal should be driven not only by the test results but also other complementary issues such as skills or tasks proposals through problem-based methods (Kreber 2001; Wilkes 1999).

The future will probably be the implementation of courses tailored to the needs of students with online high probability. Evaluation systems of these courses must be adapted to each of them, but mainly to the following facts: the group of students to whom it is addressed, the objectives pursued in the course, course duration, the scope for action of the students. Evaluation systems as developed in our hospital can serve as a model or basis for developing other more complete, complex, or just different, but adapted to the group of students that the course addresses.

CONCLUSION

In our experience of an online radiotherapy course, all students (100%) reached the minimum final score required in the course, fulfilling the objectives of each subject and evaluation block and obtain-

ing the corresponding certificate. The results showed that students were getting better as performing the various blocks of the course which were arranged in a table of grades, so that students could see at any time their partial and overall marks knowing their score to overcome the required minimum for the final course certificate.

This “Comprehensive e-Learning Appraisal System” provides a fairly objective assessment method of learning, and can avoid or greatly reduce the subjectivity of the teacher assessment, as grades are displayed automatically, once students do course activities. It can be applied as a tool in the training courses in all fields of health care, and enables holistic assessment jointly with different variables of knowledge, weighting those considered most important in each specific course.

The grades or scores of the course can be accessed whenever by students and teachers by means of items designed specifically for each training activity (e.g. forums or wikis), which are integrated into the module of the course and have each of the graded sections and the corresponding score. It is a demanding system for the student, since it forces pursuing and constant work, reflecting on the final grade this degree of effort. These final grades also serve to differentiate the use of the training received, positively influencing the professional careers of workers. It is an easy system to implement in courses with an online methodology; it does not require sophisticated virtual tools or complex calculations, since practically all scores of evaluable elements are provided directly from the various items of the learning platform.

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KEY TERMS AND DEFINITIONS

Appraisal Systems: Evaluation systems for courses, attending different approaches and methodology of assessment.

Blended Learning: Combination of traditional face-to-face learning and distance (online) methods.

E-Learning: Education based in online courses. Educational system in which teachers and students are separated by physical distance, but the technology allows them to learn together.

Hybrid Learning: Finding the right mix for the student, out of all the possibilities in learning.

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Chapter 24

Flipping the Medical School Classroom

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ABSTRACT

The preparation of today's physicians is a tremendous responsibility. For medical students to be successful, they must experience a multitude of opportunities to develop appropriate clinical skills, problem solving acumen, and medical knowledge. Due to various barriers, medical students may develop gaps in critical and foundational knowledge. The use of flipped lectures has the capacity to "mobilize" education and ensure for versatility and improved content acquisition through the implementation of both online and face-to-face teaching methodologies. This hybrid learning environment has the capacity to also address the increasingly diverse needs of today's matriculating medical student. This chapter identifies tools and strategies of how to incorporate flipped lectures into medical education.

INTRODUCTION

Teaching and learning in medical schools and institutions is a multifaceted endeavor, especially as the United States' health care system continues to become more complex. Medical students need to develop a rich foundation of not only content knowledge, but also problem solving and technical clinical skills. However, due to various barriers such as inadequate or limited clinical placements, an unpredictable learning environment, and duty hour time restrictions (Feng et al, 2013; McLaughlin et al., 2014; Tainter et al, 2016), medical students may develop gaps in knowledge that could impact their future success. To circumvent these gaps, medical education programs must be innovative in how they deliver core content knowledge. Historically, lecture-based didactics permitted learners to be passive in the acquisition of knowledge, while teaching faculty were recognized as a "sage on the stage" (King, 1993). The role of "sage on the stage" is considered to be the keeper of knowledge and who considers students as empty vessels that need to be filled. This archaic method of interaction and learning is not appropriate in the preparation of today's 21st century medical student (O'Brien & Irby, 2013).

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Educational opportunities should be provided in a manner that is learner-centered and innovative to further increase student engagement and deeper comprehension of the required medical knowledge (Irby, Cooke, & O'Brien, 2010; Prober and Heath, 2012). Suggestions from Irby, Cooke, and O'Brien (2010) assert four goals that are imperative for the future of medical education:

1. Standardization of learning outcomes and individualization of the learning process,
2. Integration of formal knowledge and clinical experience,
3. Development of habits of inquiry and innovation, and
4. Focus on professional identity formation (pg. 5-6).

With these objectives in the forefront, educational theories and practices must be revisited, tailored, in order to improve and evolve current pedagogical practice.

Rapid advancements in technology, both of software and hardware, have encouraged e-learning to emerge as a key component in curricular development, especially in the field of medical education (Dankbaar & de Jong, 2014). Students can now access and interact with required readings, cases, models, videos, simulations, and collaborate with peers across the country or the world. Remarkably, e-learning has allowed educators to “mobilize” their teaching practice and provide content at any point in time, from any location (Jashapara & Tai, 2011). However, there are always challenges when attempting to develop and implement a new e-learning strategy while simultaneously integrating face-to-face contact. Thus, how does an educator integrate both e-learning and face-to-face learning in a balanced and engaging way? This article synthesizes the method of flipped lectures or flipped learning and presents practical strategies to implement flipped learning within the unique medical education setting.

BACKGROUND

The flipped lecture, flipped learning, or inverted classroom originates from K-12 education (Bergmann & Sams, 2012) and provides students with the opportunity to interact with content prior to entering the classroom in a structured, organized way (see figure 1) (Barett, 2012; Mazur, 2009; O'Flaherty & Phillips, 2015; Lage, Platt, & Treglia, 2000). Flipped classrooms stemmed from the Khan Academy, conceived in 2006 by Salman Khan which provided access to 3200 videos and 350 practice exercises which were used by teachers for flipped classrooms (Bishop & Vergler, 2013).

From there, flipped lectures have steadily grown in popularity following a distinct curricular design. First, students participate in the asynchronous event, commonly recognized as an online component. This typically involves a module with videos, podcasts, interactive readings, reflective questions, and/or chatrooms (Prober & Health, 2012, Sharma et al., 2015). Then, during the face-to-face class time, or synchronous event, students participate in active learning and implementation of new knowledge. Flipped learning is *not* simply assigning homework or readings and then conducting teacher-led lectures. Rather, flipped learning incorporates a diverse amalgam of technology, literature, and inquiry to establish a critical knowledge base prior to engaging with the content on a higher level of learning. In turn, the learning environment becomes personalized, engaging, and content rich, thus improving the ways in which students apply abstract knowledge to solve realistic problems (Bergmann & Sams, 2012; Mann, 2011; Sharma et al., 2015).

Flipped lectures have been found as a successful method to engage students. In a study by Lew (2016) 46 medical students enrolled in an emergency medicine clerkship much preferred the flipped lecture to a more traditional lecture-based classroom. Furthermore, the students in this study remarked on the advantage of the interactivity and medical decision-making. Interestingly, Lindeman et al (2015) discovered with the implementation of flipped lectures, surgical students did not perform any better on the National Board of Medical Examiners (NBME) examination, but that students did give a higher satisfaction rating at the conclusion of their clerkship. Similarly, Liebert et al (2016) found comparable results, when investigating student NBME results from both the flipped lecture to those in the traditional classroom, there was no statistical difference. Notably, student satisfaction of the flipped lecture was higher than the traditional lecture-based classroom with individuals reporting a greater interest in surgical specialties after the clerkship.

Those who support flipped learning have found that this instructional method has a number of benefits (O’Flaherty & Phillips, 2015; Sharma et al., 2015). First, by implementing flipped learning, students learn at their own individualized pace, which is appropriate to their learning style and need. Additionally, students can take advantage of repetition and repeated exposure to the content by pausing or revisiting the material as needed (Pierce & Fox, 2012). Upon entering the physical classroom, students have a foundational knowledge of the required content. This is essential as students and educators now have the space to engage in robust discussion regarding complex cases, problems, and issues. This interactivity also provides for immediate feedback and evaluation (Sharma et al, 2015) to both student and educator regarding what additional knowledge gaps exist. Furthermore, this flipped model encourages students to take ownership of their learning as they are required to be prepared to actively engage to solve problems and address cases.

MAIN FOCUS OF THE ARTICLE

Issues, Controversies, Problems

The traditional United States medical school follows a 2 + 2 curriculum, two years of basic science education and 2 years of clinical clerkships. The clinical clerkships are a particularly unique learning experience as medical students are required to rotate through six or more medical specialties to develop an understanding of diagnosis and health management appropriate for each discipline. Each clerkship has its own entity and student experiences vary due to different clerkship objectives, clinical content, variability in care, and teaching faculty. There is however, a common expectation for clerkships to provide didactic, explicit educational experiences outside of the clinical setting. The Association for American Medical Colleges (2008) asserts that the aim of medical education is to “equip each student to develop the lifelong habit of skill learning and self-assessment, in order to further develop and maintain clinical performance expertise” (p. 5). To do so, students need to be involved in a multitude of hands-on learning experiences to further advance clinical skills, clinical problem solving, and medical knowledge.

The surgical clerkships, or surgical block which typically incorporates obstetrics and gynecology, surgery, and anesthesiology are unique as these are conducted with, “rapid transitions from one discipline to another, one patient population to another, one setting to another, and from one culture to another”

(Irby, Cooke, & O'Brien, 2010, p. 84). As such, this fast-paced, transient learning environment becomes a revolving door, quickly pushing medical students through specialties (Bell, et al., 2008; Hammoud, et al., 2006). This revolving door becomes further exacerbated due to the limited time faculty have to plan, teach, mentor, observe, and evaluate medical students (Irby, Cooke, O'Brien, 2010). Thus, this environment further asserts the need for multifaceted, active opportunities which provide for a blended learning experience. An environment where students learn independently to build a foundation of knowledge as well as interact with peers to engage in critical problem solving to further reinforce the necessary medical content.

Due to the various methods of content presentation, flipped learning has slowly gained popularity among specialties in medical education. Surgery, radiology, obstetrics and gynecology, intensive care, pharmacology, and emergency medicine (Belfi et al, 2015; Heitz et al, 2015; Khanova, et al., 2015; Liebert et al, 2016; Morgan et al., 2014; Tainter et al., 2016) have all explored the implementation of flipped learning with medical students. ‘

The research conducted on the radiology clerkship presented by Belfi et al (2015) employed flipped lectures as a method to address the reduced amount of teaching time from 20 hours to 12 hours. Medical students were given an outline of the topics and the available online modules called: *RadCasts*, *RadTutorials*, *RadGames*, and *Interactive Clinical Anatomy and Radiology Utilization Simulator (ICARUS)*. The *RadCasts* were short 10-15 minute PowerPoint presentations that reviewed the clinical approach to imaging with self-assessment questions students needed to complete. To review specific clinical conditions or a specific patient population, students accessed *RadTutorials*. *RadGames* were more interactive modules that students completed regarding chest diagnosis. The simulator *ICARUS* incorporated online simulation that encouraged students to use various problem-solving skills. The in-class sessions were mindfully planned, taking into consideration the prior knowledge students were constructing with the online components. Case-based teaching was implemented, with students encouraged to use an audience response system, a Jeopardy-type review game was facilitated to build on students' collaborative skills, and additional face-to-face simulation workshops were facilitated. Overall, this pedagogical design was very successful two-fold, medical students achieved higher posttests after the flipped classroom and students perceived the inclusion of such diverse teaching practices to be beneficial to their learning.

Of course, with any curricular change, challenges emerge which need to be addressed. “Practical considerations” when implementing flipped learning are documented by Tainter et al. (2016, pg. 4). First is the resistance to change of the traditional medical education framework. The argument being that medical education continues to prepare excellent physicians, why bother changing what has been in place for decades. The second deterring factor is of course, time and cost. Teaching faculty will need to make time outside of their clinical obligations to learn of the various technological resources and how those are implemented with learners. Third is a concern that students will not complete the online assignment(s) prior to meeting in the face-to-face setting. The fourth challenge is “resistance to active learning” (pg. 5), which embodies two constructs. First, there are students who prefer to be passive participants in the learning environment rather than engaging with peers during group discussion. Second, some students may be uncomfortable when teaching faculty put more ownership and responsibility on the learners during case-based or team-based learning experiences. Any one of these barriers may preclude teaching faculty from attempting or successfully integrating flipped learning into the curriculum.

SOLUTIONS AND RECOMMENDATIONS

To alleviate potential challenges in the field of medical education, implementing flipped learning opportunities provides greater flexibility for student and teaching faculty. Students have the ability to view and understand material prior to engaging with the content at a higher level in the classroom. By providing learning objectives online or virtually, teaching faculty have clearly delineated the expectations in the acquisition of content. Rather than simply assign a chapter to read in a text, employing multiple modalities of technology allows students to further scaffold their learning (Vygotsky, 1978). This method encourages medical educators to plan wisely and outline the required learning goals and targets imperative for the student's success. Furthermore, this process assures for greater transparency between the teaching faculty, the content, and the student as the requirements and learning objectives are clearly delineated through the selected material.

The structure of a flipped learning experience requires that the teaching faculty develop an online component for students to interact with. Detailed recommendations provided by the AAMC (2008) and research conducted by Moffett (2014) identify how various technological resources can be incorporated (see Table 2) to enhance the flipped learning environment. Integration of social networking, social media, podcasts, and simulations are a few of the examples teaching faculty may include to encourage students to construct an understanding of the required content. Sharma et al. (2014) emphasized the importance for faculty educators to also interact with the students online prior to the face-to-face activity. This encourages students to become more immersed in the content as they engage with peers and teachers. Finally, to integrate appropriate online content, teaching faculty who develop these learning experiences must keep the learning objectives and goals in mind to assure that students are receiving the necessary material throughout the entire experience. As such, an adequate timeline must be established to allow students enough time to navigate through the online material prior to entering the face-to-face classroom.

When students do enter the face-to-face classroom, teaching faculty must be prepared with advanced content and avoid simply reiterating the information already presented online. This may be a complex case that students must collaboratively solve. Team-based learning is another strategy for engagement in the classroom. This approach incorporates three steps that first, requires students to complete a pretest independently. During the second step, students collaborate in teams to further conceptualize the material, and finally, at the conclusion of the class, students complete a posttest with their assigned group of peers. This process encompasses the strengths of various learning styles, specifically independent work to collaborative work. An additional strategy teaching faculty could employ is case-based learning (CBL) which encourages students to engage in self-directed learning. CBL integrates a particular and detailed scenario, known as the case which students need to critically evaluate (Gade & Chari, 2013). This type of strategy allows students to work independently or in a group solving exploratory questions.

Technology is a tremendous component of both the online, synchronous portion and the in-class asynchronous teaching. Traditionally, voiced over PowerPoint presentations or short video clips are used, however, there are a number of other online tools to make learning more dynamic (see Table 1).

The above table is not exhaustive of the current available resources applicable for the classroom. As technology and research advances are made, many more applications and online tools will be developed to improve and increase engagement in this blended classroom environment.

Table 1. Examples of flipped lecture tools

Flipped Lecture Tool	Brief Description
ed.ted.com	Use YouTube to create private videos and embed quiz questions, links, and additional content.
Poll Everywhere	Online application for in-class response system. Can create graphs and real time tallies of who is responding and where misconceptions exist.
Loca Moda	Students can “post” a text message onto an online bulletin board to stimulate discussion.
Google Hangouts	Students can engage in an online, password protected chat room which saves discussions for future reference.
Kahoot	A free, online application that allows for in-class surveys and quizzes.
Articulate Storyline 2	A software program which allows the user to design interactive, online modules with questions, videos, short readings, and simulations.
Wikispaces	Free online tool to allow students and teachers to collaborate and discuss questions and online cases.
TEDTalks and TEDxTalks	Both TEDTalks and TEDxTalks have developed into a vast library of videos that reach a global audience to inspire critical thinking.

FUTURE RESEARCH DIRECTIONS

There is an ongoing need to bridge the gap between educational theory and practice in medical education institutions (Kim, et al., 2014). To accomplish this, additional research should be conducted to further investigate the effectiveness of flipped learning on the development of the student, especially in relation to the acquisition and retention of complex medical content and the implications on patient care. Little research exists regarding the retention and implementation of knowledge as medical students transition to different disciplines, into a residency program, or into their professional career. Flipped learning experiences are multifaceted and it is difficult to pinpoint specifically, which area impacts student learning.

A secondary research area is to investigate the ways in which teaching faculty develop their own professional pedagogical practice. By developing flipped learning experiences, faculty have the potential to also expand their own teaching practice by shifting control away from the “sage on the stage” approach, to instead empower rising physicians. This necessitates supplementary research on teaching faculty’s willingness and acceptance to integrate new technologies and strategies and, in turn, how these new learning experiences are perceived by students.

CONCLUSION

Flipped learning has generated interest and action for change in the education community, from K-12 through to medical education. With the advancements and increased accessibility of technology, students have the opportunity to engage with complex content through various modalities, addressing the diverse learning needs of today’s medical student. This curricular process requires that medical educators are well versed in their pedagogical practice in order to design, organize, and implement a flipped learning experience.

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KEY TERMS AND DEFINITIONS

Asynchronous E-Learning: The use of online learning resources to facilitate resources without constraints of time or place. Takes the form of discussion boards and blogs.

Flipped Lecture: Students engage with assigned content through online or mobile methods, then attend a face-to-face class to explore the content in more critical ways.

Pedagogy: The art or science of teaching.

Synchronous e-Learning: Online learning that takes place real-time from various remote locations. Takes the form of videoconferencing and online chat rooms.

Theory of Active Learning: The belief that people learn best from experience and “doing”.

Transactional Distance Learning: Definition of distance education which implies the separation of teachers and learners (Moore, 2007).

Transformative Learning: How learners comprehend, validate, reflect on, and reformulate the meaning of their experience.

Zone of Proximal Development: A concept that informs how learners build on their learning to the ultimate goal of independence.

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APPENDIX

Table 2. Flipped lecture activities

E-Learning Activities and Assessments	In-Class Activities and Assessments
• Online readings, interactive PDF • Reflective questions • Online survey • Online discussion • Pod cast • Videos • Online Simulation • Social networking (LinkedIn) • Social media (Twitter, Facebook)	• Use of audience response systems • Think Pair Share • Jig Saw activity • Case-study learning • Problem-based learning • Fishbowl discussion • Role play • Written reflections • Debate • Peer instruction • Problem-based learning • Simulation with standardized patient

McKeachie & Svinicki (2006); Moffett (2015).

Chapter 25

Integrating Evidence-Based Practice in Athletic Training Though Online Learning

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ABSTRACT

Evidence-based practice (EBP) involves a healthcare professional using his or her own knowledge, the current research published, and the needs of the patient to make the best clinical decision. This has been a hot topic in many different branches of healthcare and recently athletic trainers have begun to embrace its importance. In December of 2015, athletic trainers (ATs) will need to have completed 10 of their 50 continuing education units (CEUs) in EBP to maintain certification. While ATs recognize the significance of implementing EBP into clinical decision making, there are many barriers slowing the change. This chapter includes information about how EBP is currently being used by athletic training clinicians and educators, the barriers ATs perceive to using EBP, the importance of using EBP, and managing the transition needed to successfully adopt the use of EBP. Online learning will be reviewed as the primary method of diffusing EBP into the profession of athletic training.

INTRODUCTION

Health care is always changing and as a result the associated health professions must adapt. As challenges persist such as rising health care costs, an aging population and the need to treat increasing numbers of people with chronic health conditions, the field of health care must continue to explore ways to deliver quality care while reducing costs. Like many other health care professions, athletic training has turned to evidence-based practice to assure that athletic trainers are trained to deliver the highest quality of care in the most efficient way to their patients. The transition to integrating evidence-based practice can be challenging and will require a massive diffusion of innovation throughout the field of athletic training.

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Athletic trainers (ATs) are defined as “health care professionals who collaborate with physicians. The services provided by ATs comprise prevention, emergency care, clinical diagnosis, therapeutic intervention and rehabilitation of injuries and medical conditions. ATs work under the direction of physicians, as prescribed by state licensure statutes” (Profile of athletic trainers, 2014, para. 1). The profession of athletic training is constantly growing, and athletic trainers can be found in many different settings including high schools, colleges, working with the athletic teams, the military, and workplaces. Despite many employment opportunities, some people in the health care industry are unfamiliar with the responsibilities of the AT and it is apparent that athletic training as a profession is still lagging behind other allied health professions (Hankemeier & Van Lunen, 2013a).

BACKGROUND

In order to change the perceptions of ATs to the public, the National Athletic Trainers’ Association (NATA) is introducing the use of evidence-based practice (EBP) in both the education of new ATs, and in the clinical setting with athletic trainers already working in the field (Hankemeier & Van Lunen, 2013; Hankemeier et al., 2013; McCarty Hankemeier, Walter, Newton, & Van Lunen, 2013; Welch, Van Lunen, & Hankemeier, 2014b). There are many benefits to increasing the use of evidence-based medicine (EBM). One reason that is frequently discussed is improving both the image and recognition of athletic trainers as health care professionals and not personal trainers, physical education teachers, or the people carrying water bottles on the sideline of games. Other benefits to using EBM include improving the care provided to the patients and justifying third party reimbursement (McCarty et al., 2013; Welch et al., 2014a).

Using EBP can be broken down into five steps as shown by Sackett et al. (1996). These steps include: defining clinically relevant questions, searching for the best evidence, critically appraising the evidence, applying the evidence, and evaluating how effective evidence-based medicine was when put to use. While these steps seem relatively simple when written out, most athletic training clinicians are not presently using EBP in their current treatment practice, but 98% of them were found to believe that it is important for the credibility of the profession (McCarty et al., 2013). Hankemeier et al. (2013b) showed that clinicians had a lower perceived importance score and a lower knowledge score when compared with post-professional educators. ATs who work in an athletic training education program have been more exposed to the notion of EBP and therefore are more knowledgeable regarding it and understand its importance more than individuals that only work in the clinical setting.

Since EBP is very new to the field of athletic training, practicing clinicians that are not recent graduates likely did not learn about EBP in the educational curriculum and would not be familiar with it unless the individual took initiative to learn the process independently. In a study completed by Hankemeier and Van Lunen (2013a) less than 20% of the surveyed clinicians had received any form of EBP training. Based on the information provided in this survey, very few clinicians have been trained to use EBP. These clinicians with no background in using the five steps would need some training in order to be able to effectively integrate EBP into daily clinical practice.

Disseminating knowledge about EBP to ATs is essential in this transition. Continuing education (CE) is an important method for educating athletic training clinicians on what EBP is and how to use. In order for CE to be truly effective, athletic trainers need to understand what modes are best for presenting this information to promote long term knowledge retention and knowledge translation. Popular ways that CE is presented is through online learning, in person lectures, discussions, hands on demonstrations, and

mixed mode learning. Studying modes individually for these gains or comparing one type of CE with another will help to advance understanding on how EBP should be presented to maximize an increase in knowledge and use.

Distance education, e-learning, computer mediated, web-based, and online instruction are terms used to describe education delivered through computer-based technologies. Whatever term is chosen, such computer-based technologies are essential components of the preparation and continuing education of health professionals. One of the most frequently used modes of CE, particularly for learning EBP, is online learning. Web-based learning has become very popular due to its flexibility and ease. This type of learning can be done from anywhere and completed at the convenience of the individual taking the course (Militello, Gance-Cleveland, Aldrich, & Kamal, 2014).

Allied health care tends to use three models of online learning and instruction: blended learning, online learning, and continuing education (Stewart & Wright, 2004). Blended learning includes both face to face and online learning and instruction. Online learning is learning and instruction that is completely web-based. Continuing education for health professionals is offered in both blended and online formats. In fact, most health-related disciplines are using a combination of online and face-to-face learning in their programs.

From a theoretical standpoint, characteristics of an effective online learning experience have been outlined. Reeves and Reeves (2008) provided 10 dimensions to be considered when designing, implementing and evaluating an online class in health and social work. The model they described for health and social work education included 10 dimensions of interactive teaching and learning:

1. Pedagogical philosophy;
2. Learning theory;
3. Goal orientation;
4. Task orientation;
5. Source of motivation;
6. Teacher role;
7. Metacognitive support;
8. Collaborative learning support;
9. Cultural sensitivity; and
10. Structural flexibility.

In the discussion of developing online learning formats, best practices often discussed include attention to instructor and student interaction, application of active learning techniques, providing prompt feedback, and attending to diverse ways of learning. While the aforementioned guidelines make sense, they have not been vetted through research. This brings us to the next questions of whether web-based instruction can be as effective as face-to-face education. The answer is that we really do not know how effective face-to-face education is, because comprehensive assessment is rarely conducted of student learning for specific courses. Many factors play a role (i.e., faculty training and course design) in the effectiveness of any course. Most health professionals rely heavily on technology in their practice and thus, it seems appropriate for technology to play a role in the education of future health professionals. In fact, Hollis and Madill state (2006), "Evidence suggests that blending combinations of technologies with computer mediated learning enhances interaction and could address the higher order learning needs of professional programs such as occupational therapy" (p.61).

Through a review of research focused on computer-enhanced classroom-based teaching, online courses, online degree programs, and online continuing professional education, Hollis and Madill (2006) recommended that both online and face-to-face teaching and learning opportunities accommodate all types of students and faculty. Hollis and Madill (2006) emphasized the use of multiple technologies to enhance interaction between students, and between students and instructors. However, to optimize the effectiveness of online learning, they suggested appropriate preparation and support is required for both students and faculty. Again, these suggestions make sense, but also must be vetted through research designed to assess effective online learning experiences.

How is blended and online learning and education being used in health professions? Konin (2004) discussed how to enhance clinical education, like athletic training, through the use of web-based programs. Like most health professionals, education and training includes some type of fieldwork, or internship placement. Information and assessments for clinical instructors can be delivered electronically through an online course management system such as Blackboard. Face-to-face class formats can be enriched through the availability of a multitude of supplemental online materials.

A study was completed with nursing clinical preceptors who worked with undergraduate nursing students. In this study the preceptors took part in a series of online CE course objectives. These objectives were geared toward the roles and expectations of a clinical preceptor. The results showed that there was a statistically significant gain of knowledge between the pre-test and post-test, showing that knowledge was gained from online learning (Zahner, Tipple, Rather, & Schendzielos, 2009). While this study showed that online learning can increase knowledge, it did not compare online learning with traditional learning methods such as live lectures.

There is research that has been done that compares online learning with traditional live lectures. One study completed by Phillips (2015) investigated the effects of teaching a lesson online versus the traditional in person lecture class. This study was completed using a class in a pharmacy program. Students were randomly assigned to either the control group of traditional lectures, or the experimental group of active online learning. The experimental group performed higher on a multiple choice quiz given immediately after the lesson, but there was no significant difference on the final exam scores between groups. The experimental group did express that the online class was enjoyable and felt that it should be used in conjunction with traditional lectures, but should not replace lectures altogether.

Online learning and instruction is also essential to the continuing education of health-related professionals. Williams (2006) conducted a meta-analysis of 25 studies assessing achievement in distance education in allied health and found that distance education is as effective as face-to-face instruction. Student achievement outcomes were positively correlated with work experience and professional knowledge. Outcomes were also better for distance education experiences that included multiple learning and instructional strategies including, but not limited to, interaction and introspection.

Continuing education for ATs is offered in many different forms including taking college courses, publishing papers, presenting at conferences, attending in person meetings or education seminars, and online learning (Board of Certification, 2016). Studies have shown that online CE is frequently used because of the cost effectiveness and the ease of completing it individually (Armstrong & Weidner, 2011). December 2015 was the first reporting period that required athletic trainers to complete CE in an evidence-based practice category. During this period, ATs could choose from many different online options. These were typically formatted with a lesson that ended in a quiz to test knowledge. Passing the quiz was necessary for receiving the continuing education units. Because this reporting period ended

so recently, there is no research yet available on its effectiveness. However, a study was completed by Welch et al. (2014a) that looked at the web-based modules pertaining to EBP.

In this study, there was an experimental group that had access to the continuing education learning modules, and a control group that did not. Both groups were given a pretest and a posttest to assess knowledge. The experimental group did significantly better than both their own pretest and the control group's scores on the pretest and the posttest. Learning was achieved in this study, but only short term knowledge gain was investigated. Whether this knowledge was retained in the long term from the online learning modules has not yet been concluded.

The experimental group in the previous study was also interviewed on their perceptions of evidence-based practice following the intervention. Overall, the response was positive with the individuals all feeling that they had learned from the modules and had a better understanding of the concepts of EBP and how to use it (Welch et al., 2014b). However, the clinicians reported that the modules did not cause a change in clinical practice and that although they learned they did not change the way they made treatment decisions. Other qualitative studies have also been done regarding the attitudes toward EBP education. A topic that was emphasized was the need for constant repetition and increased exposure to evidence-based practice. These participants felt that the more exposure one has to EBP, the more comfortable they will become with it and the more likely they will become to use it (Welch et al., 2014c). A recent study by Keeley et al. (2016) found that participants felt that EBP was important, but overall they had not used EBP concepts at all in the eight weeks prior to completing the survey. The importance of EBP and short-term knowledge gain seem to be occurring, but there is still a gap between putting that knowledge to practice.

The reason that EBP is such a hot topic in the world of health care is to improve clinical outcomes, decrease cost, and increase patient satisfaction. To effectively implement EBP into athletic training, the athletic trainers must be using what they are learning through CE (Hankemeir & Van Lunen, 2013; Welch et al., 2014a; Welch et al., 2014b). More research needs to be done that helps to understand whether online, traditional, or a mixed mode of CE is most effective for knowledge gain and clinical use. Research that measures how well an individual is learning and whether that person is retaining the knowledge will help to make adjustments to the current situation regarding EBP. Comparing different ways of receiving the knowledge for effectiveness will also help to promote meaningful learning and knowledge translation. December of 2015 is the first time that ATs needed to report CEUs from an EBP category. It is likely that this will not be perfect on the first attempt. Continuing to understand the best ways to increase the translation of knowledge in athletic training will help the profession to successfully incorporate EBP into daily practice.

Some studies have been completed that investigate the notion of using a mixed mode method of learning. This type of CE would include different methods of learning such as combining web-based learning with an in-person discussion, or hands on demonstration that complements what was previously learned (Militello et al., 2014). The idea that mixing a passive lecture whether online or in person with an active discussion or demonstration works well with the idea that individuals learn differently. Furthermore, reinforcing a topic often promotes long term retention, comprehension, and may increase the chance that it will be implemented into clinical use (Schreiber, Perry, Downey, & Williamson, 2013; Zahner, et al., 2009).

A particular study that utilized a more comprehensive and multifaceted approach was completed by Schreiber et al. (2013). This study used a course that was geared for physical therapist (PTs) and met on three separate occasions in conjunction with an online community used to foster discussion. During

the in-person meetings, there were lectures, hands on demonstrations, and time to talk about successes and barriers to implementing the clinical change learned. In the final session, all PTs were required to discuss how they had already used what was learned in the previous courses in the clinical setting with patients. They also needed to describe an EBP activity that they had undertaken in the clinical setting. This study showed that the participants enjoyed this mixed methods learning and showed improvement in knowledge and practice behaviors such as supporting colleagues' use of interventions and tests and measures that were related to the course content.

Studies are showing that multifaceted learning increases knowledge and the translation of knowledge into clinical practice (Schreiber et al., 2013; Zahner et al., 2009). In order for change to truly occur in the field of athletic training more research needs to be completed that investigates how effective the current CE learning methods are. Short term knowledge gain is not enough to truly make a change. Whether long term knowledge gain is occurring is also important. If an individual is forgetting the course content immediately following the course then the information is not being relayed effectively (Phillips, 2015). This information must be something that the AT can comprehend and remember after a period of time. Even more importantly, however, is the idea of translating this knowledge in to clinical practice.

FUTURE RESEARCH DIRECTIONS

As previously mentioned, one of the benefits to online continuing education is that it can be completed at the convenience of the individual. This however, can also be a drawback. Each reporting period for continuing education is two years (Board of Certification, 2016). During that two-year period, athletic trainers can complete all of the CEUs at any time. This means that the CEUs can be completed two years early, or one day before the reporting period ends. It may be more beneficial to the profession if the EBP continuing education had benchmarks throughout the two year period that needed to be met. This would allow for continual exposure to the concepts and the idea of EBP throughout the reporting period, without it all being crammed into a few days or weeks and then forgotten about. Online learning would easily allow for this to happen with lessons and quizzes having due dates throughout the reporting period.

A more interactive online learning experience may be beneficial. Most of the online continuing education to this point includes a lesson followed by a quiz at the end (Welch et al., 2014a). This allows for an individual to pay minimal attention to the lecture itself and only focus on the quiz at the end. However, if there were checkpoints throughout the lecture where the individual had to answer a multiple choice question, or fill in the blank there would be more attention paid to the lecture. This may also increase interest in the topic. The quizzes that are used at the end should also be evaluating a true understanding of the topics that are being presented and should be challenging enough that individuals are proving that they understand the information that was presented. Online continuing education is received positively by athletic trainers due to the cost and convenience, so making it effective is important to increasing the use of EBP (Armstrong, 2011).

Continuing education in EBP was provided through online courses, at sessions at the national and regional conferences, and at in-person seminars throughout the country. The way an individual athletic trainer received the CEUs was a personal decision. It is frequently shown that expense and convenience of continuing education play a very significant role in why it is selected (Cuppett, 2001). Athletic trainers that work in a traditional setting such as a high school or college and are working unpredictable hours

and weekends may be more inclined to complete the CEUs online due to convenience. Additionally, many ATs are paying for the continuing education independently and therefore will pick the most cost effective option. Unlike students in an athletic training program who will receive EBP information in a formal didactic setting that is constantly reiterated, certified ATs are only receiving this information when it is presented in the CE and through an additional education sought out individually (McCarty et al., 2013). Certified ATs may take longer to truly feel comfortable with the concept of EBP and may need additional reinforcement beyond the CE to promote a behavior change.

One of the major recurring themes relating to barriers of implementing EBM is that ATs are not comfortable with the process and therefore will not use it (Hankemeier & Van Lunen, 2013a). Many of the practicing athletic trainers were not taught how to use the process of EBP while in school resulting in not being comfortable reading scholarly articles and deciding what should be considered when making treatment decisions. This is one of the reasons that EBP is now in all athletic training education curriculums, but this does not help ATs that are already practicing. The other major complaint is that the ATs working in many of the various clinical settings do not have time to go through the whole process of using EBP, particularly reading through lengthy articles to help with treatment decisions (McCarty et al., 2013; Welch, 2014a). Truly analyzing a peer-reviewed article to determine its value can be very time consuming. In a clinical environment where athletes and other patients may constantly be around and needing attention, it can be difficult to take the time to read articles and determine whether it has any relevant information that can be applied to the particular situation. Due to the time consuming nature, many ATs feel it is easier to just do what is comfortable or what has always been done because it allows patients to be seen and taken care of in a timelier manner (McCarty et al., 2013; Welch et al., 2014a). One study indicated that ATs stated that if the information in the articles were in a quicker, more streamlined medium there was a higher chance of reading it and utilizing it because it would be less time consuming (Welch et al., 2014a).

A possible way to help ATs understand scholarly articles is through the use of an online database. Since ATs understandably would be challenged with reading scholarly articles, it seems like asking researchers to provide EBP application summaries of their articles to an online open access database for ATs would be a good solution. The *Journal of Athletic Training* (JAT) is currently available to all members of the NATA. This journal comes out quarterly with monthly supplements and is available online. Currently ATs have access to the abstract, full text, and a PDF version. This is a great asset to ATs, but a frequent complaint is that using EBP and looking through research articles is too time consuming for the fast paced unpredictable nature of the job (McCarty et al., 2013). Since this journal is published for athletic trainers and typically by athletic trainers it would be beneficial if each author were asked to provide 3-5 bullet points that were directly related to applying the information in the article to practice. These bullet points could be added to the end of the abstract and would help to streamline the information in the article which has been requested by practicing ATs (Welch et al., 2014a). The abstract and the EBP bullet points would allow ATs to quickly look to see whether an article is worth taking the time reading through and may allow clinical ATs to put more evidence into practice without spending valuable time reading through something to end up not using it.

If this were to become successful and widely used the NATA could also begin to provide research from other journals outside of JAT. While the JAT is a great source for information for athletic trainers, there are many other journals that also produce useful information from other allied health professions. It could be beneficial for ATs to have exposure to research that is being done in other fields such as

nursing and physical therapy. This exposure would broaden the knowledge of ATs and could increase interprofessional collaboration. Finding a way for ATs to be able to quickly determine whether an article is worth reading could be one way to increase the use of EBP and using bullet points that are provided with the abstract is one possible solution.

CONCLUSION

A major transition is occurring to achieve the implementation of EBP throughout the field of AT. In December of 2015, athletic training professionals were required to report ten of their fifty CEUs in an EBP category. This was the first time that athletic trainers needed a portion of CEUs to come from an EBP section. This means that all athletic trainers who would like to maintain certification have recently taken courses either online or in person that teach about EBP. The goal is that this will familiarize all ATs with EBP in hopes that it will begin to be used more. However, since this is the first reporting period that required the EBP category, there is little known about how effective adding CEUs in the field of EBP will be and whether knowledge will be gained and translated into practice. Changing the way online continuing education is presented and completed by ATs may increase comprehension and understanding of EBP. This understanding may lead to using it in clinical practice. Having benchmark requirements for completing the CEUs throughout the two year period could lead to more frequent exposure to all ATs and may increase the understanding. This checkpoint process would prevent ATs from completing all CE at the beginning or end of the reporting period, and would instead spread it out throughout the two years allowing for increased exposure. One major complaint for using EBP in the clinic is a lack of comfort with how to use it (Hankemeier & Van Lunen, 2013a). Increasing frequency of exposure may help to make clinicians more comfortable with how to use EBP causing a change in practice. While there will no doubt be challenges associated with the implementation of EBP in athletic training, the use of online learning mentioned in this chapter may ease the transition for athletic trainers, managers, and organizations.

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KEY TERMS AND DEFINITIONS

Allied Health: The segment of the workforce that delivers services involving the identification, evaluation and prevention of diseases and disorders; dietary and nutrition services; and rehabilitation and health systems management.

Athletic Trainers (ATs): Health care professionals who collaborate with physicians to provide prevention, emergency care, clinical diagnosis, therapeutic intervention and rehabilitation of injuries and medical conditions (Profile of athletic trainers, 2014, para. 1).

Continuing Education: Education provided for adults after they have left the formal education system, consisting typically of short or part-time courses.

Evidence-Based Practice: Evidence based medicine is the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients (Sackett et al., 1996).

Knowledge Translation: A dynamic and iterative process that includes synthesis, dissemination, exchange and ethically-sound application of knowledge to improve the health of patients, provide more effective health services and products, and strengthen the health care system (Graham et al., 2006).

National Athletic Trainers' Association (NATA): A professional membership association serving certified athletic trainers and others who support the athletic training profession in the United States.

Transitions: Change processes that involve a beginning, middle, and an end.

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Chapter 26

Integrating Web-Based Technologies Into the Education and Training of Health Professionals

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ABSTRACT

The integration of online learning and instruction into the education and training of health professionals continues to gain popularity. Curriculums that have previously been thought to be inappropriate for web-based delivery are now being offered online. Innovations in online learning and instruction have improved the delivery of web-based education and have provided educational opportunities for many that were “unreachable” by traditional classrooms. In this chapter, a description of how computer-based technologies are being applied in the training and continuing education of health professionals is provided. Suggestions for creating online learning and instruction for education and training in healthcare are provided.

INTRODUCTION

With rising health care costs and the need to treat more and more people with chronic health conditions, many people wonder how healthcare can be advanced in America. Along with healthcare reform, education and training will play a significant role in meeting increased demands for health professionals. In this chapter, exploration of how online learning and instruction can be used to meet the educational needs for the healthcare industry is detailed.

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Distance education, e-learning, computer mediated, web-based, and online instruction are terms used to describe education delivered through computer-based technologies. Whatever term is chosen, such computer-based technologies are essential components of the preparation and continuing education of health professionals. For many health professions, formal education, as well as continuing education, includes some type of web-based learning, with some programs completely online.

The American Journal of Health Promotion (2009) defined health promotion as:

Health Promotion is the art and science of helping people discover the synergies between their core passions and optimal health, enhancing their motivation to strive for optimal health, and supporting them in changing their lifestyle to move toward a state of optimal health. Optimal health is a dynamic balance of physical, emotional, social, spiritual, and intellectual health. Lifestyle change can be facilitated through a combination of learning experiences that enhance awareness, increase motivation, and build skills and, most important, through the creation of opportunities that open access to environments that make positive health practices the easiest choice.

In this chapter, health promotion refers to all education and programming relating to health that is intended to promote positive health outcomes. Many health promotion interventions and programs are conducted online. In fact, the term e-health has been created to describe web-based health promotion initiatives. Health care professionals and health educators are using online instruction to teach patients. Higher education courses that promote lifelong wellness, including physical activity-based courses, are also using online learning formats.

The objectives of this chapter are: 1) to understand the benefits, quality indicators and use of online learning and instruction in health; 2) to discuss whether online learning and instruction is appropriate for training health professionals and for the delivery of health promotion; 3) to review an example of how blended and online instruction can be used for health promotion in higher education; 4) to discuss future trends for online learning and instruction in health.

BACKGROUND

In 2013, the Bureau of Labor Statistics reported there were more than 15.8 million jobs in the combined healthcare industries (Torpey, 2014). It is projected that over 4 million jobs will be added between 2012 and 2022, which is more than any other industry (Torpey, 2014). As the largest industry, the demands for preparation and continuing education of health-related professions comprise a significant percentage of adult education conducted in the United States.

Health care professionals are in demand throughout America, but are particularly needed in Health Professional Shortage Areas (HPSAs). According to the U.S. Department of Health and Human Services (2016), 8,200 practitioners are required to meet the need for primary care providers in HPSAs. In order to meet the demands for qualified health care professionals in America, institutions of higher education have sought cost efficient and effective methods of preparing and training health care providers. One way to address the high demand for education, especially for areas that do not have institutions of higher learning, is to begin to offer and expand distance education opportunities. The current use and continued expansion of online learning and instruction in higher education has caused health-related disciplines (and most other disciplines) to ask some difficult questions, which will be explored in this chapter.

SIGNIFICANT QUESTIONS AND ISSUES IN ONLINE LEARNING AND INSTRUCTION IN HEALTH

The health and wellness of individuals, communities, and society are largely dependent on health care providers and health promotion. Consequently, much discussion and debate has occurred as the delivery of adult education and training has evolved to include web-based learning and instruction in the field of health. Some of the significant questions and issues in the discussion about online learning and instruction include the benefits, quality indicators, and the current use in the field of health.

One of most often asked questions is, “what are the benefits of online learning and instruction?” For potential students who are employed full-time, on active-duty in the military, have family obligations, or are geographically remote, online programs may be the only option for completing their education. According to Chaney et al. (2009), distance education programs benefit students and the university at large. For students, graduation time can be decreased through easier access to courses. Chaney believes distance education diversifies student populations as courses are accessible from any part of the country or world. For the university, strains on the built environment are resolved as no space is needed on campus. Costs are also reduced as all types of printing are eliminated when course materials and assessments are conducted online.

Online learning and instruction can also benefit the environment. Many campuses have struggled to resolve parking and air quality issues. Distance education reduces travel to and from campus, which significantly reduces student and faculty costs for travel, and the inevitable environmental effects associated with auto admissions.

Another question asked is, “what are the quality indicators of online learning and instruction for health-related professional education?” Like all disciplines, health professionals, faculty, and students have their opinions about what contributes to effective web-based learning and instruction. Reeves and Reeves (2008) provided 10 dimensions that should be considered during the instructional design, implementation and evaluation of online courses in health and social work. The model they describe for health and social work education includes 10 dimensions of interactive teaching and learning:

1. Pedagogical philosophy;
2. Learning theory;
3. Goal orientation;
4. Task orientation;
5. Source of motivation;
6. Teacher role;
7. Metacognitive support;
8. Collaborative learning support;
9. Cultural sensitivity; and
10. Structural flexibility.

While the description of these dimensions is beyond the scope of this chapter, overall they emphasize important pedagogical practices translated from the face-to-face to the online environment.

Chaney et al. (2007) described some similar quality indicators of distance education, with some additional ones specifically related to technology. These researchers agree with the importance of interaction, especially between the students and teacher. Other best practices include incorporating the use of

active learning techniques, providing prompt feedback, and respecting diverse ways of learning. It is essential for any distance education program to correlate to the mission of the institution, implements the use of appropriate, and reliable multimedia tools, all while providing sufficient student and faculty support and resources. Instructors designing these courses need to provide a clear course structure and means for program evaluation and assessment so improvements can be made.

How is online learning and instruction used in the training of health professionals? Allied health care is using three models of e-learning: blended learning, online learning, and continuing education (Stewart & Wright, 2004). Blended learning includes both face to face and online learning and instruction. Online learning is learning and instruction that is completely web-based. Continuing education for health professionals is offered in both blended and online formats. In fact, most health-related disciplines are using a combination of online and face-to-face learning in their programs.

Perhaps the most salient question to ask is, "Is web-based instruction an effective mode of educating health professionals?" While this question is still in need of additional research evidence to provide data-based answers, and many factors play a role (i.e., faculty training and course design), it certainly can be. Most health professionals rely heavily on technology in their practice and thus, it seems appropriate for technology to play a role in the education of future health professionals. In fact, Hollis and Madill stated (2006),

Evidence suggests that blending combinations of technologies with computer mediated learning enhances interaction and could address the higher order learning needs of professional programs such as occupational therapy. (p.61)

Through a review of research focused on computer-enhanced classroom-based teaching, online courses, online degree programs, and online continuing professional education, Hollis and Madill (2006) recommended that both online and face-to-face teaching and learning opportunities accommodate all types of students and faculty. Hollis and Madill (2006) emphasize the use of multiple technologies to enhance interaction between students, and between students and instructors. However, to optimize the effectiveness of online learning, they believe appropriate preparation and support is required for both students and faculty.

How is blended and online learning and education being used in health professions? Konin (2004) discussed how to enhance clinical education, like Athletic Training, through the use of web-based programs. Like most health professionals, education and training includes some type of fieldwork, or internship placement. Information and assessments for clinical instructors can be delivered electronically through an online course management system such as Blackboard. Face-to-face class formats can be enriched through the availability of a multitude of supplemental online materials. McLeod and Barbara (2005) reported, "The use of online chat rooms was seen to be beneficial to encouraging peer support while on fieldwork for allied health students" (p.276).

Web-based education has also been used to teach medical students. A web-based self-study was developed to teach medical students how to help smokers quit and how to prevent others from starting to smoke. The curriculum helped medical students develop effective counseling skills in the prevention and treatment of smoking (Pederson, Blumenthal, Dever & McGrady, 2006). In another study, third- and fourth-year medical students completing a web-based women's health curriculum valued learning women's health, preferred this self-directed learning over lecture, scored highly on knowledge tests, and were involved in more high-level discussions of women's health with faculty (Zebrack et al., 2005).

Online learning and instruction is also essential to the continuing education of health-related professionals. Williams (2006) conducted a meta-analysis of 25 studies assessing achievement in distance education in allied health and found that distance education is as effective as face-to-face instruction. Student achievement outcomes were positively correlated with work experience and professional knowledge. Outcomes were also better for distance education experiences that included multiple learning and instructional strategies including, but not limited to, interaction and introspection.

WEB-BASED HEALTH PROMOTION

Researchers have examined online health promotion and found them to be effective methods of information delivery (Parlov, Cowdery & Hoerauf, 2004; Shegog et al., 2005). Wantland et al. (2006) conducted a meta-analysis of effects of patient knowledge and behavioral change outcomes in web-based and non-web-based interventions. In 16 of 17 web-based interventions reviewed, participants showed improved knowledge and behavioral outcomes. D'Abundo, Fiala, and Mariano (2010) found that an online learning module was an effective way to deliver information about smoking to college students in a general education fitness and wellness course. Some advantages of computer-based health promotion activities include individual tailoring, consistency of content, the incorporation of media, and availability of the program when a person is ready to make a change.

In order to meet the health promotion goals of many universities and colleges, university basic study curriculums include required hours in courses that promote life-long wellness. Many such courses are delivered in face-to-face formats and require participation in some type of physical activity. Like issues involved in the preparation of future health professionals, there are obstacles encountered in accommodating the diverse needs of learners in the university setting. The option of web-based delivery of such courses may help meet the demands of an ever- expanding student population.

RECOMMENDATIONS

For the practitioners and faculty that design, implement and evaluate training of future health professionals and health promotion interventions and programs, it may be difficult to envision how to develop blended and online courses/programs from existing traditional curriculums. There may also be concerns about how to ensure that objectives are being met in blended and online formats. The following are suggestions about developing blended and online instruction focused on health promotion in higher education. The information may be applied to the training of future health professionals as well health promotion activities outside of education.

1. **Start with Blended Courses Before Moving to Completely Online Formats:** For some health professionals and health faculty, it is difficult to decide how to adapt existing educational materials, activities and programs to web-based delivery. For both blended classrooms and completely online learning environments, there are a numerous online resources that are available for educational purposes. For example, PBS provides much of their health-related programming on their website and includes educational materials for discussing the content. Bennett (2005) described the potential for using The Multimedia Educational Resource for Learning and Online Teaching (MERLOT)

as an online resource linked to thousands of learning objects. Resources available include online learning materials, peer reviews, learning assignments, and user comments, all organized by discipline. Instructional technology consultants are also available to assist with the development of online learning materials and curriculums.

2. **When Moving Completely Online Go Beyond Content and Strive to Increase Interaction!** One criticism of online learning and instruction is that it limits both student-to-student and instructor-to-student interaction. Those of us that teach both online and face-to-face formats realize that interaction largely depends on the facilitation of class and the members of the class itself. In order to continue to raise awareness about web-based education, it is important to educate practitioners, students, and the public about the potential of online education.

One way to alleviate some of the concern about the lack of instructor and student interaction in online classes is to design strategies to promote interaction and build community among student and participants. Stow (2005) stated that in online courses, activities should include multiple types of interaction. The author recommends that the instructor communicate with the students in a timely manner. Stow suggested that methods like chat rooms, discussion, and feedback allow the students to become actively engaged in order to decrease the transactional distance.

One way to increase student interaction and build community in blended and online course formats is the establishment of "Course Buddies." The objective of using "Course Buddies" is to build community in blended and online courses and in health promotion programs delivered in a web-based format. To begin the "Course Buddy" selection, instructors can ask students to post introductions that include three things that most people do not know about them and include a picture. The next step is to have students review each others' introductions and find three people that they have things in common with or they want to get to know better. Then instruct students to e-mail potential "Course Buddies" to exchange contact information or just communicate by using e-mail. The process of finding "Course Buddies" in itself helps build community and enables students to learn more about each other. Once "Course Buddies" are established, students can discuss activities, study for exams or work on assignments.

FUTURE TRENDS

The future for online learning and instruction in health seems promising as we strive to meet the demands of an ever-changing health care system with accessible training and continuing education opportunities. However, to further facilitate successful use of online delivery methods to train health professionals and to promote health, data-based research describing and analyzing its effectiveness is essential. Advocacy on the part of professionals in health-related disciplines is also critical for web-based education methods to be embraced. Part of such advocacy includes increasing awareness of the online opportunities that already exist and exploring the potential of alternate computer based methods of delivery. Those interested in advocating for online education may want to join The United States Distance Learning Association.

In order for online learning to continue to grow and become embraced, myths associated with this mode of instruction need to be dispelled. While it is undoubtedly serving a need, and the technologies available to interact with learners from a distance continue to evolve, professionals and educators with

substantial reservations regarding its role in teaching and learning remain. It is recognized that online learning is not for everyone, and it may not be the best method for teaching certain types of curriculum, it is certainly effective if taught based on sound instructional design principles and well trained instructors. A successful future that optimizes the use of online teaching and learning depends on the collaboration and communication among professionals regarding the most effective ways to meet learning objectives. Once those are established, technology use can be designed around those objectives, and not vice versa.

Another trend in online education is peer review. As online learning and instruction continues to expand in health-related disciplines, much discussion focuses on how to ensure the quality of web-based programming. Peer review has been suggested as a way to review and improve online course delivery as well as health promotion efforts. Quality Matters © (QM) (Quality Matters, 2016) is a peer-review process designed to certify the quality of online courses. The Quality Matters process uses a rubric to review eight broad standards in blended and online courses that include: learning objectives, assessment and measurement, resources and materials, learner engagement, course technology, learner support and accessibility. Many programs throughout the country have created their own versions of peer review or “online observations” to assess the quality of web-based curriculums.

CONCLUSION

As described in this chapter, online learning and instruction have become important components of formal and continuing education for health professionals and in health promotion programs. Curriculums that have previously been thought to be inappropriate for web-based delivery are now being offered online. Innovations in online learning and instruction have improved delivery of web-based education and have provided educational opportunities for many that were “unreachable” by traditional classrooms. As web-based educational opportunities continue to expand, it is our hope that more health professionals and the general public will learn about the efficacy and possibilities of online learning and instruction.

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KEY TERMS AND DEFINITIONS

Blended Learning and Instruction: Includes both face- to-face and online learning and instruction.

Course Buddies: An ice-breaker or introduction strategy used to build community in blended and online courses and in health promotion programs.

E-Health: Health promotion initiatives delivered online.

Face-To-Face Learning and Instruction: Course activities and instruction occur in the traditional classroom without the use of online learning and instruction.

Health Promotion: Refers to all education and programming relating to health that is intended to promote positive health outcomes.

Health-Related Professions: Professions that delivery medical care and health promotion including but not limited to nursing, occupational therapy, athletic training, respiratory therapy, physicians, physician assistants, social workers, and health educators.

Online Learning and Instruction: Learning and instruction that is completely web-based.

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Chapter 27

Interactivity in Distance Education and Computer–Aided Learning, With Medical Education Examples

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ABSTRACT

Medical educators commonly place considerable importance on the notion of “interactivity” in the educational process. Interactivity may be defined as a reciprocally active situation whereby a two-way flow of information or opinion exists between a source and a user, and where the source responds to the user’s input. Advocates of interactivity maintain that well-designed interactivity in educational systems helps capture the learner’s interest, has the potential to speed the learning process, and even allows for continuous assessment of the degree to which the material is mastered. Medical educators also point out that technology can allow for high-quality interactivity by providing for frequent and relevant user feedback, by recognizing when students misunderstand a concept, and by providing learning aids such as animations or graphs that vary depending on user input. However, badly designed interactivity can also impede student progress.

INTRODUCTION

Webster’s Revised Unabridged Dictionary defines interaction as: 1. intermediate action, 2. mutual or reciprocal action or influence; as, the interaction of the heart and lungs on each other. The *Oxford English Dictionary* defines interactivity as reciprocally active, allowing a two-way flow of information between source and user, responding to the user’s input. This is the view advocated by many observers (Wagner, 1994; Wagner, 1997; Anderson, 2003). Notes Anderson: “Simply stated, interactions are reciprocal

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events that require at least two objects and two actions. Interactions occur when these objects and events mutually influence one another” (p. 8). The concept of “interaction” in education and training varies with subject domain (e.g., philosophy versus physics), with format (e.g., conventional versus distance education) and with other factors. Although the term is frequently overused and poorly understood, the notion of interactivity remains important and useful, and is especially topical given the availability of technologies designed to support advanced interactivity.

BACKGROUND

In his book *The Art of Interactive Design*, Crawford (2002) discusses the notion of interactivity in terms of a conversation: “a cyclic process in which two actors alternately listen, think, and speak,” and notes that the “quality of the interaction depends on the quality of each of the subtasks (listening, thinking, and speaking).” This model of interactivity avoids some of the pitfalls associated with some definitions offered in the past.

As noted above, educators place considerable importance on interactivity in learning (Anderson & Garrison, 1995; Fahy, 2005; Garrison & Cleveland-Innes, 2005; Lapadat 2007, Faghihi et al., 2016). Well-designed interactivity can help capture the learner’s interest, has the potential to speed learning, and allows for continuous assessment of the degree to which the material is mastered. Technology (at least theoretically) can allow for high-quality interactivity by providing for frequent and relevant user feedback, by recognizing when students misunderstand a concept, and by providing aids such as animations or graphs that vary with user input. However, badly designed interactivity can also impede student progress, suppressing, or making more difficult, program flexibility and learner independence (Burbules & Callister, 2000; Faghihi et al., 2016) (*vide infra*).

The importance of interactivity in learning is illustrated by the fact that a number of journals address this topic. For instance, the *Journal of Interactive Learning Research* (JILR) publishes manuscripts dealing with “the underlying theory, design, implementation, effectiveness, and impact on education and training of the following interactive learning environments,” including such varied topics as “authoring systems, cognitive tools for learning computer-assisted language learning, computer-based assessment systems, computer-based training, computer-mediated communications, computer-supported collaborative learning, distributed learning environments, electronic performance support systems, interactive learning environments, interactive multimedia systems, interactive simulations and games, intelligent agents on the Internet, intelligent tutoring systems, microworlds, virtual reality based learning systems,” and anything else related to these.

In this review, we will discuss interaction in distance education and training, with an emphasis on medical education. Since educational technologies are often used to support interactivity, an important theme will be how technologies can support or impede interaction.

Interaction in Publication

Few would argue that published documents form a very important component in education. Stevan Harnard (1992) has emphasized that electronic publication provides a dimension of interactivity in

document publication that is radically new. While online journals are still in evolution, and the form they will ultimately take – combining reader access with content credibility and publisher concerns – is still being determined, there can be little doubt that online journals are here to stay.

Interaction in Distance Education

One simple definition of “distance education” is that it is the delivery of instruction that does not require the student to be present in the same location as the instructor. What then is “interaction” in distance education? We suggest that it is a generic or broad term, covering all manner of notions of amplification, appraisal, clarification, commentary, communication, exploration, feedback, involvement and participation in the context of an educational exercise.

In more concrete terms, interactivity may be based on, or supported by, communication technologies such as the telephone, e-mail, instant messaging, or computer conferencing, as well technologies such as computer-based simulation. As such, it may be hard to define the concept of interaction precisely. Regardless, the notion of interaction should become clearer as the reader reads on.

Finally, it should be noted that although many individuals (e.g., Gilbert & Moore, 1998) use the terms “interaction” and “interactivity” interchangeably, some authors draw a distinction between the two. For example, Wagner (1994, 1997) defines “interaction” in terms of an interplay of behaviors in which individuals and groups influence each other, while “interactivity” is defined in terms of real-time characteristics of technological systems.

Importance of Interaction in Distance Education

Moore & Kearsley (1996) describe three types of interaction within distance education. McIsaac & Gunawardena (1996) add a fourth type, which takes into account the interaction that occurs when a learner must use educational technologies as part of the learning process. In these descriptions, students in a distance education “learning environment” are thus said to interact variously with the instructor, the content, the technology, and with other students.

In addition to these four forms of interaction, further distinctions must be made between instantaneous (“real time”, “synchronous”) and delayed (“asynchronous”) interaction, as well as between “same-place” and “different-place” interaction. Generally speaking, delayed and different-place interaction offer the student more flexibility and opportunities for thought and reflection, while immediate and same-place interaction, some would say, may allow for a greater sense of spontaneity, impulsiveness and even exhilaration.

With conventional classroom-based teaching, the focus is predominantly on student-teacher interaction, with student-content interaction also taking place, especially when out-of-classroom reading takes place. In the distance education setting, with the heavy use of self-study materials, the focus is usually on student-content interaction, with other forms of interaction occurring to varying degrees. Interaction with technology is also frequently important. Finally, recent research in collaborative and cooperative learning environments, especially those involving computer networks, has led to new insights into the nature of student-student (or more generally, peer-peer) interaction.

Note also that the above four-pronged approach to interactivity in education is not the only available model. In some educational domains alternate models may prove to be useful. For instance, we have

developed a rather different six-category approach to interaction, outlined in Table 1, which we believe works well to help explain the notion of interaction in the realm of distance education, using examples from medical education.

Learners and instructors will have preferences regarding interactivity, and some forms of education will rely on some forms of interactivity more than others. Regardless, the wise use of interactivity will help “engage” students and help ensure an enduring learning experience - learning enhanced by the potential individualization of the experience (Simonson et al., 2009).

Interactivity as a Driver of Change in Education Delivery

Interactivity requires a fundamental change in the manner in which education is delivered. Tapscott (1998) has identified seven ways in which this change occurs:

- From linear to hypermedia learning.
- From instruction to construction and discovery.
- From teacher-centered to learner-centered education.
- From absorbing material to learning how to navigate and how to learn.
- From schooling to lifelong learning.
- From learning as torture to learning as fun.
- From the teacher as transmitter to the teacher as facilitator.

Table 1. Types of interactivity in teaching and education, with examples focusing on medical education

[1] Person-to-person (student / teacher) interaction with both persons in direct verbal communication (“same place interaction”)
• Formal classroom or auditorium teaching (such as a question and answer period at the end of a lecture)
• Informal hallway or bedside discussions
[2] Person-to-person interaction (student / teacher) using remote communication technology (“different place interaction”)
• Telephone and audio conferencing
• Writing (paper, e-mail)
• Video conferencing
• Telemedicine (e.g., clinical discussion centering around a radiographic image)
[3] Paper-based interactivity [can also be “morphed” to a computer model]
• Interactive paper scenarios (If X is true then go to page Y otherwise go to page Z)
• Example 1: Patient with chest pain presents to the ER where Y = “admit patient to hospital”
• Example 2: Patient with abdominal pain presents to the ER where Y = “operate on patient [laparotomy]”
[4] Paper-based interactivity based on “developer pen” technology [can also be morphed to a computer model]
• Developer pen technology allows the student to see the result of a study or laboratory test once it has been “ordered”; based on the result of the selected investigation the student selects other clinical options (e.g., asks more questions, attempts to elicit a particular clinical finding, orders another test)
[5] Computer-based interactivity not using the World Wide Web. This usually involves using programming languages such as C++ or various older authoring platforms.
[6] Web-based interactivity. This usually involves using programming languages such as JavaScript or authoring platforms with Web support.

Note: further distinctions can to be made between immediate (“synchronous”, “real time”) and delayed (“asynchronous”) interaction.

Interactivity and Adult Learning Theory

Why is interactivity important in education? One reason is that interactivity is particularly compatible with established psychological models of learning and the central tenets of adult learning theory (Simpson & Galbo, 1986). In particular, constructivist principles help account for the importance of interactivity in distance education. Constructivism is the view that knowledge is “constructed” by the learner by testing ideas, concepts and approaches based on existing knowledge and one’s actively acquired experiences, including the views of others, and that knowledge is not merely acquired passively. Constructivist theory holds that students learn best when they actively and collaboratively participate in problem-solving and critical thinking while involved in an appropriately formulated learning activity, and that this learning involves the integration of newly acquired knowledge with pre-existing intellectual constructs.

Experts in adult learning also argue that traditional didactic teaching merely encourages passive learning, instead of the development of higher order cognitive skills needed for true education. They point out that active involvement is essential for effective learning, and adults learn best, they argue, when one can draw on previous experience, using techniques such as group discussion, simulation exercises, and problem solving. That is, going beyond mere looking and listening motivates people to learn on their own, gives students the motivation to try out new ideas, and encourages them to critically examine issues that were once simply accepted passively.

Interaction Between Student and the Instructor

Interactivity in the traditional classroom is primarily between the student and the instructor, and technology usually plays a secondary role; students can ask questions and get immediate replies. Outside the classroom students often interact among themselves by verbal means (“Did you understand how he solved problem 6?”) and may later interact by telephone, instant messaging and e-mail, three means of interactivity also available to distance education students.

Students in some distance education programs view videos of the regular on-campus classes, which include interactions between the on-campus students and the instructor (usually in the form of questions), but obviously such viewers cannot have any synchronous interaction with the instructor at the time of the lesson, although they are still able to exchange words with both the instructor (and, possibly, an academic advisor) via telephone, fax, instant messaging and e-mail.

In many cases distance education learners have no direct interaction with the course instructor, and instead deal only with an on-site coordinator or tutor. Still, provided these individuals are knowledgeable in the materials being taught and have well-developed communication skills, this should not be a problem. Such individuals are especially helpful in settings where there is a high ratio of students to instructor and/or when direct access to the instructor is not practical.

In contrast to the setting where students have no direct interaction with the course instructor, online services also exist which offer instructor-led courses where students can log into a message board for discussions with both the instructor and fellow students.

Interaction Between Student and Content

Many educational theorists would say that interaction between the student and the content is the heart of education, whether in the classroom or in the distance education setting (or, indeed, in the setting of

self-education). In order to learn effectively, the content must be presented in a way that will motivate the student and inspire thought. Most often, the material is presented as text with some graphics, and a good writing style with good organization of the material are the key elements to producing a useful document. The technology used for the document (printed paper, PDF, HTML etc.) is less important than the quality of the writing, although poor formatting makes even good writing hard to read.

One interesting notion in this context is Bloom's "alterable variables," modifiable factors that Bloom found to enhance group learning to the level of tutoring (Bloom 1984). Examples include the use of reinforcement, supplying corrective feedback, and offering cues and explanations. It would appear that use of Bloom's alterable variables would be excellent educational elements that might be introduced into the process of developing educational resources.

Interaction Between and Among Students

Students have always been able to communicate with one another in traditional classrooms, sometimes by passing notes, but usually by meeting informally before and after class. Such social interactions are important to making new friends and getting exposed to new ideas. These interactions also help in carrying out collaborative projects.

It is interesting to note that interaction between students is a somewhat new phenomenon in distance education, having started in a big way only since the development of the Web made computer-conferencing practical. Until relatively recently, distance education students had limited interaction with other students, their interactions being primarily with the instructor, the content, and the technology. However, the advent of Web-based computer conferencing and e-mail services has changed this. As a result of this and the development of groupware systems such as Lotus Notes, distance education is moving from highly individualized instruction (as in the correspondence education approach popular decades ago) to formats that encourage students to explore topics as a group and to undertake collaborative learning. This approach is also asynchronous, which gives learners the freedom to control their learning activities in terms of time, location and choice of collaborating partners. Other technologies, such as instant messaging or two-way video conferencing, also allow for communication among students, but are primarily synchronous in nature. By contrast, computer conferencing provides for asynchronous interaction, which fits much better into the hectic lives of many adult learners. Still, the nature of student-student interaction in distance education is fundamentally different from conventional educational settings.

Some students feel that the distance education format is often weak in the area of establishing "bonding" between classmates, who are not able to get to know one another as effortlessly as in a classroom. Students usually have no idea what their classmates look like, or what their voices sound like, thereby delaying the development of any "mental image" about the people in the class until much later, once many postings have been made and students get to know one another by means of written communications. This notion is known as "social presence" (Nippard & Murphy, 2007) which may be defined as "the degree to which participants are able to project themselves affectively within [a] medium" (Garrison 1997). Social presence affects student perceived learning (Richardson & Swan, 2003), may increase student satisfaction in online learning (Newberry, 2001), and may lead to improved emotional satisfaction (Rourke et al., 1999).

Interaction Between Student and Technology

Until recent years, educational technology was not especially capable of maintaining a high degree of interactivity with a learner, in contrast, say, to the very high level of possible interaction between a teacher and a student discussing a philosophical matter, where a series of verbal exchanges may occur that involves a cognitive effort much more advanced than mere memorization or rote repetition.

This matter will likely change favorably as computer technology inextricably advances. In particular, advances in Artificial Intelligence, educational authoring systems and scripting languages such as JavaScript will likely have a direct impact on the evolution of computer-based interactivity. Still, computer-based learning is much more complex than working through a textbook, and many students who are uncomfortable with computers see no reason to deviate from a curriculum based on a well-written textbook, particularly if accompanied by study guides and solution manuals.

Many advocates of computer-mediated distance education draw attention to the helpful aspects offered by computer-based methods, and understate the kinds of communicative and technical difficulties learners may experience. When students use complicated equipment in their learning environment, it is important to ensure the technologies used help rather than hinder the learning experience. Students using unfamiliar technologies may experience frustration, anxiety, and confusion related to computer hardware problems, software problems at the level of the operating system or the various software applications, as well as difficulties with Web access. Files may mysteriously “disappear.” Attachments sent by e-mail may be “lost”. Random “disconnects” may frustrate the user. Unless students are moderately familiar with computers, substantial effort may be expended on technology-related issues rather than learning the intended materials.

Thus technologies that are awkward, unintuitive or present the learner with a steep learning curve may hinder interaction and even impede learning. Various means by which technology can impede interactivity include: haphazard, unintuitive or disorganized user interfaces; poor screen layout; poor use of fonts and icons; systems that respond too slowly to user inputs; or systems that crash frequently. While a detailed discussion of this matter is beyond the scope of this review, books by design gurus Jakob Nielsen (1994) and Donald Norman (1999), are recommended as a good place to explore the nature of good and bad user-interface design.

Studies show that technical problems can occasionally render the educational undertaking to be a substantially negative experience. For instance, Hara & Kling (1999) carried out a study of a web-based distance education course at an American university, and commented that distance learners may experience problems and frustrations that are not well documented in the literature. They noted that three interrelated sources accounted for most of the problems: “lack of prompt feedback, ambiguous instructions on the web, and technical problems.” They concluded that the frustrations the students experienced “inhibited their educational opportunity”. In a related paper Hara & Kling (2000) voiced similar concerns.

Interactivity in Medical Education

The Royal College of Physicians and Surgeons of Canada (RCPSC) has long taken an active role in the post-certification education of Canadian specialists through their Maintenance of Certification (MOC) program and its forerunners. Although they use the term “Continuing Professional Development” (CPD) in referring to this process, it is, in essence, simply another term for Continuing Medical Education (CME).

The MOC program requires that members complete 400 credit hours of acceptable CPD in a five-year period to maintain specialist certification. Among the most popular means of collecting credit is through “Section 1” educational activities (attending lectures, seminars, scientific meetings, journal clubs, etc.). Other acceptable activities involve “practice audits,” “personal learning projects,” and education via medical simulation.

The RCPSC feels strongly that Section 1 activities are of increased educational value where there is an opportunity for interaction between the “expert” speaker and the participants. This is often in the form of a question and discussion period that serves to further engage the listener, as well as to clarify some of the issues that may remain unanswered at the end of the formal part of the presentation.

The MOC program requires that “at least 25 per cent of the time of a CPD event should be allocated for interactive learning.” Otherwise, the program coordinators believe, the event takes place at the expense of audience involvement, a key ingredient in learning. This view is supported by a landmark meta-analysis of the effectiveness of formal CME by Davis et al. (1999), who showed that traditional didactic methods do not generally lead to a change in clinical practice, or to an improvement in patients’ health outcomes, whereas interactive techniques are more likely to lead to a change.

Simulation in Medical Education

In many respects, simulators offer the ultimate in interactivity and appear to have an excellent future in medical education. Computer-based simulators used in medical education fall into four general categories: (1) Screen-based text simulators, (2) Screen-based graphical simulators, (3) Manikin-based simulators, and (4) Virtual reality trainers.¹

Screen-based text simulators create verbal scenarios in which the users pick one of several responses and, based on the chosen response, a new text scenario is produced. For instance, in a scenario involving a patient presenting with a severe headache, the user may be offered options such as prescribing an analgesic such as Tylenol or getting a CT-scan of the head. Based on the user’s choice, a new narrative is then generated and more management choices are offered. Being purely text-based, screen-based text simulators are relatively simple to construct, making them popular in early medical simulation efforts. However, since they are lacking in graphical elements, they are rarely used today.

Screen-based graphical simulators such as ‘Gasman’ (Philip, 1986; Philip, 2009) and ‘Body’ (Smith & Davidson, 2009) aim to recreate elements of reality in graphic form on a computer screen, often to elucidate the processes associated with drug administration. Usually, only a mouse interface is involved. While these simulations help one understand the conceptual theory underlying clinical practice, they usually do not confer practical skills. Their strength lies in an ability to help one understand abstract concepts while remaining portable and inexpensive.

Manikin-based simulators come in various levels of complexity, but are expensive. The advanced models include a physical model of the human body and provide continuous signals representing numerous physiological parameters. While some earlier systems required the intervention of a trainer to actively ‘stage manage’ the scenario in response to interventions, others make use of computer models of human physiology and pharmacology to automatically generate appropriate responses in the manikin. In contrast to screen-based simulations, these simulators appear to recreate enough elements of reality to allow the acquisition of skills that are transferable back to the clinical environment.

Virtual reality trainers are just beginning to gain popularity, especially amongst surgical trainees. They offer a transition from the two-dimensional world of the textbook to the three dimensional world

of simulated patients. The principal problem so far has been the lack of reality modeling in terms of offering a tactile 'feel'. However, "haptic" solutions that provide feel and heft are being actively researched in centers, often using micro-engineering techniques.

Kinds of Interactivity in Medical Education

We have already noted that, as with all areas of education and training, interactivity plays an important role in medical education. While the RCPSC emphasizes means such as question and answer sessions to achieve this goal, many other methods can be imagined. One possible taxonomy of the kind of interaction in medical education is outlined in Table 1.

Social Media in Education

Social media such as Facebook can help serve to connect millions of learners, forming a virtual learning community where information, ideas, resources and suggestions are informally exchanged, offering community members ready access to knowledge, both from experts and other students. Some social media like Yahoo Answers focus on allowing users to submit questions and answer questions asked by others. As a way to encourage participation, members may get the chance to earn "points." Users can also comment on answers, rate questions and answers, and offer suggestions to improve the service. However, such sites have sometimes been criticized as a problematic venue for serious education because of difficulties in readily deleting incorrect answers, and a point structure that rewards participation over accuracy (Liebenluft, 2007).

Massive Open Online Courses

The Khan Academy (www.khanacademy.org) is a popular non-profit educational website created in 2006 by Salman Khan. It has delivered millions of lessons in topics as varied as physics, chemistry, biology, mathematics, astronomy, economics and history. The Khan Academy has both enthusiasts and critics. Enthusiasts support the academy for its ingenuity, its popularity, and its eradication of economic barriers to education. Others, however, are concerned that the videos lack interaction and active engagement.

Coursera (coursera.org) is an educational technology company founded by Andrew Ng and Daphne Koller. Rather than the mini-lecture approach taken by the Khan Academy, Coursera offers hundreds of free noncredit university level courses in computer science, engineering, mathematics, business, social sciences, humanities, and other fields. In the future, students may be take Coursera courses for university credit, at costs competitive with brick-and-mortar universities, via exams administered via an online proctoring service that allows students to be watched via webcam. Similar initiatives have also been launched by Education Portal (<http://education-portal.com/>) EDX (edxonline.org), Minerva Project (minervaproject.com) and Udacity (udacity.com). All are examples of Massive Open Online Courses (MOOCs).

Course Management Systems

Course management systems (sometimes also known as learning management systems) are software platforms that provide an instructor and students with a set of resources (course document storage, e-mail,

discussion threads, videos, examination capabilities, etc.) that facilitate the development and delivery of online courses. Examples include Blackboard (www.blackboard.com), Moodle (moodle.org), Pearson LearningStudio (www.pearsonlearningsolutions.com/pearson-learning-studio/), OLAT (www.olat.org), and Sakai (www.sakaiproject.org). These systems are primarily intended for asynchronous content delivery; for the delivery of synchronous content, technologies such as videoconferencing and web conferencing are often used. Examples here include the use of Skype (www.skype.com), Webex (www.webex.com) and GoToMeeting (www.gotomeeting.com) for the delivery of lectures and for virtual class discussions.

Interactive Learning Games

Interactive games are not only intrinsically engaging, but can also serve to help develop interpersonal and collaboration skills leadership, and promote creativity, critical-thinking, and problem-solving skills (Gee, 2003). Examples range from simple “typing tutor” games, where characters are falling down the screen and the learner must stop them before they reach the ground by pressing the corresponding key on the keyboard, to elaborate flight simulation games where one can learn the principles of flying an aircraft.

FUTURE RESEARCH DIRECTIONS

Although it is taken as a given in many circles that the addition of interactivity in the learning process is beneficial, the evidence for this viewpoint is not as strong as one might expect in medical education (v. Bridges (1992)). While use of interactivity offers a number of theoretical benefits (for instance, it is compatible with the constructivist model of learning), empirical proof remains rather limited.

Despite the obvious importance of interactivity in the educational process there are a number of questions that await definitive answers:

- Does interactivity really matter?
- How, if at all, does interactivity affect learners and learning?
- Do students prefer interactive learning?
- Do students perform better when exposed to interactive learning methods?

Perhaps the best available review of this topic in a medical context is a meta-analysis by Davis et al. (1999). In their study of a small number of “well-conducted” trials on methods of CME, they noted that traditional didactic teaching sessions “do not appear to be effective” in changing physician behavior but noted that there is “some evidence that interactive CME sessions that enhance participant activity and provide the opportunity to practice skills can effect change in professional practice.”

CONCLUSION

Adult learning theory emphasizes the importance of interactivity in the educational process. In exploring the differences between traditional teaching methods and distance education, the issue of differences in the patterns and properties of interaction in the two settings figures prominently. Students in distance

education interact variously with the instructor, the content, the technology, and with other students. Although four kinds of interactivity have been identified in the literature, other models specific to particular domains are possible. Interaction with technology will likely become increasingly important in computer-based distance education, but good design principles must be adhered to for successful outcomes.

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KEY TERMS AND DEFINITIONS

Adult Learning Theory: Pertaining to the art and science of adult learning. Also known as andragogy.

Asynchronous Interaction: Interaction that does not take place synchronously and so is independent of time restrictions. Examples include messages sent via e-mail, SMS or messages posted to a discussion server. Contrasted to synchronous interaction, as exemplified by classroom teaching or holding a telephone conversation.

Course Management System: Software platforms that provide an instructor and students with resources (course document storage, e-mail, discussion threads, videos, examination capabilities, etc.) for the delivery of online instruction.

Distance Education: The delivery of instruction that does not require the learner to be present in the same physical location as the instructor.

Electronic Publication: Also referred to as e-publishing or digital publishing or online publishing, electronic publication includes the digital publication of e-books, digital magazines, and journal articles, often in HTML: or PDF format.

Interaction: Mutual or reciprocal action or influence, as with the interaction between the moon and oceans causing tides.

Interactive Learning Environment: An environment that promotes learning via interactive processes, as exemplified by computer-based training or interactive computer simulation / games.

Interactivity: Reciprocal events that involve two or more objects and actions via mutual influences.

Massive Open Online Course (MOOC): An online course (often a university course) that offers unlimited participation, open access via the web, and automatic evaluation of the learner's progress.

Social Media: Websites and applications that enable users to create and share content (e.g., photographs) or to participate in social networking. Examples include Facebook, Twitter and MySpace.

ENDNOTE

- ¹ In the world of aviation, simple simulators are usually called “trainers”, with the term “simulator” being reserved for machines that provide graphics and/or full-motion replication of aircraft motions or actions.

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Chapter 28

Medical Equipment and Economic Determinants of Its Structure and Regulation in the Slovak Republic

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ABSTRACT

The changing paradigm of health as well as its new tasks requires constant updating of state health policy. Health of the population in the Slovak Republic is considerably worse according to many indicators in comparison to the advanced countries of the European Union. The new health policy should reflect the economic capacity of the country based on the current data about health of the population, the requirements of the healthcare providers, and the healthcare sector itself. Its modification should be based on updated information on the health status of the population and its trends as well as the situation in use of medical devices and equipment. It reflects the contribution of these factors and should be designed to provide healthcare in the most appropriate way. Aspect of the medical equipment localization in the Slovak regions is an important point making solution of the mentioned issues clearer. Results of the analysis have confirmed the relevant facts there is unsuitable distribution of the medical equipment among the healthcare facilities in the Slovak Republic.

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INTRODUCTION

Healthy population is a significant component in the process of economic growth of the country, because the full economic potential can only be achieved health. The health sector is affected by the innovation process, which includes skilled workforce healthcare sector is one of the largest in the European Union. Research and development in the health sector has the potential to reach 0.3% of gross domestic product. healthcare sector is one of the largest in the European Union, representing around 10% of the European Union gross domestic product and employs one in 10 workers with a higher than average proportion of workers with tertiary education. Support for human health is an integral part of the objectives of smart and inclusive growth and Europe 2020 (European Commission, 2011). An innovative development is necessary to exist to ensure the sustainability of the sector, as well as to achieve inclusive growth in the context of demographic change. It is not related only with the growing health needs of the population, but also pressure to increase the efficiency of the health system.

BACKGROUND

Modern medical equipment and technologies enable efficient and rapid diagnosis and treatment of diseases, hence their deployment in the health system necessity (Rosina et al., 2014). In addition to the quantifiable economic savings also it happens to humane treatment, prevention of possible complications, and thus to the elimination of the additional costs in the event of subsequent medical care for patients. Timely and successful diagnostics will save unnecessary medical procedures according to experts who make up one third – analysis of the European Association of medical technology Eucomed. Modern medical technologies, modern approaches to diagnosis and treatment combined with early detection also allow to shorten hospitalisation time for some diseases from several weeks to a few days. Reducing the number of hospital admissions and inpatient treatment time and replace feature to make it by the day surgery has been a global trend lately (Gavurová & Šoltés, 2014). In addition to radical savings in the health system derived from therapeutic and diagnostic procedure in conjunction with application of the latest research findings and health technologies, the macroeconomic view on this issue is also important. Within the medical technology industry in Europe more than 500,000 people are employed, making it a production of medical technologies important element of the gross domestic product of individual European countries. Upgrading of medical technologies occurs not only to improve them, but also to their constant replacement of modern and innovative technologies in the short term. This is confirmed by the fact that, for instance in 2012 the European Patent Office received more than 10,000 patent applications in the field of medical technology and the number is increasing. It is related to the significant progress in research and development.

Despite the positive development of modern medical technology an important component in the process of successful diagnosis and treatment becomes their availability. Availability of advanced medical technologies in the Slovak Republic is not proportional and regionally balanced. There are various problems that have long-term systemic nature (Gavurová & Šoltés, 2014; Kneppo et al., 2014).

If we look at the situation abroad, the density of medical equipment in different countries varies considerably in the European countries – for instance in the case of devices for x-ray computed tomography and magnetic resonance imaging. The Greeks have ten times more magnetic resonance imaging devices

for a person like the Hungarians, the Austrians three times more than the British. The Greeks have the most devices for x-ray computed tomography, there are three times more x-ray computed tomographs per person than the Dutch have or just like the Italians. The differences are evident not only among countries but also within countries. For instance, there are four-fold differences between trusts in the number of top medical equipment in the United Kingdom. If we conducted an international comparison of the other kinds of medical equipment in the country, we would have confirmed the existing significant differences between countries. Therefore, it is difficult to determine the optimal number in the country.

The primary objective of introducing and using of the variety of health technology is to improve the health of the population of the country. The Slovak Republic has still lacked standard procedures to govern the rational use of various diagnostic technologies. The negative consequences include unnecessary tests, which are also reflected in the economics of the Slovak healthcare system (Gavurová et al., 2014). There is no methodology to determine the optimal number of medical devices. Their introduction into medical practice is now accompanied with many obstacles. These are linked with the strategies of health insurance companies and with the waiting time for examinations -- waiting lists for procedures. Waiting, keeping the patient on the waiting list respectively, waiting time refer to the time between the placing of a patient on the waiting list and its disposal (Roberts et al., 2004). In relation to the effective healthcare, this is generally the time between approval and implementation of procedures (Mužík & Szalayová, 2013). According to the Organisation for Economic Co-operation and Development one of the reasons for the increase waiting lists has been a significant advance in surgical techniques and anaesthesia during the last two or three decades, what greatly have improved range, safety and efficacy of surgical procedures (Siciliani & Hurst, 2013). Many of the procedures have carried out at lower unit costs consequently a dramatic increase has occurred in demand for surgery, especially in effective – not acute – procedures, such as cataract surgery, hip surgery, or bypass in all the Organisation for Economic Co-operation and Development member countries. Waiting lists are a serious problem in these countries, including the Slovak Republic (Eriksson & Björnberg, 2009, Mužík & Szalayová, 2013). Long waiting times for efficient performances are typical for countries that combine health insurance with no or low deductibles and limited capacity of the patient (Siciliani, 2003). Fewer occurrences are in countries with insurance schemes, in which choice of health insurance is allowed.

Waiting times for examinations cannot be reduced by introducing a greater number of devices in the diagnostic process, because, for example, many machines on magnetic resonance imaging or x-ray computed tomography examinations are currently used only a few hours per week (Mužík & Szalayová, 2013). A significant limiting factor for higher and more efficient use is mainly contractual limits by health insurance companies that this whole mechanism availability and use of appliances targeted manner.

ANALYSIS

Our analysis is based on the individual types of the medical equipment used in the healthcare facilities. We have applied categorisation of this equipment according to National Health Information Center (Národné centrum zdravotníckych informácií) of the Slovak Republic that differentiates twenty-nine types of the healthcare devices. We have focused not only on this categorisation, but also on the localisation of this medical equipment from a view of elementary administrative division in terms of the highest level of self-government in the Slovak Republic. There are eight self-governing regions, where the Banská By-

trica Self-governing Region, the Bratislava Self-governing Region, the Košice Self-governing Region, the Nitra Self-governing Region, the Prešov Self-governing Region, the Trenčín Self-governing Region, the Trnava Self-governing Region and the Žilina Self-governing Region belong.

Dataset

Our dataset contains data coming from seven years from 2008 to 2014. For each year every type of the medical equipment in counted according to its localisation in the particular self-governing regions.

At first, the basic look at the distribution of the individual equipment types is offered with total numbers of these types and in the separate self-governing regions.

Figure 1 displays localisation of the equipment types in the separate self-governing regions. The x axis shows order of all the equipment types recognised by the dataset from the National Centre of Health Information of the Slovak Republic and the y axis signifies the administrative division of the Slovak Republic at the level of the territory units in terms of the self-governing regions. Grey shading of the x axis tags represents a share of the number of equipment of that type in the total number of all the 29 equipment types on the x axis, respectively a share of the equipment localised in the individual self-governing regions in the total number of the equipment in the whole Slovak Republic on the y axis. Circles' diameter in the individual cells and its shading are determined by a share of the particular equipment in the total number of all the equipment in the peculiar self-governing region in a column

Figure 1. Number of the equipment types in the self-governing regions in 2008

Source: Own elaboration compiled by the authors, 2016.

Legend for the x axis: 1 – angiograph; 2 – brachytherapy apparatus; 3 – bronchoscope; 4 – cystoscope; 5 – dialysis monitor; 6 – electrocardiograph; 7 – electroencephalograph; 8 – electromyography; 9 – endoscope, laparoscope, arthroscopy; 10 – gamma camera; 11 – gastroscope, duodenoscope; 12 – isotope irradiator; 13 – colonoscope, sigmoidoscope, proctoscope; 14 – colposcope; 15 – cryogenic device; 16 – laryngoscope; 17 – laser; 18 – linear accelerator; 19 – lithotripter; 20 – magnetic resonance imaging device; 21 – mammograph; 22 – monitoring device; 23 – positron tomograph; 24 – x-ray; 25 – tomograph; 26 – ultraviolet and infrared emitter; 27 – ultrasound device; 28 – uretroscope; 29 – high-frequency device. Legend for the y axis: BB – the Banská Bystrica Self-governing Region, BA – the Bratislava Self-governing Region, KE – the Košice Self-governing Region, NR – the Nitra Self-governing Region, PO – the Prešov Self-governing Region, TN – the Trenčín Self-governing Region, TT – the Trnava Self-governing Region, ZA – the Žilina Self-governing Region.

Equipment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Region																													
BB	5	2	13	5	46	187	19	9	63	4	31	4	21	5	2	7	45	2	4	4	7	309		97	12	1	112	3	28
BA	8	1	13	21	457	288	18	15	102	13	54	3	41	16	8	20	60	5	6	7	19	500	2	145	14	6	248	18	55
KE	9	4	26	15	20	265	12	15	115	10	43	6	39	6	8	19	35	2	4	10	13	431		120	9	2	131	11	79
NR	1		22	11	30	111	9	10	53	2	14	4	20	3	2	6	16		5	5	6	202	1	103	6	4	114	5	22
PO	7		25	9	27	117	11	8	69	10	15	2	21	2	2	6	24	1	4	5	9	293		83	8	7	101	7	27
TN	3	1	11	10	15	129	12	2	41		12	1	20	3	1	2	13	2	2		5	119		61	4	5	73	3	21
TT			8	10	39	88	12	3	48	2	17		16		5	8	12		4	1	5	149		75	6		59	12	12
ZA	7	3	23	13	54	208	11	7	90	3	44	7	23	9	4	9	29	2	4	1	8	420		116	11	5	124	8	39
	40	11	141	94	688	1393	104	69	581	44	230	27	201	44	32	77	234	14	33	33	72	2423	3	800	70	30	952	67	2838800

way and also by a share of the particular equipment in the total number of all the devices of that type in the whole Slovak Republic in a row way. Empty cells express zero number of that type equipment (Bendixen, 2003).

At the beginning of the observed period in 2008 the most numerous type of medical equipment is monitoring device with 2423 pieces in the whole Slovak Republic. The Bratislava Self-governing Region has exactly 500 items, what expresses also the highest number of any type. On the opposite side there is positron tomograph, which is the least numerous type of the medical equipment. There are only 3 such devices in all the regions.

There are 8800 devices together in all the healthcare facilities. From 29 types, 9 of them are not localised in everyone region – the mostly absents is positron tomograph in 5 regions and then brachytherapy apparatus in 3 regions.

At the end of the observed period in 2014 monitoring device remains the most numerous type. Its number was increased by 57 pieces to the total number of 2480. The highest share belongs to the Žilina Self-Governing Region with 519 devices. The least numerous type a positron tomograph was doubled by a brachytherapy apparatus, which are represented by 7 items in all the regions together.

There are 9192 medical devices in all the Slovak healthcare facilities. There is to note that also these two equipment types – positron tomograph and brachytherapy apparatus – were missing in the largest number of the regions – in 4, while on the one hand positron tomograph was added in 2 regions and on the other hand brachytherapy apparatus was set aside in 1 region.

Localisation of the Medical Equipment Types

To analyse distribution of the devices throughout the Slovak Republic, we quantify an equipment profile for each type of the equipment in 2014. This profile performs as a share of that type equipment localised in the particular self-governing region of the total number of the equipment in the whole country.

Unsuitable localisation of the devices among the self-governing regions in 2014 is seen mainly in a case of the least numerous types that are mentioned above.

Figure 2. Number of the equipment types in the self-governing regions in 2014

Source: Own elaboration compiled by the authors, 2016.

Legend: The same as for Figure 1.

Equipment	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
Region																														
BB	5	1	9	7	53	196	11	5	46	1	28	1	21	6	6	6	27		2	2	8	312	1	61	10	7	145	1	30	1008
BA	5	1	18	17	100	283	15	14	113	7	54	3	36	16	19	24	43	6	5	9	22	404	3	108	15	18	278	16	68	1720
KE	7		16	4	151	233	10	11	77	8	29	3	25	2	6	17	25	3	1	2	11	292	1	65	8	10	131	4	36	1188
NR	3		19	8	109	157	9	8	46	2	16	3	14	6	2	8	19	1	3	4	10	185	2	76	9	3	116	6	42	886
PO	8	2	27	8	83	144	11	8	76	3	27	3	19	4	3	9	29	2	7	6	10	407		74	11	14	151	8	40	1194
TN	3		11	9	125	155	13	4	72		15		21	3	1	4	21	2	2	4	9	147		60	11	13	107	5	25	842
TT	1		7	13	87	113	12	9	65		21		17		6	7	17		5	4	8	214		61	7	7	90	21	21	813
ZA	5	3	20	11	108	243	14	5	110	4	36	6	20	9	6	9	33	3	5	5	11	519		96	13	14	170	11	52	1541
	37	7	127	77	816	1524	95	64	605	25	226	19	173	46	49	84	214	17	30	36	89	2480	7	601	84	86	1188	72	314	9192

Table 1. Equipment profiles in 2014

	BB	BA	KE	NR	PO	TN	TT	ZA
1	0.1351	0.1351	0.1892	0.0811	0.2162	0.0811	0.027	0.1351
2	0.1429	0.1429	0	0	0.2857	0	0	0.4286
3	0.0709	0.1417	0.126	0.1496	0.2126	0.0866	0.0551	0.1575
4	0.0909	0.2208	0.0519	0.1039	0.1039	0.1169	0.1688	0.1429
5	0.065	0.1225	0.185	0.1336	0.1017	0.1532	0.1066	0.1324
6	0.1286	0.1857	0.1529	0.103	0.0945	0.1017	0.0741	0.1594
7	0.1158	0.1579	0.1053	0.0947	0.1158	0.1368	0.1263	0.1474
8	0.0781	0.2188	0.1719	0.125	0.125	0.0625	0.1406	0.0781
9	0.076	0.1868	0.1273	0.076	0.1256	0.119	0.1074	0.1818
10	0.04	0.28	0.32	0.08	0.12	0	0	0.16
11	0.1239	0.2389	0.1283	0.0708	0.1195	0.0664	0.0929	0.1593
12	0.0526	0.1579	0.1579	0.1579	0.1579	0	0	0.3158
13	0.1214	0.2081	0.1445	0.0809	0.1098	0.1214	0.0983	0.1156
14	0.1304	0.3478	0.0435	0.1304	0.087	0.0652	0	0.1957
15	0.1224	0.3878	0.1224	0.0408	0.0612	0.0204	0.1224	0.1224
16	0.0714	0.2857	0.2024	0.0952	0.1071	0.0476	0.0833	0.1071
17	0.1262	0.2009	0.1168	0.0888	0.1355	0.0981	0.0794	0.1542
18	0	0.3529	0.1765	0.0588	0.1176	0.1176	0	0.1765
19	0.0667	0.1667	0.0333	0.1	0.2333	0.0667	0.1667	0.1667
20	0.0556	0.25	0.0556	0.1111	0.1667	0.1111	0.1111	0.1389
21	0.0899	0.2472	0.1236	0.1124	0.1124	0.1011	0.0899	0.1236
22	0.1258	0.1629	0.1177	0.0746	0.1641	0.0593	0.0863	0.2093
23	0.1429	0.4286	0.1429	0.2857	0	0	0	0
24	0.1015	0.1797	0.1082	0.1265	0.1231	0.0998	0.1015	0.1597
25	0.119	0.1786	0.0952	0.1071	0.131	0.131	0.0833	0.1548
26	0.0814	0.2093	0.1163	0.0349	0.1628	0.1512	0.0814	0.1628
27	0.1221	0.234	0.1103	0.0976	0.1271	0.0901	0.0758	0.1431
28	0.0139	0.2222	0.0556	0.0833	0.1111	0.0694	0.2917	0.1528
29	0.0955	0.2166	0.1146	0.1338	0.1274	0.0796	0.0669	0.1656

Legend: The same as for Figure 1.

To examine profile of the self-governing regions from an equipment type point of view regional equipment profile is applied. It characterises the particular type of medical device in the light of all the self-governing regions. Regional equipment profile expresses a mean share of all the equipment profiles in each region.

Regional equipment profiles demonstrate average localisation of the equipment types according to the self-governing regions. The largest decrease all over the observed years appeared in a case of the Bratislava Self-governing Region, where regional equipment profile sank from 0.2458 in 2008 to 0.1871

Table 2. Regional equipment profiles

Year	BB	BA	KE	NR	PO	TN	TT	ZA
2008	0.119	0.2458	0.1658	0.0894	0.1023	0.0649	0.0672	0.1457
2009	0.1246	0.2118	0.1756	0.0875	0.1107	0.0719	0.0647	0.1533
2010	0.1178	0.2043	0.1939	0.0828	0.1092	0.0751	0.0696	0.1473
2011	0.117	0.2024	0.1978	0.0798	0.1091	0.0744	0.0684	0.151
2012	0.1187	0.2011	0.1956	0.0818	0.1093	0.073	0.0753	0.1452
2013	0.1173	0.1992	0.1963	0.0804	0.113	0.075	0.0747	0.1441
2014	0.1097	0.1871	0.1292	0.0964	0.1299	0.0916	0.0884	0.1676

Legend for the x axis: The same as for the y axis of Figure 1.

in 2014. In terms of the absolute numbers of equipment it means fall from 2163 to 1720 devices. The largest year-over-year change happened to the Košice Self-governing Region, where in the last observed year was reduction from 0.1963 in 2013 to 0.1292, which in the absolute numbers mean loss of 881 devices – a 42.58% share of 2013. The Banská Bystrica Self-governing Region keeps its share on the same level roughly. All the other regions were slightly increasing their regional equipment profiles throughout the explored period with the highest year-over-year increment between 2013 and 2014.

Equipment Distribution

Distribution of the medical devices among the healthcare facilities have to take into account several parameters. From our point of view, we look at the localisation at level of the highest tier self-government. Equipment spreading depends on financial capacity of individual healthcare facilities in the region, as there are public and private ones. Methods of their financing are considerably differentiated. Public healthcare facilities, whose debt steadily annually increases, have limited investment opportunities unlike other private healthcare facilities, which operate at a profit. It is difficult to pick up a need for proportional distribution. To get more detail analysis it is necessary to obtain information about investment strategies and financial possibilities of healthcare facilities and contracted volumes of medical services by health insurance companies.

There is to note that statement about oversizing or undersizing of numbers is based only on conclusion of our correspondence analysis.

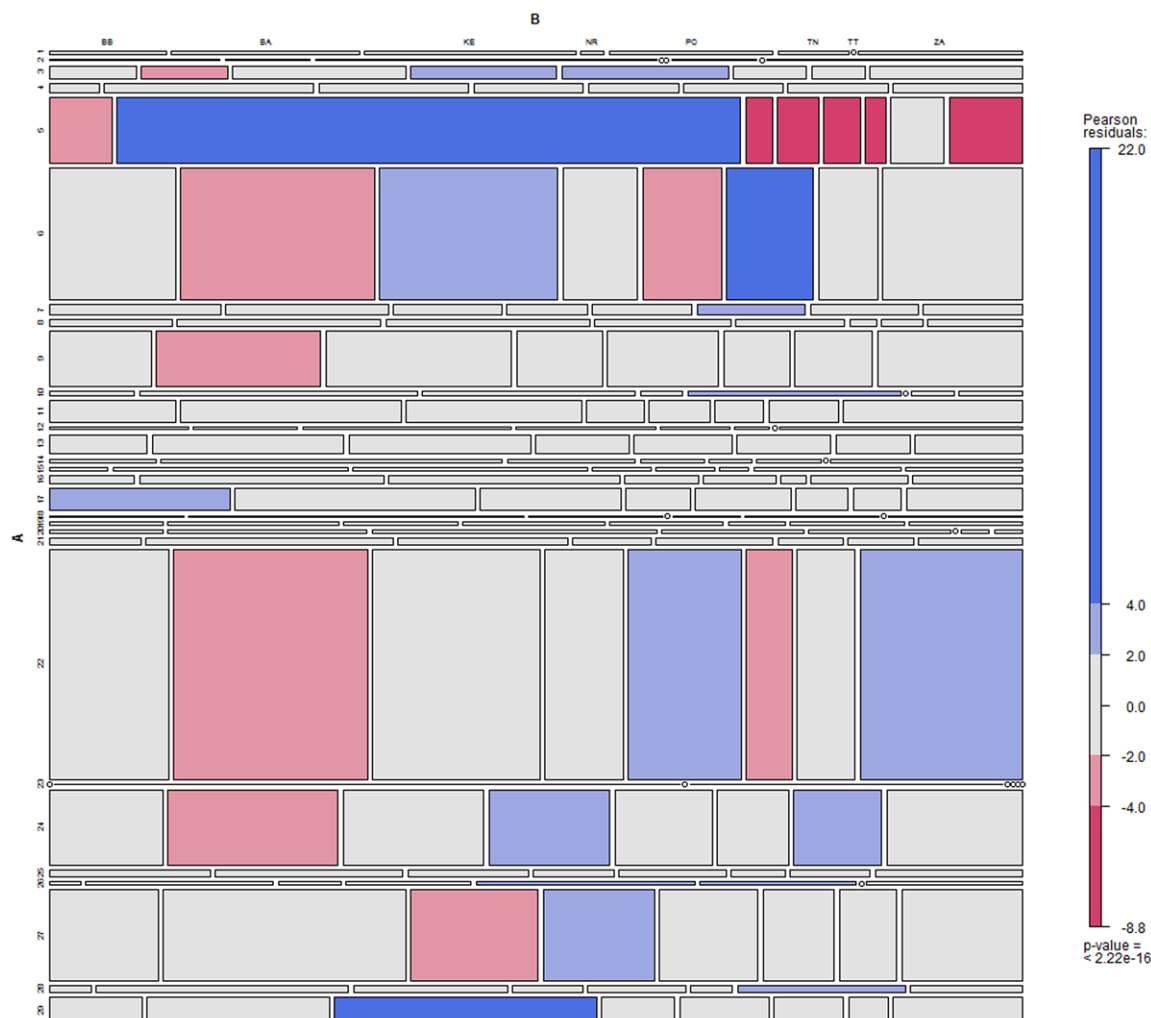
Diagram marked as Figure 3 demonstrates localisation of the equipment types according to the individual self-governing regions regarding its share in these regions and its share among all the devices of that type too. Quadrilateral area of one cell represents a share of a number of the particular type equipment in the total number of all the equipment in the whole Slovak Republic or in the particular self-governing region. Blue shading expresses a situation, when a number of the particular type equipment is higher than it was in a case of their uniform distribution among all the healthcare facilities in the Slovak Republic. On the other hand, the red shading indicates a state where there is a smaller number of that type equipment localised in the specific self-governing regions than it was in a case of uniform localisation.

The most unsuitably distributed device among the self-governing regions at the beginning of the observed period in 2008 is dialysis monitor. There were 457 monitors in the Bratislava Self-governing

Figure 3. Equipment localisation in 2008

Source: Own elaboration compiled by the authors, 2016.

Legend: The same as for Figure 1.



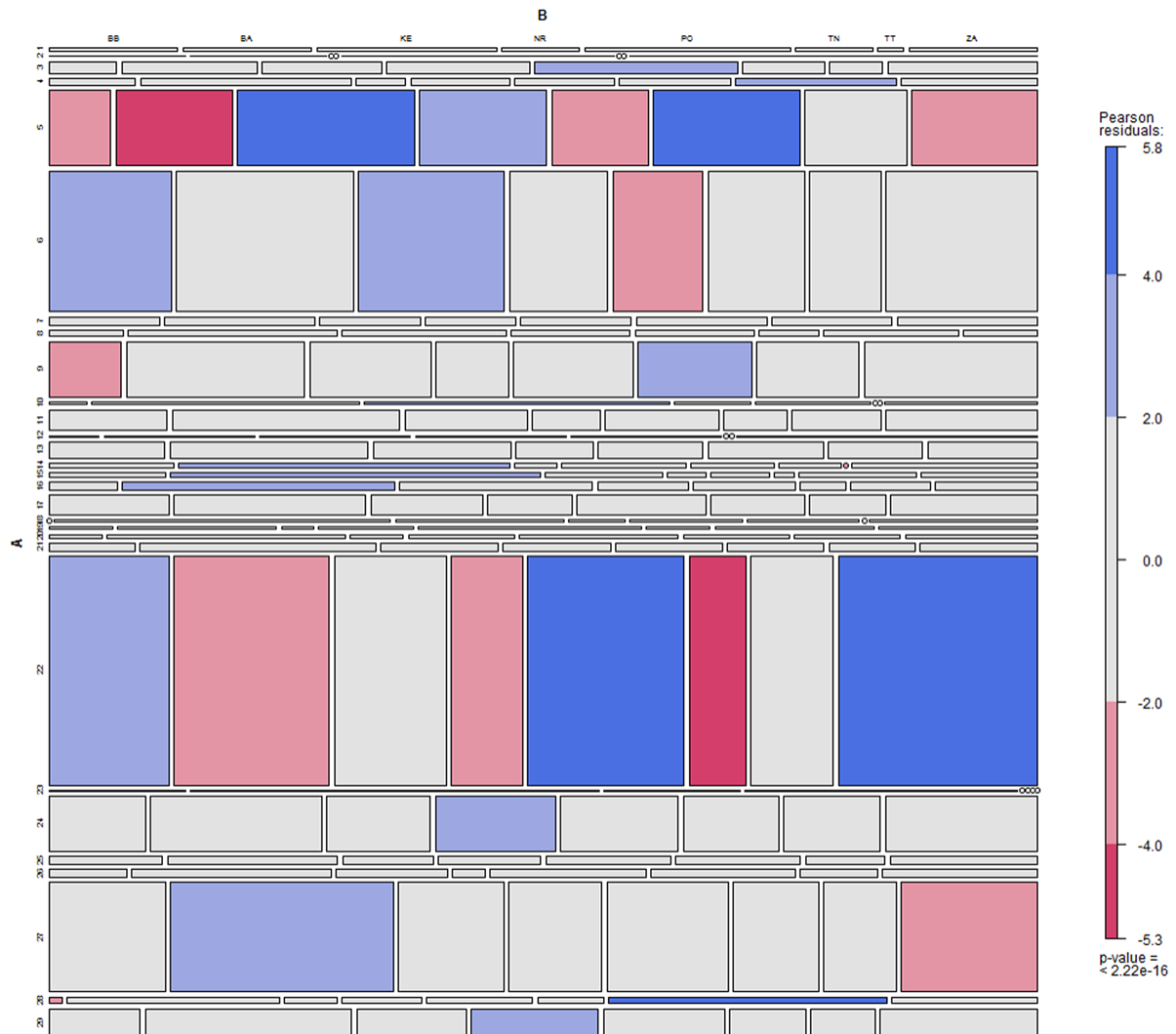
*For a more accurate representation see the electronic version.

Region, where it reaches a dataset's maximum value of Pearson residual. It creates a share of 66.42% of this type total number and this can be considered oversized. Such a situation is reflected in the lowest Pearson residual in the five other self-governing regions – in the Košice Self-governing Region, the Nitra Self-governing Region, the Prešov Self-governing Region, the Trenčín Self-governing Region and in the Žilina Self-governing Region – where a number of dialysis monitors is undersized. There are still two extreme cases – electroencephalograph and high-frequency device. A number of electroencephalographs in the Trenčín Self-governing Region is 129; although it is not a minimum value of all the regions, regarding the other equipment, it can be marked as undersized here. The second one extreme case is created by high-frequency device in the Košice Self-governing Region, where 79 devices are situated, what is a share of 27.92% of all that type devices in the Slovak Republic. Speciality of this case is the

Figure 4. Equipment localisation in 2014

Source: Own elaboration compiled by the authors, 2016.

Legend: The same as for Figure 1.



*For a more accurate representation see the electronic version.

fact that no other region suffers from an undersized number of that type equipment. Such an instance only confirms that these analysis takes into account not only distribution of the equipment type among the regions, but also localisation of other equipment in the same region.

The situation in localisation of the equipment changed considerably over the explored period. In a case of dialysis monitor it turned the opposite way – its number decreased in the Bratislava Self-governing Region to 100, what represents a share of 12.25% of this device total number in the whole country, whilst in the Košice Self-governing Region its number increased to 151 with an 18.5% share in the Slovak Republic and this region is deliberated to be oversized by this device. Looking at the previous figure, there is another unsuitably localised medical device – monitoring device, whose situation does not change

very significantly compared to the beginning of the observed period in 2008. Existing relations were only deepened more. Partially new situation occurred in cases of electromyograph and ultrasound device. Lack of the electromyographs in the Bratislava Self-governing Region in 2008 moved to Prešov Self-governing Region in 2014. In a case of ultrasound device, its lack in the Košice Self-governing Region in 2008 disappeared and raised in the Žilina Self-governing Region in 2014. On the other hand, its surplus from the Nitra Self-governing Region in 2008 moved to the Bratislava Self-governing Region in 2014.

Similarities in Equipment Localisation

State of medical equipment localisation among the healthcare facilities is very various in the Slovak Republic. To measure differences between situations in two equipment types we compute chi-squared distance.

The largest difference among the equipment types was in 2008 between brachytherapy apparatus and positron tomograph at level of 4.305. The largest similarity connects monitoring device with endoscope, laparoscope and arthroscope – their mutual distance is only 0.026. In 2014, the largest difference was between the same types as at the beginning of the observed period, but sank to 3.427. On the opposite side the two most similar devices stand – laser and ultrasound device that are separated from each other by only 0.008. In 2008, they lie at distance of 0.43. In the previous year, the most similar devices were in 2014 more distant from each other by 0.105.

If we compare individual distances between the equipment types at the beginning and at the end of the observed period, we could find changes of similarities of the same equipment type pairs. There are two cases, when no change happened after the explored period – between angiograph and group of colonoscope, sigmoidoscope and proctoscope and then between laryngoscope and mammograph.

FUTURE RESEARCH DIRECTIONS

The main results of the executed analysis can be summarised subsequently. The most numerous healthcare equipment is monitoring device, dialysis monitor, electrocardiograph, and ultrasound device. The total number of the healthcare equipment was slightly increasing from 2008 to 2013, but in the last observed year 2014 fell down by 16.44% to 9192 devices. Some of the equipment types are not localised in each self-governing region, although during the explored period a few types were supplemented in the regions where there was lack of them.

Shares of a number of the equipment were throughout the observed period various. The Banská Bystrica Self-governing Region retained approximately the same shares, whilst share of the Bratislava Self-governing Region was sinking throughout the whole period from 24.58% down to 18.71%. In the Košice Self-governing Region, a share was raising from the beginning of the period to 2013, but then in the last year fell sharply from 19.92% to 18.71%. In the other self-governing regions, shares remained the same, but there was their small increase in the last observed year 2014.

Situation in the medical equipment types localisation was as in the successive lines. Dialysis monitor was oversized in the Bratislava Self-governing Region in 2008, but in 2014 already undersized. Oversizing of this equipment occurred also in the Košice Self-governing Region oversized in 2014.

Table 3. Chi-squared distances of equipment profiles in 2008 and 2014

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1	0	0.567	0.307	0.42	1.476	0.191	0.449	0.295	0.194	0.274	0.238	0.377	0.249	0.349	0.596	0.371	0.221	0.334	0.515	0.466	0.198	0.147	2.982	0.342	0.268	0.516	0.278	0.684	0.153
2	1.041	0	0.974	1.001	2.54	0.559	0.991	0.871	0.674	1.325	0.524	0.477	0.761	0.765	0.95	0.787	0.754	0.802	1.21	1.138	0.873	0.659	4.305	0.876	0.811	1.662	0.928	1.367	0.457
3	0.127	1.107	0	0.222	1.808	0.224	0.323	0.187	0.123	0.498	0.342	0.278	0.171	0.635	0.552	0.392	0.361	0.815	0.173	0.382	0.228	0.168	2.602	0.13	0.232	0.366	0.206	0.527	0.239
4	0.608	1.702	0.409	0	1.158	0.11	0.184	0.244	0.087	0.55	0.186	0.509	0.05	0.386	0.222	0.186	0.281	0.49	0.112	0.548	0.093	0.157	2.064	0.066	0.186	0.476	0.088	0.17	0.201
5	0.376	1.923	0.258	0.24	0	1.193	1.394	1.24	1.332	1.151	1.055	1.935	1.224	0.653	1.166	1.028	0.975	0.844	1.316	1.596	0.932	1.174	1.094	1.28	1.178	1.778	0.93	1.046	1.398
6	0.213	1.365	0.21	0.218	0.129	0	0.125	0.146	0.037	0.452	0.05	0.288	0.029	0.227	0.271	0.147	0.081	0.277	0.175	0.426	0.061	0.048	2.363	0.063	0.071	0.574	0.059	0.333	0.073
7	0.344	1.525	0.261	0.074	0.095	0.084	0	0.325	0.153	0.658	0.226	0.601	0.118	0.529	0.416	0.34	0.158	0.47	0.13	0.67	0.188	0.198	2.623	0.1	0.089	0.652	0.151	0.351	0.337
8	0.38	1.861	0.28	0.184	0.21	0.177	0.186	0	0.115	0.291	0.189	0.266	0.131	0.368	0.347	0.146	0.149	0.608	0.17	0.108	0.105	0.099	1.889	0.123	0.162	0.703	0.101	0.426	0.129
9	0.277	1.266	0.204	0.121	0.115	0.069	0.043	0.182	0	0.354	0.075	0.283	0.031	0.344	0.207	0.111	0.133	0.46	0.109	0.349	0.051	0.026	2.453	0.036	0.068	0.547	0.073	0.259	0.076
10	0.472	1.618	0.612	1.115	0.787	0.524	0.917	0.583	0.664	0	0.458	0.816	0.407	0.632	0.507	0.315	0.356	0.725	0.525	0.266	0.231	0.302	2.436	0.488	0.422	0.833	0.385	0.516	0.358
11	0.232	1.16	0.244	0.187	0.275	0.058	0.131	0.143	0.08	0.485	0	0.274	0.119	0.178	0.207	0.107	0.091	0.339	0.23	0.498	0.105	0.045	2.369	0.117	0.078	0.801	0.111	0.294	0.123
12	0.501	0.746	0.373	0.997	0.81	0.534	0.833	0.787	0.612	0.469	0.538	0	0.39	0.429	0.716	0.478	0.383	0.796	0.468	0.54	0.438	0.23	2.658	0.314	0.336	0.857	0.356	0.893	0.277
13	0.249	1.566	0.256	0.146	0.117	0.038	0.045	0.134	0.055	0.648	0.068	0.786	0	0.335	0.235	0.135	0.141	0.374	0.119	0.363	0.039	0.079	2.245	0.043	0.107	0.498	0.052	0.253	0.085
14	0.543	1.198	0.464	0.574	0.682	0.299	0.526	0.594	0.438	0.662	0.28	0.499	0.411	0	0.583	0.374	0.218	0.178	0.537	0.743	0.251	0.239	1.76	0.367	0.314	0.744	0.205	0.651	0.325
15	0.734	1.722	0.768	0.392	0.726	0.372	0.492	0.312	0.414	0.63	0.188	0.994	0.341	0.432	0	0.054	0.392	0.772	0.302	0.53	0.219	0.267	2.46	0.266	0.323	1.219	0.32	0.078	0.264
16	0.316	1.633	0.314	0.349	0.311	0.15	0.302	0.095	0.207	0.254	0.099	0.588	0.156	0.377	0.192	0	0.205	0.57	0.229	0.292	0.096	0.127	2.164	0.171	0.198	0.991	0.171	0.156	0.122
17	0.162	1.166	0.151	0.175	0.179	0.028	0.07	0.17	0.049	0.583	0.031	0.543	0.036	0.285	0.35	0.162	0	0.283	0.224	0.408	0.098	0.075	2.211	0.143	0.049	0.723	0.086	0.43	0.2
18	0.491	1.503	0.482	0.691	0.519	0.371	0.561	0.582	0.351	0.38	0.369	0.652	0.391	0.361	0.572	0.293	0.366	0	0.739	0.979	0.329	0.402	2.432	0.525	0.433	0.704	0.341	0.818	0.409
19	0.497	1.149	0.278	0.226	0.506	0.455	0.29	0.314	0.271	1.166	0.321	0.823	0.394	0.807	0.677	0.519	0.301	0.906	0	0.448	0.147	0.148	2.058	0.033	0.1	0.617	0.097	0.214	0.32
20	0.368	1.356	0.175	0.103	0.243	0.195	0.122	0.184	0.095	0.837	0.15	0.712	0.141	0.391	0.436	0.255	0.109	0.405	0.159	0	0.307	0.348	2.132	0.413	0.474	1.041	0.38	0.681	0.267
21	0.277	1.511	0.191	0.134	0.144	0.05	0.087	0.097	0.066	0.557	0.057	0.626	0.036	0.279	0.288	0.096	0.04	0.306	0.344	0.077	0	0.055	2.019	0.083	0.101	0.51	0.037	0.219	0.103
22	0.159	0.789	0.158	0.278	0.325	0.113	0.172	0.255	0.105	0.565	0.062	0.376	0.164	0.378	0.417	0.24	0.061	0.495	0.236	0.195	0.16	0	2.331	0.066	0.043	0.57	0.063	0.304	0.1
23	1.527	3.427	1.36	1.498	1.454	1.119	1.527	1.057	1.54	1.158	1.177	1.479	1.251	0.759	1.053	0.882	1.236	1.34	1.991	1.359	1.002	1.521	0	2.156	2.375	2.52	1.789	2.285	2.522
24	0.257	1.331	0.135	0.11	0.115	0.044	0.047	0.125	0.046	0.674	0.074	0.534	0.06	0.341	0.414	0.186	0.032	0.448	0.252	0.082	0.035	0.099	1.188	0	0.055	0.533	0.044	0.242	0.175
25	0.23	1.309	0.158	0.145	0.121	0.049	0.035	0.221	0.049	0.776	0.103	0.644	0.046	0.34	0.498	0.265	0.026	0.42	0.18	0.096	0.056	0.127	1.329	0.028	0	0.642	0.072	0.306	0.22
26	0.255	1.228	0.266	0.248	0.223	0.165	0.118	0.346	0.064	0.776	0.165	0.809	0.103	0.508	0.545	0.327	0.101	0.305	0.365	0.142	0.149	0.188	1.827	0.163	0.094	0	0.457	1	0.693
27	0.196	1.233	0.168	0.175	0.209	0.035	0.097	0.152	0.072	0.547	0.026	0.543	0.044	0.222	0.286	0.125	0.008	0.332	0.326	0.099	0.022	0.087	1.069	0.038	0.043	0.134	0	0.292	0.168
28	1.417	2.422	1.071	0.315	0.813	0.901	0.598	0.516	0.62	1.783	0.725	1.699	0.753	1.489	0.752	0.843	0.82	1.472	0.422	0.57	0.716	0.822	2.438	0.663	0.825	0.875	0.823	0	0.422
29	0.212	1.204	0.106	0.219	0.195	0.052	0.142	0.161	0.095	0.494	0.068	0.375	0.104	0.203	0.378	0.135	0.041	0.329	0.33	0.109	0.039	0.097	0.976	0.031	0.066	0.206	0.028	0.863	0

Legend for the axes of Table 3 is the same as for the y axis of Figure 1. Legend for values of Table 3: Numbers written in the upper right half of the matrix belong to year 2008 and numbers displayed in the lower left half of the matrix belong to year 2014; main diagonal is the same for the both years because of its characteristic.

Another apparatus oversized in this region was high-frequency device in 2008. Unsuitable localisation in 2008 with deepening of this state throughout the observed period occurred with monitoring device. Electromyograph appeared undersized in the Bratislava Self-governing Region in 2008 and in the Prešov Self-governing Region in 2014. Ultrasound device is a type of medical equipment with uneven distribution across the country too. Its number was undersized in the Košice Self-governing Region and in the Nitra Self-governing Region oversized in 2008, in the Žilina Self-governing Region undersized and in the Bratislava Self-governing Region oversized in 2014. All these numbers suggest there is missing systematic distribution of the medical equipment (Pharr, 2013; Otawová et al., 2015). This issue should be subject to discuss in future (Zavadil et al., 2016).

CONCLUSION

The development process and the mortality of global aging are processes that have impact on the system in the country and are limited by a number of determinants. In addition to health insurance system, expenses intended for healthcare, a network of healthcare providers and demand for them an important role is played in the quality of treatment processes and sophistication of medical technology. This is varied all over the different countries its level is influenced by the historical development of scientific and technical progress and the rate of implementation of research and development into practice. There is no long-term monitoring of the status of medical equipment in healthcare facilities in the Slovak Republic. Some of the healthcare facilities have still limited access to tomography or magnetic resonance imaging device. A critical condition occurs when in urgent cases – often in hospitals – patient wait for x-ray computed tomograph for several weeks. It is questionable whether the condition is caused by a lack or absence of financial resources from health insurance companies. At the present time, the Slovak economy health system is set so that it does not allow natural reproduction of health technologies. Healthcare providers are not able to secure the financial resources to purchase new equipment during its operation life. It is therefore necessary to address this urgent problem and to deal with the availability and quality of instrumentation and to communicate at government level, the need to purchase diagnostic equipment for coordinating public health department, an issue to initiate setting of adequate normative that would force healthcare provider to modulate equipment in corresponding time period. An alternative to solve this problem would be the introduction of the process of financing healthcare technology from the state budget or by reimbursement from health insurance companies. Investments into radiological technology should be one of the most important indicators monitored within the Slovak health service strategic framework. Another issue is unsuitable distribution of medical equipment all over the Slovak regions, where are significant regional disparities between healthcare providers. They are not only in the field of localisation of the particular types of the medical equipment, but also in a way related to a share of the equipment in the individual self-governing regions of the Slovak Republic. These outputs should serve as a monitoring platform in evaluating accessibility and quality of healthcare technologies for use in this country. To obtain more detailed conclusions from the analysis we would need to have access to more data, which is the subject of our current research activities and cooperation with the institutions of the healthcare system.

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KEY TERMS AND DEFINITIONS

Efficiency: Known as effectiveness or productivity generally refers to the efficiency of the used resources and the utility obtained by their use. It is a ratio of inputs and outputs of an activity or a system.

Equipment: A device used in healthcare facilities to perform health care.

Health Care: A range of activities and measures leading to prolonged and sustained life of individuals, to improve quality of life and its protection, promotion, strengthening, improving and restoring health.

Health Policy: A guideline applied to health care system by state authorities responsible for health services.

Healthcare: A social set of professional knowledge institutions, establishments and authorities, workers and their corresponding activities, serving specifically to providing health care with an appropriate order to promote, preserve and restore health.

Healthcare Facility: A place where medical equipment is used to perform health care.

System of Health Care: Provision of health services. It is one component of health care and health policy determined by the state.

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Chapter 29

Use of Technology in Problem-Based Learning in Health Science

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ABSTRACT

Recent advances in the field of digital technology have had a significant role in changing the concept of learning and teaching for both students and teachers. These developments have enabled educational systems to move from their traditional classroom-based teaching models to a more enhanced blended/e-learning approach including an array of electronic learning tools such as digital microscopy, electronic cell counter, 3D virtual reality, and demonstration videos. An integration of these digital tools along with contemporary face-to-face teaching can significantly improve student learning outcomes and provide convenient and flexible access to education and training. This model demonstrated a positive impact on laboratory-based courses such as Laboratory Medicine at Griffith University. The objective of this chapter is to highlight the impact and advantages of this particular model from the student- and teacher-based perspective. This chapter will also discuss some of the challenges of implementing this mode of teaching and provide future directions.

INTRODUCTION

In current tertiary education environments, Information and Communication Technologies (ICT) has impacted on both the design and delivery of education to students with a strong focus on e-Learning (Clothey et al., October 2012). Interactive technology incorporating e-Learning has the ability to promote active learning, seeking information through accessing multiple modes of information and self-directed

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individually paced learning (Dede & Fontana 1995; Kahn 1993). Tertiary education faces a number of common challenges such as increasing class size, diverse cultural backgrounds, limited resources and teaching space facilities as well as concerns around the alignment of course curriculum for graduate capabilities (Gunn & Harper, 2007)(Smyth, Andrews, Caladine, & Bordujenko, 2011). To meet these demands, institutions such as Griffith University have had to employ existing technologies to increase learner autonomy. Through the introduction of e-learning activities, students have more flexible access to education and training, whilst avoiding increasing costs to campus infrastructure, laboratory staff and resources. This article will discuss the current use of technology to deliver various innovative forms of e-learning and blended problem based learning (PBL) as well as some models that are being developed and trialled at Griffith University to train undergraduate Medical Laboratory Science (MLS) graduates for the global health workforce. Some of these technological models were designed and developed by the authors from Griffith University. These include digital slide microscopy, introduction of computerized cell differentiation counters, 3D virtual reality (a 360 degree panoramic view of a live pathology laboratory), demonstration videos and the use of electronic portfolios (e-portfolios). Throughout the 4 years of the degree program, simulated and real world case studies have been developed and scaffolded across the courses within the program both vertically across the year levels and horizontally across courses within same year level. This strategy of mix mode use of technology aligns with the cognitive learning principles identified by Swann (2013) suggesting that inclusion of multimedia requires learners to split their attention between different means of instructions and helps mentally integrate the learning.

Although digital microscopy has been widely used in laboratory based teaching for some time, its advantages have been limited due to its restricted access of images for students. With the recent development of Image Scope, this software platform has allowed students to view Aperio scanned slide images on multiple computers across campus and off campus and has enabled students to access their dedicated course pathological slides without having to enter into a physical containment 2 (PC2) laboratory facility. Standardisation of training materials and extending the life capacity of rare and exotic case based slide sets that can degrade over time (such as loss of staining intensity due to long term storage) have also been achieved through the use of digital microscopy.

Simulation computer based morphology programs using Raspberry Pi mini computers have also enabled institutional laboratory facilities to incorporate electronic cell counters into haematology based practical sessions. This allows students to familiarise themselves with current cell counter technology found across private and public pathology laboratories. The computer system has been able to enhance educational learning and permits software development to be tailored to intuitional needs, without the burden of having to outlay large financial costs.

Furthermore, use of short demonstration videos showing different laboratory techniques have shown to improve student experience in understanding the techniques in detail. The demonstration videos had a significant impact through saving time and reducing the teaching load during laboratory sessions. Additionally encouraging students to develop their e-portfolio, a collection of their learning, accomplishments and experiences can greatly increase their employability. The use of e-portfolio has been recommended by a number of universities as it helps the student to develop their cognitive skills from self-directed learning. As the emergence of new technologies transform our traditional classrooms into virtual educational facilities, key challenges faced during the process, and issues yet to be addressed will also be highlighted in this article. As the demands for education and training continue to increase to meet

the demands of current and future workforce, this article will focus heavily on how e-learning tools and blended PBL have impacted on MLS students studying at Griffith University and the challenges that were faced from both students and teachers.

BACKGROUND

Current electronic learning (e-learning) tools along with recent advances in Information and Communication Technologies (ICT) have significantly increased students access to evidence and problem based learning techniques (Clothey et al., October 2012). This has impacted on both designing and delivering education to health science students with a strong focus on e-learning (Gértrudix Barrio, Carmen Gálvez de la Cuesta, Álvarez García, & Valle, 2007; Kirkwood & Price, 2005; Salmon, 2011). Traditional teaching in classrooms accounted for conventional academic based didactic teaching, where investigator initiated and discipline based knowledge is taught in isolation. Today the face of learning and teaching is changing to context driven, problem based, work integrated, transdisciplinary and interprofessional knowledge, where the primary focus is on building an effective and efficient team to work for a short period of time on solving a specific problem from the real world (Gibbons, 1994)

E-learning technology can act as an active instigator for creating constructivist teaching methods and active learning strategies to enhance student knowledge and prepare them for the digital age. This mode of teaching can also enable the students to develop skills such as critical analysis and personal interpretation of knowledge (Cummings, Mason, Shelton, & Baur, 2015). E-learning has been a dynamic part of the educational landscape since the start of the 21st century and has been defined in various ways over time (Sangrà, Vlachopoulos, & Cabrera, 2012). Massy and Zemsky (2004) suggest three major categories of e-learning. The first category of e-learning described as distance education where courses are delivered almost entirely online via the internet. The second and third category of e-learning termed electronically mediated learning is where learning materials are digitally delivered through various technologies and e-learning is facilitated by transactions software. The software management systems organise and manage teaching and learning schedules. In relevant terms for the purpose of this article, Ashwin (2006) also defines it as 'any form of the new technologies or applications in the service of learning or learner support' which includes any software, hardware, digital resources or technology to deliver and support education e-learning. It can also be replaced with mix mode learning where technology is used to replace some of the face to face teaching with technology mediated teaching. Even though there are many definitions for e-learning, it is evident that all e-learning forms may provide a learning opportunity for individuals to use various e-learning simulation and real case base learning tools, to produced more positive learning gains than traditional lecture methods (Cummings et al., 2015, Lencastre & Coutinho, 2015) .

Griffith University Bachelor of Medical Laboratory Science program uses a combination of all the above means of e-learning to deliver a four year program preparing graduates for the global market. The early adoption of an integrated, automated, central and supported e-Learning environment allows reliable and ubiquitous delivery of services, in combination with other in-class learning tools. With increasing use of smart devices by students, learning-space technology is being delivered as software to the student's computer instead of hardware to the learning spaces. This enables Griffith University to encourage students to actively learn not only in the classroom but also at home or while travelling, and

permits the use of new technologies in an economical way. Similarly health institutions using simulated 3D virtual videos can encourage and motivate not only students to practise critical thinking and reflective skills but to also allow new training methods for all staff types to revise and train on analysers that are not regularly available for training. Simulations can replace laboratory activities that can reduce the costs of lab resources such as time, equipment, supplies, staff expertise, and minimise health risks associated with dangerous activities (Cummings et al., 2015). In an edited book series by Clothey et al. (October 2012), a study by Robyn Smyth, Trish Andrews, Richard Caladine, and Jason Bordujenko discuss the great potential for use rich media technology across a number of Australian universities in reducing costs and environmental footprints. They also found similar findings compiled from the National Centre of Science, Information and Communication Technology and Mathematics Education for Rural and Regional Australia (SiMERR) that the greatest benefits of using rich media technologies helped improved collaboration, convenient, reduced the ease of travelling, cost effective and promoted deeper discussions of course material (Clothey et al., October 2012).

E-learning can also promote inquiry based learning via exploration and can be individualised to match learners need and training requirements (Cummings et al., 2015). In a case study by Charl Wolhuter, Hennie J. Steyn, Elsa Mentz, and Ferdinand J. Potgieter in (Chapter 4) of Clothey et al. (October 2012), they found that the launch of blended learning classes across South African universities, were found to be more positive than traditional face to face teaching structure as it allowed for flexible language choice, helped with the demands of increased enrolments and strained teaching resources.

MAIN FOCUS OF THE ARTICLE

The authors at Griffith University developed innovative, technology-based resources, to give students 24 hour access not only to PBL cases, lectures and published material but also digital technique videos and electronic haematology (e-Haem) Atlas which was developed by imaging our actual blood films of various disorders collected from Victoria, New South Wales and Queensland. Whole slide imaging (WSI) is a conventional way of digitally scanning slides in order to produce a virtual image (Pantanowitz, Farahani, & Parwani, 2015). WSI technology has been employed worldwide in pathology departments and has overcome barriers such as limited glass slide cases, faded stained films stored over a number of years, use of slide sets at home or outside of a laboratory facility and allowed the standardisation of training sets for all students. With flexible slide accessibility, this complements student's morphology skills gained by actual microscopy in the laboratory, without the need for a demonstrator during students' voluntary self-study period. Suggestions were incorporated from peers to use videos of actual blood flow, platelet and WBC activity to help students understand the concepts easily. These teaching strategies build students' self-confidence, employability, and capacity to apply their skills and knowledge to a range of contexts not just within the Australian workforce but also relevant to the global workforce. These new innovative tools take the "classroom to the students" to enhance flexible learning where the software is available on every computer for students on campus as well as on their personal electronic devices.

For vertical and horizontal scaffolding of students learning across various courses an e-Portfolio is being rolled out to monitor and support student progress on and off campus; in collaboration with: Haematology Technical Staff, Curriculum, Assessment & Technology, Technical Solutions (Electronics), Network and Collaboration Services, Information Services, Corporate Technology Infrastructure and Griffith IT security teams. These innovative ways of using technology as a mainstream teaching

tool has been recognized by peers from other institutions and countries resulting in multiple presentations about this curriculum design and teaching strategies within Australia and overseas, including as invited guest speaker.

Some of the techniques filmed at Griffith University were reviewed and discussed as part of the pre-laboratory session prior to each laboratory class. At this stage students were assessed by providing verbal answers and sometimes written responses on the worksheets provided for the case study covered in that particular practical class. Some of the questions asked were related to the techniques they had viewed before physical demonstration of the techniques in the class. The assessment for Histology and Haematology courses includes mid-semester and end of semester practical exams. The impact of the videos on the routine laboratory and practical exam assessment were determined via a paper based survey and a formal question is included in the student evaluation of the courses.

A few of the methods filmed for MLS program were re-taken and edited after initial use, based on the industry and student feedback. Therefore some techniques videos which were implemented as part of teaching tool were complemented by incorporating still images of the same techniques provided to students. Responses to the modified teaching videos were very positive. Similar responses were also received from the teaching team, including demonstrators (experienced senior industry practicing scientists), as this allowed them time to focus efforts in improving students skills. Since the video of the whole set of the techniques was not available to any class at the start of the semester, official student evaluations could not be performed.

In 2014 all the videos formed a component of teaching material on the university's course website. It was ensured that each technique was made available for respective courses online at the start of semester and students were surveyed at the end of semester to obtain feedback on their experiences.

A current project underway in collaboration with staff of various departments at Griffith University is to develop and implement a Raspberry Pi2 (RPi) linked to old LCD monitors with built-in USB port to use as keyboard for the input. The RPi 2 systems are an inexpensive credit card sized computer that can be personalised to run an Ubuntu Linux operating system whereby programs such as the cell differential counter can be programmed and set up for individual use. RPi was founded by the not-for profit Raspberry Pi foundation in the United Kingdom for use in education to allow children to familiarise themselves with computer hardware, programming and to enhance their computing learning experience (Ioannou, Ioannidis, Papadopoulos, & Tapeinos 2014). At Griffith University, instead of using this as a teaching tool only, we have incorporated the use of the RPi to program and run an electronic cell counter without having to outlay large costs for electronic cell counters available on the market. It also develops the skills of students who can familiarise themselves with the process of performing differentials using the computer based technology that is commonly found in industry pathology laboratories. By personalising the cell counter program we can allow students to perform white cell differential counts in class electronically and save these case base differentials on a file format which can be collated as part of e-portfolio for future review alongside digital images that can be accessed outside of the laboratory or of campus.

Primarily RPis will be used as an electronic cell counter device; however it has the potential to be used as minicomputer for the laboratory where it can allow the automatic connection of cameras to the microscopes networked in the teaching laboratories. This application of RPis will allow students to build their e-portfolio across all year levels as an evidence of competency of the skills gained during practical laboratory sessions in the classroom as well as in industry on clinical placement with endorsement by respective academic and industry supervisors. Upon graduation the students can then carry the same portfolio to job interviews.

E-portfolios are controlled by students for sharing certain folders with the academic and industry supervisors. This allows staff to monitor in real time the progress of the students and provide them with in time feedback and guidance instead of waiting until the end of semester and giving them final grades only. Also these portfolios can be carried by students across all 4 years of their study and they can use them to compile all their ongoing class work in other courses (they develop folders/portfolios for example blood and tissue slides to identify the diagnostic features of the tissues and blood cells) in Haematology, Histology & Histopathology to gain multi skilled experience. Instead of carrying multiple folders with them to the clinical placement they can have all the material in one e-portfolio for future reference as well as an evidence of their competencies endorsed by academics and industry supervisors when they apply for jobs in workforce.

RPI in particular can be extremely beneficial for microscopy training in Haematology, Histology and Histopathology courses, with application in Clinical Biochemistry and Clinical Microbiology during first 3 years of the program and e-portfolio from 1st year through to 4th year. Assessment is an important driver for educational practice (Guskey 2003). E-portfolio can be used as an effective platform for formative assessments. With e-portfolio, students will have access that they control but can share files/folders with their academic supervisors as well as industry supervisors when on clinical placement. This will allow students to have all their study material across the courses in one single portfolio and will allow the supervisors to monitor their progress in real time to provide timely comments and feedback particularly in 1st year and 4th year where they have to keep a weekly reflective journal as part of their main assessment instead of end of semester final exam. Any work done by students on or off campus as part of an assessable critical reflection can be saved on their e-portfolio directly or through their external storage device. It will be very beneficial to have a user friendly system where students can save their reports and tissue/blood slides features to take with them to clinical placement and job interviews upon graduation, with their supervisors comments/feedback and endorsement of having met competencies.

Digital, role play, and simulations have become increasingly popular in higher education to provide a more authentic and engaging learning experience for students. There is extensive evidence that ICT increases motivation, confidence and engagement (Blamire 2009). The virtual Reality 3D pathology experience project is underway. The purpose of this project is to show in the classroom and teaching laboratory the routine functioning, daily maintenance required and other basic details of the equipment routinely used by most laboratories worldwide but not practical or realistic for the universities to have these pieces of equipment in their schools or departments. This will allow students to have a better concept of automation in addition to all manual methods they perform at the university. With close attention to design, development and implementation of how to use and maintain various laboratory analysers' universities can increase the professional capabilities of students as well as new and experienced staff from rural and multi-skilled emergency laboratory health scientists that require this skill in the workplace.

By sharing the interactive 3D images of various instruments and explaining the principle behind each test, students can get a better understanding of daily maintenance and simple troubleshooting. Furthermore, by actually filming the instrument in action, as shown to new staff while training upon initial employment, it could help both the students and trainee scientists to gain a better understanding of the processes and acquire an overall representation of procedures prior to hands on experience.

Industry senior administrators, management and scientists-in-charge are excited about the idea and can see enormous benefit both for students work readiness and their new employees' standardized training. Utilisation of the facilities at the Gold Coast University Hospital was suggested as our students visit

these labs in 1st year of the program and senior scientists can explain the whole process in each of the departments. Incorporating this virtual laboratory interactive sessions across various courses in 3rd year courses prior to clinical placement, students will be better prepared for placement and industry should find these graduates to be more work ready than other university graduate clinical scientists.

Issues, Controversies, Problems

There have been several issues that the teaching team came across during the development and incorporation of the e-learning technologies. Time was one of the major issues that the teaching and technical team had to face. Collaboration on projects can also be time consuming as different parties need to identify the project's objectives before identifying roles that are critical to driving the process. Development of the 3D virtual reality video was a collaborative project that required active participation from various departments such as the pathology team from the hospital, the teaching team from the University and the filming crews. Issues such as time constraints and communication between departments have been some of the major causes for the delay of the project. Furthermore the 3D virtual reality video is the representation of one of the most modern and fully automated laboratories however the equipment shown in the video cannot be universal as different laboratories depending on their geographical location, workload, patient population needs and financial capabilities may have different analysers performing the same tests. Similarly, the development of RPi's as cell counters has taken a lot of time to trial and program the software to ensure it is robust yet functional enough for student and staff use. Understanding how software programs work and what is required had to be communicated frequently between the software developer and haematology staff to perform certain functions and make the program user friendly.

The paradigm shift from face-to face learning using mix mode learning is heavily based on technology and its consistency in delivery and accessibility are still institutional barriers that can decelerate learning potential. Accessibility of Aperio e-Atlas images can be improved by Image Scope, however data capacity and storage facilities of each slide image are yet to be resolved. Current limitations of WIS such as a lack of higher power magnification, image quality, digital slide storage and downloading massive files over slow networks have proven to be an issue for both students and staff. Institutions need to work alongside Information network Services (INS) to overcome online data storage and for students to be able to access and deliver data without having to use their own storage/ hard drive devices.

The main complications with the e-portfolio have been sharing their reflective journals with their respective academic and industry supervisors. Issues such as software incompatibility between various operating systems has inhibited the supervisors ability to monitor the student's progress in real-time. There has also been another issue, where by the assessment policy of university requires the same format of portfolio between students, however software incompatibility between operating systems does not allow that all the time.

Facility spacing and networking still remains an issue even with the adoption of RPi computers. RPi requires power outlets and networking ports in order to optimise cell counters and have the added features of printing and sending across real time e-portfolio entries. Laboratory facilities that do not support ethernet ports at every student station can propose a costly issue for institutions that would like to network their RPi. Alternatively by installing each RPi device using old monitors and PC2 compliant mouse and keyboards, can take up a reasonable amount of bench space that is predominantly taken up by other lab equipment such as water baths, microscopes and centrifuges.

Technology advances very quickly and to maintain or keep up to date with these changes requires constant updates and key accountabilities to continually support and upgrade systems, links and connections and can be a financial burden. With a range of advancements in e-learning technologies, studies have also shown that there is an increasing divide between the levels of access to the technological resources but also between the abilities of the user to benefit from these learning tools. And with an ever increasing access to IT, there has been a significant shift that has not only caused a digital divide but also a cognitive divide between students based on their level of literacy within the IT medium. One of the many reasons for this divide can be the diversity in the rate by which technology is being incorporated into the early education system across different universities and countries (Cox, 2013).

SOLUTIONS AND RECOMMENDATIONS

Several strategies were devised to overcome the issues that were faced by the teaching team. Funding schemes can help start-up costs and take the load off elements and their financial burden. Sharing costs between a numbers of groups can also help reduce budget concerns and increase collaborative use of technology enhancing tools in delivering a number of courses. Action working parties have also been developed to help collaborative efforts to maintain good communication and keep everyone updated of their roles and responsibilities

For collaborative timetabling of the 3D virtual filming process, the filming crew was requested to start filming before the morning round of patient sample collection from the different wards because most of the start-up and maintenance on different equipment is performed early in the morning prior to early morning blood and sample collection in the industry. The student will be informed by annotation about the variation in equipment and changing technology that may lead to them working with different pieces of equipment. This will be reinforced by starting the presentation with an explanation of the same.

The students who are unable to share their reflective journals from the e-portfolio, due to different operating system or software variations with their respective supervisors will be requested to upload their assessment using Microsoft word as an attachment to e-portfolio. This is not an ideal solution but provides at least some support through occasional even though not regular feedback to students.

To combat limited laboratory space issues, the upgraded version of raspberry version Pi 3 which has a Wifi and Bluetooth capability as well as the new Rpi touch screen monitors can provide us with a portable solution to ethernet cabling and reduce lab space usage. The implementation of a customized keyboard with copper or silver loaded plastic and antibacterial keys we can reduce the size and still be able to comply with laboratory health and safety standards.

As developments in technology continue to advance, processing powers of computers, cloud storage solutions and increases in data transfer speed will help ease the burden of slow data image transfers and increase the accessibility of slide images with better quality images. Similarly upgrading Aperio scanning imager to increase the number of slide sets being scanned can also reduce the predicament of time restricted technical staff.

Finally feedback from students and educators can help identify specific e-learning tools that are beneficial and how they can best be managed or improved.

FUTURE RESEARCH DIRECTIONS

Although there has been a significant raise in the usage of e-learning technology in various programs, the need to design and provide a more engaging and high quality content is crucial for creating an effective learning atmosphere for learners. This requires teaching and learning scholarship.

This article has discussed the innovative way in which a mixture of various technologies has been trialled. Some have been successful while others still require refining. However, it is also inevitable to face resistance to the implementation of e-learning technologies which requires changes to the traditional systems of educational institutions. It has been shown that the relationship between age and adoption of technology was mediated by cognitive abilities, computer self-efficacy, and computer anxiety (Czaja et al 2006). For this kind of change to be effective, evidence needs to be collected to demonstrate the favourable outcomes and the ease of implementation. This can be achieved through survey based research showing successful incorporation of some of these technologies in teaching and learning of Health Science. The data collected from this research should also be used to convince the decision maker of universities and institutions to show the benefit of investing into multiple technologies for collaborative use.

CONCLUSION

In conclusion, e-learning is being increasingly embraced in tertiary education at numerous institutions and has gained approval from both the students and the teachers. Currently most of the e-learning tools are fragmented, incorporating just one or other technologies in class rooms. However, a standardised mix-mode of various online learning tools is required to cater for student from different socio-economic and educational backgrounds. At Griffith University the introduction of a mixed-mode of e-learning technologies including 3D virtual reality video, digital microscopy, Rpis, demonstration videos and e-portfolio has been demonstrated to be of effective educational value for students studying Medical Laboratory Science. In the future, studies should be performed to further evaluate the possible use of e-learning technologies in the education system and finding ways to convince the educators to embrace this mode of teaching and learning pedagogy. Finally, it is essential to standardise the use of education with maintenance of confidentiality and individuality to prepare graduates ready for global work force.

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KEY TERMS AND DEFINITIONS

Cell Differentiation Counters: A counting tool used to count and tally different types of leukocytes.

Demonstration Video: A filmed video clip of a process or skill being performed for observation and review.

Digital Microscopy: The ability to view digital slides using a computer instead of a microscope.

E-Portfolio: A collection of electronic evidence assembled and managed by a user, usually on the Web. They are becoming standard practice for academics, students, and professionals and typically include examples of skills and achievements, as well as a reflective blog element.

Medical Laboratory Science: A four year undergraduate course in the field of medical science diagnostics and pathology.

Mix-Mode Learning: The use of technology to replace some of the face to face teaching with technology mediated learning tools.

Problem Based Learning (PBL): A student centred interactive learning pedagogy that challenges students to learn through engagement in a real life problem.

Raspberry Pi: A credit card sized computer that uses Linux Operating System.

Self –Directed Learning: Individuals perform their own study in an un-facilitated environment.

Simulations: A program or external setting that mimics an event or process, where participants can re-enact the process outside of a real-time event.

Tertiary Education: All post-secondary school education including but not limited to universities.

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Section 7

Medical Technologies

Chapter 30

Defining and Characterizing the Landscape of E-Health

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ABSTRACT

There has been a surge of electronic health (e-health) technologies encompassing a range of services available to various stakeholders within the healthcare system in both developed and developing countries. As technology has evolved, the features and functionalities offered by e-health technologies have grown dramatically, leading to a proliferation of advanced technical solutions. As a result of this increased focus, various definitions for what constitutes the term e-health have emerged in the literature. This lack of consensus is further inhibited by a dearth of research documenting the characteristics (i.e., features and functionalities) of such e-health technologies. The authors propose to define and characterize the landscape of e-health technologies from an information systems (IS) perspective in this chapter. By examining existing literature and reviewing the market place, this study reveals that there is a need to integrate the various features and functions of e-health technologies, thereby arguing that integration and interoperability is important for the growth of e-health.

INTRODUCTION

The need for reforming the delivery of healthcare services to accommodate the needs of modern societies is being experienced on a global scale. Government expenditure for the healthcare domain is increasing on a yearly basis (Bergamo, 2015). Population figures are growing with a reported increase of one billion people within the next 15 years, reaching 8.5 billion in 2030 (UN, 2015). Such a rapid increase in population is placing pressure on existing resources for healthcare (Keehan et al., 2015), thereby stressing the need for healthcare services to be reformed. Within the rapid rates of population growth, the fastest growing segment in the European population is the over 65 age group (Coale and Hoover, 2015), a group which utilises three to five times more healthcare services than their younger counterparts. Additionally,

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disease growth is on the increase as population rates incline. Despite the major progress in reducing death rates from various diseases, dramatic changes in global diseases have occurred whereby diseases have shifted to more lifestyle-related diseases (e.g. obesity, chronic obstructive pulmonary disease, type 2 diabetes and heart disease). Issues such as expenditure, population and disease growth enhance the need to reform the delivery of healthcare services. It is recognised that Information Systems (IS) is a critical success factor in the achievement of health care reform goals (Heeks, 2006) as the general use of IS globally is a powerful driver for change across the healthcare industry. Advantages of successfully implementing IS within the healthcare domain are reported in literature. These include reduced time to diagnosis, improved access for patients to care, quality of life and patient satisfaction, enhanced healthcare provider decision making, increased accuracy in medical treatment and cost-savings (Bergamo, 2015).

Hospital Information Systems (HIS) were the main and earliest use of IS in healthcare (Reichert, 1975). Prior to 1960, electronic computers were not in general use in hospitals (Austin and Greene, 1978). From these early days HIS were defined as systems for “transmitting data among various personnel in different support units of the hospital” which ultimately seeks to “integrate all elements of information processing related to patient care into one system with a shared database” (Barnett and Zielstorff, 1974, p. 158). This definition of HIS has been used as a guide to defining the various eHealth technologies which subsequently emerged. However, since the 1970s HIS have evolved by incorporating other types of eHealth technologies, e.g. electronic medical records or electronic health records (EHR), electronic clinical decision support systems (CDSS), which has resulted in the varying definitions we observe in literature today.

Building from this, the objective of this paper is to define and characterise the landscape of eHealth technologies from an Information Systems (IS) perspective. The next section defines and characterises the concept of electronic Health (eHealth). In doing so, various features and functionalities of eHealth technologies are reported. It is argued that the evolving nature of technological artefacts influence how the term eHealth is defined. In light of this, the concepts of eHealth integration and ontologies are subsequently discussed. Concluding this chapter is an overview of both academic and practitioner-orientated contributions and future eHealth research directions.

BACKGROUND

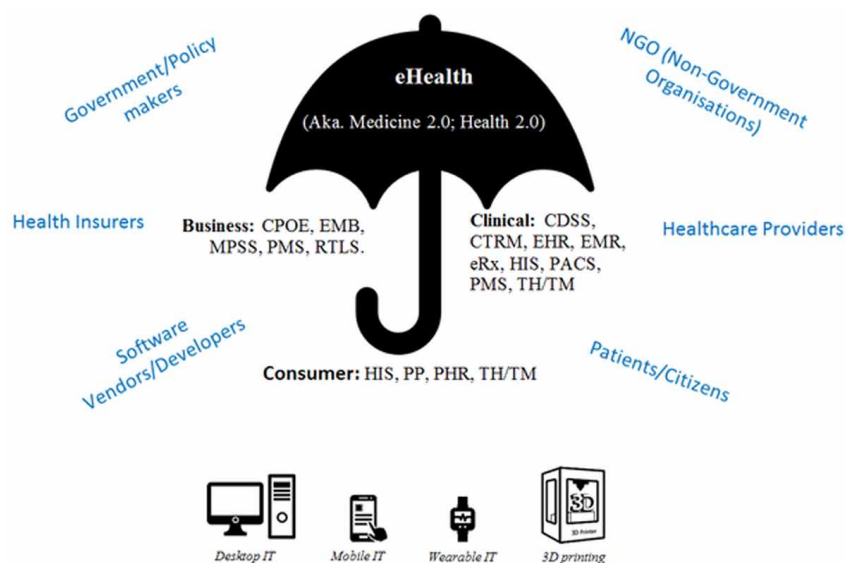
Although the term electronic health or ‘eHealth’ first emerged in the literature circa 1999-2000 (Eysenbach, 2001; Ahern et al. 2006) the use of IS within the healthcare system occurred well before then (Blum, 1984). According to Goldschmidt (2005) the first electronic health record was designed and deployed in the late 1960s-1970s, thirty to forty years before the term eHealth was coined. Since the turn of the 21st century the term eHealth has received attention in both academia and practice. Subsequently, eHealth has been defined by many people but a lack of evidence as to the existence of a comprehensive definition has emerged (Della Mea, 2001; Oh et al., 2005; Pagliari et al., 2005; Boogerd et al., 2015). To address this issue, journals such as “Journal of Medical Internet Research” published papers which explicitly sought to clarify what is meant by eHealth (cf. Oh et al., 2005; Pagliari et al., 2005) as part of its “What is eHealth” series leading to various reports about definitions concerning eHealth. For example for Ontario Hospital eHealth Council, eHealth is a consumer-centred model of health care where stakeholders collaborate, utilising ISs, including Internet technologies to manage health, arrange, deliver and account for care, and manage the health care system (Alvarez, 2002). The Internet clearly drives the

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development and adoption of eHealth applications; standing alone, it has the reach, the infrastructure, and the acceptance to achieve widespread change. Similar to this definition, Eng (2001) describes eHealth as the utilisation of emerging IS, especially the Internet, to improve or enable health and healthcare. While many definitions for the term eHealth were proposed, it was the work of Della Mea (2001) which received the most attention as he described eHealth as a broad term that encompasses multiple domains (Boogerd et al., 2015). Over ten years later, and due to the rapidly changing field of eHealth, Boogerd et al., (2015) argues that a clear, uniform definition for eHealth still remains to be identified with many terms (such as Medicine 2.0, Health 2.0, mHealth) being used interchangeably.

For the purposes of this paper, eHealth is expressed as an umbrella term which encompasses three domains (i.e. business, clinical and consumer). According to DeLuca and Enmark (2000) business eHealth refers to systems focusing on financial and administrative transactions required to conduct the daily operations of healthcare whereas clinical eHealth refers to systems focusing on transactions which involve the collection, transmission and analysis of electronic health-related data by healthcare professionals. Consumer eHealth engage patients (i.e. consumers) in managing their own health care, to facilitate communication with providers and social networks, meeting their informational needs, making knowledgeable health decisions, using patient education resources, and promoting healthy lifestyles (Kreps and Neuhauser, 2010). Building from this, eHealth is defined as “the use of any information technology by various stakeholders which transmits, stores, searches, and/or retrieves digitised data electronically for business, clinical and/or consumer purposes” (adapted from De Luca and Enmark 2000; Della Mea, 2001). Further, the World Health Organisation (WHO) defines eHealth as “the transfer of health resources and health care by electronic means... encompasses three main areas: (1) The delivery of health information, for health professionals and health consumers, through the Internet and telecommunications; (2) Using the power of IT and e-commerce to improve public health services, e.g. through the education and training of health workers; (3) The use of e-commerce and e-business practices in health systems management. This definition of eHealth is diagrammatically represented in Figure 1 and illustrates that eHealth (sometimes referred to in literature as Medicine 2.0 or Health 2.0) is an overarching term for the

Figure 1. Overview of eHealth



use of IT within the healthcare domain and comprises several subsections. Table 1 briefly synthesises fourteen eHealth subsections (i.e. technologies), associating them with at least one of the three domains. Note this is not an exhaustive list.

Information Systems (IS) research is typically characterised by the three pillars of People, Process and Technology (Earl, 1989). Figure 1 represents all three facets of IS identifying (1) the various stakeholders/*people* involved within the eHealth domain (i.e. government/policy makers, health insurers, software vendors/developers, patients/citizens, healthcare providers and NGOs); (2) business, clinical and consumer *processes* associated with eHealth and (3) sample *technologies* (i.e. desktop, mobile, wearable IT and 3D printing) used to collect, store, retrieve, and analyse medical-related data/information. Therefore, eHealth goes beyond technology to focus on further understanding the role of people and new models of care within the health care domain (Wyatt and Sullivan, 2005).

Table 2 presents some of the commonly referenced definitions by academics and practitioners for well-known and widely used eHealth technologies. While a general consensus exists for defining some eHealth technologies there remains inconsistencies in defining EHR, EMR and PHR.

In order to fully appreciate how the eHealth technologies are defined (see Table 2), it is imperative to explore the characteristics (i.e. features and functionality) of the technologies. For the purpose of this study, we have focused on five key eHealth technologies namely, EHR, EMR, OHR, eRx and CDSS in Table 3. In order to identify the features and functionalities of the technologies the authors (i) reviewed three sources of the top ten eHealth technologies, (ii) identified five consistently named technologies across the lists, (iii) reviewed the selected technologies, and (iv) identified key features/functionalities. It is important to note that the core features and functions of eHealth technologies were captured as some technologies had 100+ features/functionalities.

Table 1. Various eHealth Technologies

eHealth Technologies	Domain
1. Clinical Decision Support System (CDSS)	Clinical
2. Computerised Physician Order Entry (CPOE)	Business
3. Critical Test Result Management (CTRM)	Clinical
4. Electronic Health Record (EHR)	Clinical/Consumer
5. Electronic Medical Billing (EMB)	Business
6. Electronic Medical Record (EMR)	Clinical/Consumer
7. ePrescription (eRx)	Clinical
8. Healthcare IS (HIS)	Clinical/Consumer
9. Medical and Patient Scheduling Software (MPSS)	Business
10. Picture Archiving and Communication System (PACS)	Clinical
11. Patient Portal (PP)	Consumer
12. Patient Health Records (PHR)	PHR
13. Real Time Location System (RTLS)	Business
14. Telehealth/Telemedicine (TH/TM)	Clinical/Consumer

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Table 2. Definitions of eHealth Technologies

Type	Definitions
CDSS	“any program designed to help healthcare professionals make clinical decisions” (Musen et al., 2001, p. 575) “any electronic system designed to aid directly in clinical decision making, in which characteristics of individual patients are used to generate patient-specific assessments or recommendations that are then presented to clinicians for consideration” (Lobach et al., 2012).
CPOE	“a process that allows a physician to enter medical orders directly and to manage the results of these orders” (Aarts et al., 2007, p. S4) “a computer application healthcare providers use to enter orders for medications, diagnostic tests, and ancillary services into a computer system. The EMR refers to a computerized record of patient data” (Dykstra et al., 2009, p.158)
CTRM	“also known as Critical Test Results Reporting, and Closed-Loop Reporting, is the software that handles a medical test result that has returned as critical to a patient’s health. It prevents the critical result from being lost in communication failures, improves patient safety, and documents the delivery of the results.” (MedicExchange, 2015)
EHR	“digitally stored healthcare information about an individual’s lifetime with the purpose of supporting continuity of care, education and research, and ensuring confidentiality at all times” (Lakovidis, 1998, p.106) “a paperless form of a patient’s medical record where HCPs [Healthcare providers] can enter and retrieve information utilizing a computerized system rather than writing in a paper chart” (Wallace et al., 2012, p.34)
EMB	.. allows interaction between payers/insurance companies and healthcare providers/organizations, managing payment for healthcare services (MedicExchange, 2015)
EMR	“an electronic health record that shares data only within its organization” (Bryne et al., 2010, p.637) “the health record used to gather, store, retrieve, and analyze medical information (Richards et al., 2012, p.121)” “synonymous with EHR” (Duncan, 2015, p.12)
eRx	“entering a prescription for a medication into an automated data entry system, and thereby generating a prescription electronically, instead of handwriting the prescription on paper” (Kilbridge, 2001, p.9) .. entire process of prescribing a medication in electronic format whereby the clinician prescribes medications which is then sent electronically to a pharmacy, and feedback comes back to the clinician when the patient collects the prescription (Cusack, 2008)
HIS	Includes all the elements that facilitate the capture, storage, processing, communication, security, and presentation of computer-based patient record information (Janczewski and Xinli Shi, 2002) “a comprehensive, integrated information system designed to manage the administrative, financial and clinical aspects of a hospital which encompasses paper-based information processing as well as computerised data processing” (Ismail et al., 2010, p.16).
MPSS	“provide intelligent scheduling system applications for healthcare practice, and let the care provider manage/schedule patient appointments through electronic preference cards” (MedicExchange, 2015)
PACS	..medical imaging technology which provides economical storage, rapid access to images from multiple modalities and simultaneous access to the same image at the one time (Choplin, 1992). “a computerised means of replacing the roles of conventional radiological film: images are acquired, stored, transmitted, and displayed digitally” (Strickland, 2000, p.82).
PP	... an internet-based interactive website for patients to communicate with their healthcare provider and with varied functions that gives them access to portions of their medical record and other services (Collmann and Cooper, 2007; Hess et al., 2006; Lin et al., 2005; Sorensen et al., 2009).
PHR	“provider-tethered applications that allow patients to access health information that is documented and managed by a health care institution” (Bourgeois et al., 2009, p.65). “is owned and controlled by the individual patient (or proxy), and may have information that is not contained in a medical record” (Emont, 2011, p.2).
RTLS	.. uses real time tracking to “enhance oversight on an array of hospital owned equipment/items. (MedicExchange, 2015).
TH/TM	“delivery of health care and sharing of medical knowledge over a distance using telecommunication system” (Thrall and Boland, 1998, p.145) “a service where clients’ vital signs are monitored remotely, at pre-set time intervals, using technology in their home” (Cartwright et al., 2011, p.6)

Table 3. eHealth Technologies Features/Functionalities

eHealth Technologies	Basic Features	Basic Functions
EHR/EMR/PHR	• Patient management • Symptom management • Medication management • Note management • Results retrieval • Order entry • Report generator	• Identify and maintain a patient record • Manage patient demographics • Manage problem lists • Manage medication lists • Manage patient history • Manage clinical documents and notes • Capture external clinical documents • Present care plans, guidelines, and protocols • Manage guidelines, protocols and patient-specific care plans • Generate and record patient-specific instructions
eRx	• Patient management • Symptom management • Medication management • Order entry • Formulary management • Electronic Refills	• Identify and maintain a patient record • Manage patient demographics • Manage medication lists • Manage patient prescription history • Check drug interactions • Send and approve prescriptions
CDSS	• Patient management • Symptom management • Medication management • Reminder notification • Recommended diagnosis and treatment	• Manage patient demographics • Manage problem lists • Manage medication lists • Enhance diagnostic accuracy • Assist with clinical decision making • Improve patient safety

* Sources of Features/Functionalities

EHR/EMR/PHR: 1. Allscripts, 2. Athenaclinicals, 3. ClinicalWorks, 4. CareCloud, 5. PracticeFusion.

eRx: 1. Allscripts, 2. HealthFusion MediTouch, 3. NueMD, 4. PracticeFusion, 5. SureScripts.

CDSS: 1. EBMEDS, 2. IndiGO, 3. Mantis, 4. Persivia, 5. Zynx Health.

Eng (2001) embraces 5 C's which seek to express eHealth functions and capabilities including: content, connectivity, community, commerce and care. Eysenbach (2001) identifies with 10 essential E's: efficiency, enhancing quality, evidence-based, empowerment, encouragement, education, enabling, extending, ethics, and equity. Overtime, various features and functions have been incorporated within eHealth technologies which may account for the changing nature of defining eHealth technologies. Roberts and Grabowski (1990) refer to technological growth and argues that definitions for technological-related artefacts are not static but in fact evolving overtime. This may account for the varying definitions which have emerged for eHealth technologies over the last decade. It is further evident from Table 2 and from the definitions off the various eHealth technologies (Table 3) that there is a need to integrate the various features and functions of eHealth, as advocated by Eng since 2001.

FUTURE RESEARCH DIRECTIONS

Integration has been the Holy Grail of Management Information Systems since the early days of computing in organizations. (Kumar and van Hillegersberg, 2000, p.23)

Integrated health systems are widely advocated to enhance performance in terms of quality and safety as a result of effective communication and standardised protocols (Suter et al., 2009). With the diffusion

of the Internet and other information and telecommunication technologies, more integration has been enabled and demanded (Braa et al., 2007). In a healthcare context, Simoens and Scott (2005) argue that integration is integral to offering services from primary through tertiary care. The basis of integration is characterised by cooperation (O’Leary-Kelly and Flores, 2002), coordination, collaboration (Ettlie and Stoll, 1990; Kahn and Mentzer, 1998), information sharing (Pagell, 2004) and a fundamental shift away from managing individual functional processes, to managing integrated chains of processes (Akkermans et al., 1999). Building on this, it is therefore imperative that future eHealth developments move away from vertical silos to horizontal integrated systems (Adenuga et al., 2015) to ensure that a standardised delivery of care is provided (Simoens and Scott, 2005; Suter et al., 2009).

To facilitate a standardised and holistic delivery of health care services it is imperative that eHealth technologies are integrated across the three levels of delivery (Adenuga et al., 2015). These levels include primary care, secondary care, tertiary care (Reynolds, 1975). Primary care is defined as a set of universally accessible first-level contact, continuous, comprehensive, and coordinated care (Starfield, 1994) that promote health, prevent disease, and provide diagnostic, curative, rehabilitative, supportive, and palliative services (Lamarche et al., 2003). While, secondary care is a short term referral provided by informal consultations of secondary-care physicians with primary-care physicians (Starfield, 1994) to patients with symptomatic stages of a disease(s) who require moderately specialised knowledge and technical resources for adequate treatment and/or rehabilitation (Reynolds, 1975). Often health services delivered at secondary care lead to referrals for tertiary care. According to Reynolds (1975), this function encompasses levels of diseases which are acutely threatening the health of the individual and require highly technical and specialised knowledge, facilities and personnel. Integration of eHealth technologies is important because of the highly interrelated nature of the functions that are performed across primary, secondary and territory levels in the provision of patient care (Austin and Greene, 1978).

Table 3 indicates that the eHealth technologies available within the healthcare system share common features and functionalities. In order for the seamless integration of these, eHealth developers need to embrace multiple ontologies (sometimes referred to as Medical Natural Language Processing) that can be combined to fully realise meaningful integration and analysis of data in the healthcare domain (Puri et al., 2011). An ontology, according to Stabb and Studer (2013), is a description (like a formal specification of a program) of concepts and relationships that can exist for an agent or a community of agents. The concept is important in terms of building a common language for the purpose of enabling knowledge sharing and reuse, which is integral for a standardised delivery of healthcare (Nardon and Moura, 2004).

The healthcare sector is criticised for the proliferation of terminologies across medical specialities, locales, health care facilities, and it also with clinical content (Shoniregun et al., 2010). Overcoming this challenge is reported to have numerous benefits for the healthcare sector. For example, the development and use of widely understood and accepted ontologies can build more powerful and more interoperable IS in healthcare (Kim and Chung, 2014) by facilitating the easy transfer and re(use) of patient-related data (Lucas and Bulbul, 2015). Moreover, it will promote a ‘big data’ environment which could be used to analyse trends/patterns in large data sets thereby generating new insights in the medical domain (Dung and Kameyama, 2007; Bodenreider, 2008). Big data in healthcare denotes large and complex electronic health datasets which are perceived to be difficult (or impossible) to manage with traditional data management tools (Kołodziej et al., 2015).

According to Raghupathi and Raghupathi (2014, p. 2) ‘big data’ in a healthcare context amalgamates clinical data from CPOE and CDSS (physician’s written notes and prescriptions, medical imag-

ing, laboratory, pharmacy, insurance, and other administrative data); patient data in EHRs; machine generated/sensor data (e.g. vital sign monitoring), social media posts (e.g. Twitter) and web pages and less patient-specific information, including emergency care data, news feeds, and articles in medical journals. Therefore, integrated eHealth technologies with consistent ontologies will enable the creation of 'big data' for health care scenarios thus, enabling the discovery of associations and understanding of patterns and trends within the datasets for diagnosis, prognosis and treatment of illness and enhanced understanding of healthcare resource distribution (Arima, 2016).

CONCLUSION

There has been a surge of electronic health (eHealth) technologies encompassing a range of services available to various stakeholders within the health care system in both developed and developing countries. The advantages of successfully implementing eHealth technologies are reported in literature. Research indicates that these advantages significantly outweigh the heavily criticised costs associated with introducing such technological artefacts. As technology has evolved, the features and functionalities offered by eHealth technologies have grown dramatically leading to the development of many advanced technical solutions intended to serve various stakeholders (e.g. patients, clinicians, administrators). Additionally, the use of mobile telecommunications enables the use of eHealth at the point-of-care moving beyond its previously restricted desktop environments. Examples include Electronic Health/Patient Records, ePrescribing and Clinical Decision Support tools. As a result of this increased focus on eHealth, conflicting definitions for what constitutes the term eHealth have emerged in the literature. This lack of consensus is further inhibited by a dearth of research documenting the characteristics (i.e. features and functionalities) of such eHealth technologies. Given the nascent nature of eHealth research and the lack of definitional convergence, we define and characterise the landscape of eHealth technologies from an Information Systems (IS) perspective. Embracing this perspective provides a more detailed overview of the eHealth landscape. By examining existing literature and reviewing the market place, this paper reveals that there is a need to integrate the various features and functions of eHealth technologies thereby arguing that integration and interoperability is important for the growth of eHealth resulting in a more holistic approach to eHealth. Thus providing comprehensive coverage and up-to-date definitions of one of the most important issues, concepts, trends and technologies in information systems (IS) and information technology(IT); namely, eHealth.

There will be more changes in the future within the eHealth domain given how rapidly technology has evolved over the last two decades. With this in mind, eHealth definitions should be broad and flexible (i.e. modifiable with the changing components associated with new technologies). That being said, in defining eHealth it is essential that a common vocabulary (ontology) is developed and used to support the information needs of the various stakeholders, i.e. healthcare professionals and patients, while keeping standardisation and integration at the core of efficient and effective eHealth solutions.

Not only does this work contribute to the academic community, it also benefits practitioners in the decisions they make regarding eHealth technologies and the establishment of best practice in the form of eHealth standards and policies in the future.

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KEY TERMS AND DEFINITIONS

eHealth: The provision of patient-centric care and related services (i.e. people and processes) supported by technology.

eHealth Technologies: The umbrella term used to describe the wide variety of technologies, including internet based services, that support a health care system.

eHealth Technology Feature: Defines the purpose(s) of an eHealth system e.g. patient management, patient report generation.

eHealth Technology Functionality: An individual behaviour of an eHealth system e.g., identify and maintain patient record.

Information Systems: The use of people, process and technology to get the right information to the right people at the right time.

Integrated Health Systems: Technologies that are characterised by their ability to cooperate, collaborate and communicate with other technologies.

Ontology: A set of agreed rules, usually in the form of a common vocabulary and relationships, used to enable the transfer of data/information/knowledge between two or more agents.

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Chapter 31

Kinect Applications in Healthcare

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ABSTRACT

Microsoft Kinect is one of the most popular inexpensive gadgets released in recent years. Kinect is equipped with a color camera, a depth camera, and a microphone array. The device allows users to interact with a computer via a natural user interface in terms of gestures or voice commands. The authors believe that the research and development on using Kinect technology in healthcare will gain more momentum. The demand of Kinect-based applications is high, due to Kinect's low cost and portability, and its accurate and robust motion detection capability. In this chapter, the authors survey the current applications of using the Kinect technology in healthcare. Furthermore, they outline a number of open research issues that could overcome the limitations of the current Kinect technology.

INTRODUCTION

Microsoft Kinect is one of the most popular inexpensive gadgets released in recent years. Kinect is equipped with a color camera, a depth camera, and a microphone array. The device allows users to interact with a computer via a natural user interface in terms of gestures or voice commands. So far, Microsoft has released three versions of Kinect sensors. The first two, typically referred to as Kinect for Xbox and Kinect for Windows, are rather similar except that Kinect for Windows is capable of doing near-mode tracking. Because both releases use the same depth sensing technology, they are collectively referred to as Kinect version 1, or Kinect v1 for short. The most recent Kinect sensor was released together with the new game console, Xbox One. Hence, it is some times referred to as Kinect for Xbox One. It uses a completely different depth sensing technology, which is based on time-of-flight measurement. As such, the new sensor is also referred to as Kinect version 2, or Kinect v2 for short. Kinect v2 has made drastic

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improvements over Kinect v1, including 1080p resolution for the color camera, and higher actual depth sensing resolution (the nominal resolution for the depth sensing resolution is actually lower than that for Kinect v1). Images of the two versions of Kinect sensors are shown in Figure 1.

The low-cost and the availability of Software Development Kit (SDK) for Microsoft Kinect \ has attracted many researchers to investigate its applications in many areas, particular in the healthcare realm. As the aging population rapidly grows in the United States, demands of healthcare services, especially physical therapy and rehabilitation services, have grown enormously in recent years. To meet the increasing demands and reduce the cost of services, providers are often looking for computers and other equipment that can assist them in providing services to patients in an affordable, convenient, and user-friendly environment. As a low-cost, portable, accurate, nonintrusive, and easily set up motion detecting sensor, Kinect enables researchers to develop computer-based vision control without using traditional input devices, e.g. mouse, keyboard, or joystick. This revolutionary technology makes it possible for Kinect to meet the challenge of providing high quality evaluations and interventions at an affordable price for healthcare services, as seen from the works surveyed in this chapter.

BACKGROUND

Microsoft Kinect provides several streams of information to a software developer. The most common streams include: (1) A stream of 2D color image frames; (2) A stream of 3D depth image frames; and (3) A stream of 3D skeletal frames for at least one human subject in the view. A skeletal frame may contain the 3D position information for various number of joints. The availability of the skeletal frames has greatly facilitated Kinect application development because it frees the application developers from dealing with the complicated task of human pose estimation.

In Kinect v1, the depth of each pixel is calculated via a structured light method, which enables the use of a single infrared (IR) emitter and a single depth sensor to calculate the depth of each pixel. While this is a very clever scheme, the fidelity of the depth measurement is quite low because for the depth sensing to work perfectly, there has to be a visible unique pattern for each pixel. Because there has to be some space between two adjacent dots as part of the structured light and this space has to be wide enough for the depth sensor to distinguish, only about 1 in every 20 pixels has a true depth measurement in typical situations and the depths for other pixels must be interpolated. Hence, the depth sensing resolution is actually significantly below the nominal 640x480 for Kinect v1. The depth-sensing technology used in Kinect v2 is completely different and the depth is calculated based on time of flight. The depth of each pixel can be calculated based on the phase shift between the emitted light and the redirected light.

Figure 1. Two versions of Microsoft Kinect sensors. On the left is the Kinect v1. On the right is the Kinect v2.



Due to the maturity of the Kinect technology, developers can now publish Kinect v2 applications to the Windows store. Kinect v2 SDK also provides oial support for Unity, which is a development platform for 3D games. Finally, Kinect v2 SDK provides a tool to develop gesture recognition based on machine learning.

APPLICATIONS REVIEW

In this section, we review the applications of the Kinect technology in a number of healthcare domains. A summary of the applications is provided in Table 1 below. The detailed description of the applications is given in individual subsections.

Physical Therapy and Rehabilitation Applications

Kinect has been widely used in physical therapy exercises, sports rehabilitation processes, and post-surgery training. Research has proved that Kinect can be a viable physical rehabilitation tool. Compared to traditional motion tracking and capturing programs that use reflective markers attached to users' bodies, the Kinect technology enables the development of solutions with nonintrusive natural user interfaces and with real-time visual feedback to users.

Table 1. A summary of Kinect applications in healthcare.

Application Domain	Specific Applications	References
Physical Therapy and Rehabilitation	Kinect-based physical rehabilitation systems	Chang et al., 2011; Rahman et al., 2013; Saini et al., 2012
	Virtual reality based games for balance training and upper body rehabilitation	Lange et al., 2011; Gotsis et al., 2012
	Kinect based game for Alzheimer patients	Cervantes et al., 2012
	A hand rehabilitation system	Metcalf et al., 2013
	Providing feedbacks on the quality of exercises	Velloso et al., 2013; Su, 2013
	A guidance and monitoring system for rehabilitation exercises	Zhao et al., 2014a
Clinical Environment	Kinect-based systems for high sterile operation rooms	Johnson et al., 2011; Gallo et al., 2011; Bigdelou et al., 2012
Fall Detection	Fall motion detection using Kinect depth images	Mastorakis & Makris, 2014
	Fall detection based on randomized decision forest algorithm	Bian et al., 2012, Girshick et al., 2011, Shotton et al., 2013
	A comparison study on using Kinect and mark-based systems for fall detection	Obdrzalek et al., 2012
	Fall detection and abnormal event detection on stairways	Parra-Dominguez et al., 2012
	Overcoming occlusions for fall detection	Rougier et al., 2011
	Use of two Kinects for fall detection	Zhang et al., 2012

Using Kinect's interactive interface could get patients more motivated and engaged in physical activities, particular for regular and repetitive movements in physical rehabilitation exercises. Chang, Chen, and Huang (2011) developed an interactive Kinect-based system to assist therapists in rehabilitating students in public school settings. The system is able to detect the student's joint position, and record movement data to allow therapists to review students' rehabilitation progress quickly. It also includes an interactive visual interface to enhance students' motivation, interest, and perseverance to engage in physical rehabilitation. The result has demonstrated that Kinect's natural interactive visual computer interface can significantly attract more users. In the study of real-time gesture recognition, Bigdelou, Benz, Schwarz, and Navab (2012) concluded that most users are fond of the dynamic interaction with system. Applications using Kinect technology are overwhelmingly regarded as friendly visual interaction programs.

A research group at the University of Southern California Institute for Creative Technologies (ICT) has successfully applied the Kinect device to the study of virtual reality simulation technology for clinical purposes. Through extensive evaluation, assessment, and analysis, the researchers at the ICT have shown that Kinect technology can make a major contribution to the quality of traditional intervention with computer-based training games specializing in mental health therapy, motor skills rehabilitation, cognitive assessment, and clinical skills exercises. Lange et al. (2011) developed a virtual reality simulation game used for balance training of adults with neurological injury. Their colleagues Suma et al. (2011) developed the Flexible Action and Articulated Skeleton Toolkit, which is middleware that facilitates integration of full-body control with virtual reality applications and video games using Kinect.

Focusing on cognitive rehabilitation for Alzheimer patients, Cervantes, Vela, and Rodríguez (2012) developed a video game that replaces the traditional techniques used by therapists with the natural interaction Kinect device. The interactive body-motion controlled game increases patients' motivation to participate in exercise. An interactive rehabilitation system for disabled children was developed by Rahman et al. (2013). This application allows activities to be synchronized with on-line virtual counterparts. Patients can follow the exercise at home in the absence of the therapist because visual guidance for correctly performing the exercise is provided. Gotsis et al. (2012) demonstrated a mixed reality game for upper body exercise and rehabilitation. The exercise protocol was adopted from an evidence-based shoulder rehabilitation program for individuals with spinal cord injury.

Metcalf et al. (2013) studied an application for real-time monitoring and assessing hand movement based on Kinect. Hand rehabilitation is often needed for stroke patients' recovery. Medical professionals require detailed and accurate measurement of the hands in order to assess progress and functional recovery. The system is capable of measuring finger joint kinematics in real time for home-based clinical rehabilitation programs. This system is designed in two steps: 1) identify anatomical landmarks and classification between grip types; 2) calculate hand joint angles from a kinematic model. The initial phase detects two different modes: spread hand mode and pincer grip mode. Then the landmarks go through validation procedures first by using ground truth estimation between reviewers and the associated algorithms to assess the accuracy of landmark definition, and second by joint angles compared to a laboratory-based gold standard motion capture system and validated kinematic measurement technique. And on the other side, patients require real-time feedback on their hand posture if they participate in a virtual environment rehabilitation gaming platform. Although this novel technique can robustly track and accurately measure the movements of the hand, it only provides a limited number of gestures that are only suitable for a specific rehabilitation application.

In order to reinforce the quality of home-based real-time rehabilitation exercise, Su (2013) proposed an approach using the Dynamic Time Warping (DTW) algorithm and Fuzzy Logic for ensuring that exercise is performed correctly. First it allows a patient to perform a prescribed exercise in the presence of a professional. Then the patient's exercise is recorded as a base for evaluation of exercise at home. The outcomes of the evaluation can be used as a reference for the patient to validate his/her exercise and to prevent adverse events. A summary report of the outcomes may also be uploaded to a cloud setting for physicians to monitor progress and adjust the prescription. The DTW algorithm is used to compare two sequences that have different time lengths in order to determine the similarity between the standard and the patient's exercise movements. For the rehabilitation exercise, the trajectory and speed mainly are based on experience and subjective evaluation. Therefore traditional logic theory is not practical for evaluating the quality of rehabilitation exercise by trajectory and speed. In this application, Fuzzy Logic is employed to build a fuzzy inference of a physician's subjective evaluation.

Saini et al. (2012) presented an approach to providing stroke patients with instruction and guidelines to perform rehabilitation exercises. A "watchdog" developed in this system provides the restriction that patients cannot exceed the limited angle, and ensures that a patient who is exercising at home will not exceed the prescribed level or perform for a longer period than necessary. A centralized system stores the entire patient's data that will be used to analyze the patient's movements and activities. The biofeedback system allows the user to give feedback to the therapist, and the therapist will evaluate the patient's movement and give further instruction or direction. The biofeedback is displayed for the patient as well as the therapist. The main benefit for biofeedback is that patients can directly communicate with the therapist for further instruction for improving their movements. This strategy is beneficial for stroke patients because patients will do exercises correctly.

Recently, Zhao et al. (2014a) developed a Kinect-based system that could be used at patient's home. In addition to providing visual guidance to patients regarding how to perform a prescribed rehabilitation exercise correctly, the system is capable of assessing the quality of the exercise in realtime based on a set of correctness rules (Zhao et al., 2014b).

Clinical Environment Applications

A key technical challenge using Kinect in clinical environment, e.g. in a medical operating room, is how to recognize the gestures interactively, accurately, robustly, and effectively. Touch-free interaction with a computer makes the Kinect device suitable for clinical environments in highly sterile conditions (Johnson et al., 2011). Their study showed that the touch-free motion recognition Kinect device provides an appealing opportunity to control medical images or image-guided devices without using the hands. Some researchers investigated gesture recognition systems based on the Kinect technology to address needs in medical surgical rooms.

Gallo, Placitelli, and Ciampi (2011) developed an open source interface using static postures and dynamic gesture recognition techniques to explore CT, MRI, or PET images in operating room. Utilizing hand and arm gestures, this application is able to execute basic tasks such as image selection, zooming, translating, rotating, and pointing; and some complex tasks, e.g. manual selection for controlling medical digital images effectively. The interaction follows the event – state – action paradigm and it is developed specifically for fast operation at video frame rates. The limitation of this interface is that the number of postures and gestures used for recognition is fixed. The extension of the gesture control interface to enable interaction with immersive medical imaging environments must be addressed in future development.

Bigdelou et al. (2012) applied Kinect 3D gesture-based interface technology to an intra-operative medical image viewer in a surgical environment. They used skeleton input to recognize the gesture type and the relative poses within that gesture. The recognized gesture and poses can be used for an interface for controlling a medical image viewer. The training phase is used to define and customize gestures from skeleton images, and during the interaction phase, the actual gesture and the relative pose within the gesture is estimated by discriminative kernel regression mapping. The quantitative experiments show this method can simultaneously recognize several gestures to a high degree of accuracy. Again, the number of gestures recognized is limited to 16 due to computational complexity for human body movement.

Fall Detection Applications

The Kinect device has been used as a real-time fall monitoring and detection system for a wide range of falls, including backward, forward, and sideways; on stairways; in occlusion places; in hospital wards; and others.

In a study of detecting human body falling motion, Mastorakis and Makris (2014) adopted the use of Kinect depth images instead of skeleton data to robustly and efficiently track body motion. In their approach, a fall is detected by analyzing the 3D bounding box's width, height, and depth, i.e., the width, height, and depth of the human posture. The algorithm is provided by OpenNI. This approach outperforms the articulated model, which requires significantly more computational power. Since a human fall is a fast activity, a high frame rate in real-time systems is required to avoid missing detections. Furthermore, this algorithm has proved stable and can even detect movement when half of the subject's body is occluded by surrounding objects. Bian, Chau, and Magnenat-Thalmann (2012) presented an algorithm to improve the accuracy of skeleton extraction by rotating the human body trunk based on the pose in the previous frame.

Obdrzalek et al. (2012) presented a method that the accuracy of body tracking to a great extent depends on the type of poses being observed, the distance from the sensor and possible occlusions. They conducted a data acquisition process from captured human poses using the marker-based motion capture system developed by Microsoft Kinect. The result shows that Kinect works with much denser but less precise 3D data comparing to the marker-based system. They also observed that the markerless skeleton tracking of Kinect depends solely on dense depth information and thus frequently fails due to occlusions. For physical exercise of the elderly population, the Kinect skeleton tracking struggles with occluding body parts or objects in the scene, e.g. a chair. The occlusion is indeed an open issue for the use of Kinect technology in healthcare applications.

In the research work of Parra-Dominguez, Taati, and Mihailidis (2012), a method particularly to detect falls and other abnormal events on stairs was proposed. This work can automatically estimate the walking speed and extract a set of features that encode human motion during stairway descent.

Ni, Nguyen, and Moulin (2012) developed a computer vision based system to prevent potential falls in hospital ward environments. This system is able to automatically detect the event of a patient getting out of a bed. The nursing staff is alerted immediately to provide assistance once the getting up event is detected. The detection algorithm combines multiple features from multiple modalities via an MKL framework to achieve high accuracy and efficiency.

Rougier et al. (2011) introduced an approach to address occlusion for detecting human body falls. The method is based on human centroid height relative to the ground and body velocity. With the help

of computing 3D personal velocity just before the occlusion, this method can accurately detect falls by measuring human centroid height, because the vast majority of falls end on the ground or near the ground.

Zhang et al. (2012) proposed a system that employs two Kinect sensors to detect human falls. The statistical method is based on information about how the person moves during the last few frames. The major contribution of this research work is that it collects all training data from a specific viewpoint, and then collects all the test data from a different viewpoint. They believe the new protocol is a useful approach for measuring the robustness of the system by spatial displacement of camera images. Stone and Skubic (2012) developed a system for capturing variation of stride-to-stride gait in home environments for elderly adults. By measuring the changes in gait, falls can be predicted. If the motion of joints of a specific body subject is detected in an unusual time sequence, the prevention message is generated as a caution.

FUTURE TRENDS

The algorithms used for processing images obtained from the Kinect device play a very important role for human body motion analysis in healthcare applications. In the study of automatically tracking and detecting abnormal events, Parra-Dominguez, Taati, and Mihailidis (2012) evaluated different binary classification algorithms. Velloso, Bulling, and Gellersen (2013) suggested exploring more complex curve analysis techniques.

Although some existing applications already provide feedback for physical rehabilitation, there is still a huge range of possibilities of how this feedback may be improved (Velloso, Bulling, & Gellersen, 2013). The potential improvements could be multi-modal interaction, closer loop between the expert and the user, automated assessment, and so forth (Zhao et al., 2015).

Enhancing the entertaining and amusing elements of the system are possible for future improvement (Chang et al., 2011). It would make rehabilitation more enjoyable if more peers (or users) are engaged in rehabilitation activities simultaneously. Game-based exercises could increase patients' motivation for therapy (Saini et al., 2012). Continuously exploring 3D interaction techniques in virtual environments (Cervantes et al., 2012) will be the focus in the next generation for patients involved in physical exercise programs.

Home-based remote healthcare service might become the next generation for out-patient physical therapy and rehabilitation. With the development of advanced 3D sensors and cloud gaming software (O'Connor, Davy, & Jennings, 2013), it is very possible that more home-based rehabilitation training exercises will be available online (Rahman et al., 2013) or in a cloud server, which would be more convenient for professional therapists wishing to instruct, monitor, and assess patients' activities.

Most existing applications using Kinect technology in healthcare only apply to human upper body parts. The limited viewing range of the Kinect sensor has made it difficult to detect and track full body movements. In a study of automatically tracking and detecting abnormal events on stairs in elderly living centers, Parra-Dominguez, Taati, and Mihailidis (2012) discovered that tracking hip joint points from the skeleton frame in Kinect is more stable than tracking feet and ankles, due to the fact that feet and ankles are sometimes partially occluded from Kinect view. On the other hand, applications in healthcare services require full body motion analysis. Therefore, full-body detection is a critical challenge for the future development of Kinect applications in healthcare.

One of the main drawbacks of using Kinect skeleton in healthcare applications is that Kinect uses a very non-anthropometric kinematic model with variable limb lengths (Obdrzalek et al. 2012). In general postures, the variability of the pose estimation is about 10 cm. Future algorithms should address occlusions and self-occlusions, unconventional body postures, and use of wheelchairs or walkers.

CONCLUSION

We believe that the research and development on using Kinect technology in healthcare will gain more momentum. The demand of Kinect-based applications is high, due to Kinect's low cost and portability, and its accurate and robust motion detection capability. In this chapter, we have surveyed the current applications of using the Kinect technology in healthcare. Furthermore, we outlined a number of open research issues that could overcome the limitations of the current Kinect technology.

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KEY TERMS AND DEFINITIONS

Dynamic Time Warping (DTW): An algorithm for measuring similarity between two temporal sequences that may vary in time or speed. DTW calculates an optimal match between two given sequences (e.g. time series) with certain restrictions. The sequences are “warped” non-linearly in the time dimension to determine a measure of their similarity independent of certain non-linear variations in the time dimension. This sequence alignment method is often used in time series classification.

Fall Detection: Detection of unexpected falls.

Fuzzy Logic: A form of many-valued logic. Fuzzy logic deals with reasoning that is approximate rather than fixed and exact. Compared to traditional true or false values, fuzzy logic variables may have a truth value that ranges in degree from 0 to 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false.

Kinect SDK: A software developing kit released by Microsoft for the development of 3D sensing applications.

Randomized Decision Forest (RDF): An ensemble learning method for classification and regression that can operate by constructing a multitude of decision trees at training time and outputting the class that is the mode of the classes output by individual trees.

Rehabilitation Exercises: Exercises prescribed by a physical therapist to enhance the recovery of a patient after a surgery or certain diseases.

Virtual Reality: It refers to a computer-facilitated environment that simulates physical presence and allows the user to interact with the virtual world.

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Chapter 32

Neuroscience Technology and Interfaces for Speech, Language, and Musical Communication

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ABSTRACT

Medical practice is extensively using monitoring devices that are more or less invasive and immersive. For aural and oral communication these could be hearing aids, prosthetics, cochlear implants, or goggles detecting vestibular effects and vertigo. Recently, a wide variety of trendy mobile or wearable devices has been offered to the general public, provoking a frenzy for augmentation alongside the great expectations that the popularization of brain-computer interfaces has caused to both the consumer market and the scientific community. The use of bionic devices clinched with synapses of the nerves does not merely mingle input activity to brain activity, but also it provides a virtual channel for augmenting and manipulating speech communication, language communication, and even further, musical communication. The electromechanical parameters, the medical practices, and the learning potential for this new world of augmented human-computer interaction platforms and devices are examined under the prism of audio communication.

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INTRODUCTION

Recently, in a continuously changing environment with a wide variety of trendy mobile or wearable devices, in an increasingly demanding market for additional benefits in favor of the end user, the success of a product depends on its ability to adjust to the needs and desires of the consumer. So, new concepts have emerged in spectacular pageant for the amazed public eyes.

Within this scenic approach, the concept of Interface Design and Usability has come to surface not only for smartphones and tablets, which are definitely powerful computer devices, but also for a variety of wearable or implanted pieces of apparatuses that are in position to perform many of the functions of computing machinery.

Inevitably, the issue of Usability comes to surface, as it measures perhaps more clearly than any other factor, the ability of a product not only to affect the body but also the mind of the user. This seemed to be the situation experienced thus far only with advanced medical devices and prosthetics that enabled monitoring of subtle neurological functionality. Indeed, for diagnostic or therapeutic purposes microensors, wearable monitoring systems and various imaging assemblages provide an enhanced telecommunication channel between the actual patient organs and the monitoring clinician (Figure 1).

The initial success of implanted or portable devices used for health and fitness reasons has widely promulgated mobile device applications of all types that take advantage of the affordable imaging modalities, the immediate reporting potential, the endoscopic representations of computer generated signals, the tactile sensing, the microrobotic precision, the motion tracking, the stereotactic functionality, the GPS positioning, the accelerometer measuring of shock, vibration or orientation, and many others.

As microprocessor signal pins interface with the internal neurological architecture of the human organism, they synchronize external events with the structure and functionality of the brain. The notion of Usability, extensively used in Human Computer Interaction (HCI), refers to the potency of a product that is massively deployed to end users to bring into action specific targetable derivatives under certain circumstances (Dix et al, 2004). These are measured in terms of:

Figure 1. Wearable and implanted devices used for detecting and ameliorating oral and aural communication. Left: video Frenzel goggles that eliminate vision and provide simultaneous eye movement recording for the Dix-Hallpike maneuver that detects Benign Paroxysmal Positional Vertigo. Center: Otologic Carina™ cochlear implantation deployed within the inner ear. Right: EEG cap recording brain activity produced by electroencephalography.



1. Effectiveness, i.e. the degree to which interaction with specific computing machinery is successful in producing desirable outcomes for particular activities or purposes.
2. Efficiency, that is the design of interaction in such a way so that the ratio of useful work performed to the total efforts attempted is maximized as possible.
3. Subjective Satisfaction, which results from the fulfillment of a user's expectations or needs while using components of electronic equipment, or the whole apparatus collectively.
4. A feature that recently has become a key element in the use of electronic devices is Learnability, which has to do with prior acquired knowledge or skill in using equipment of some kind, whether this ability has been developed by study, teaching, experience or sociability. The last factor has emerged as a new attribute of computing experience out of the personal relation with social networking.

Although the first three factors give a more mechanically driven approach to the evaluation processes of HCI, it is the fourth element that has gained momentum in terms of business intelligence. Indeed, Learnability is crucial for consumer electronics, since users flock around products that have a User Interface (UI) metaphor, a paradigm or an idiom they have previously used (Rogers et al., 2011).

By this attitude, they commit much less burden into their memory and as a result they prefer modules that have well-established UI paradigms, as is for instance the Android operating environment and the iOS paraphernalia. Indeed, the smartphone market is a classic example of an advanced and multi potent computing environment that is used globally, for really sophisticated and sometimes unconventional tasks that demand no prior formal education or training received (Nielsen & Mack, 1994; Nielsen & Budiu, 2012).

This fourth factor, when bad Interaction Design is endorsed, tarnishes the acceptance of new media accounting for them the reputation of being

- Infuriating
- Confusing
- Aesthetically unpleasant

It is exactly this attitude towards Interaction Design that makes the commercial products that come up from the medical aids arena to deploy not only a new aesthetic approach but also to seek a different endurance and a smart communication that co-exists within the user habits. Indeed, as UIs become more efficient and effective, they promote their usage as Brain Computer Interfaces (BCIs) as well (Figure 2).

BACKGROUND

Although the general public's pictorial perception for a BCI is mingled between the image of an EEG cap (an electrode studded cap that reads brain activity) and a portable device like Oculus Rift, in recent proceedings a more subtle schematic view has been emerging with devices like Cochlear Implants that transform input activity to brain activity (Politis et al., 2014).

Generally speaking, there are two kinds of BCIs (Dix et al., 2004):

1. **Invasive:** This category of products, undoubtedly the flagship of Interfaces, produce overwhelming immersion into what brain activity projects. In audio matters, such devices offer state of the art

Figure 2. A series of trendy commercial devices with advanced HCI capabilities: Left, Google Glasses®. Center, the versatile iWatch™ calculating the heart rate and not only. Right, the Oculus Rift fully immersive audio-visual device in conjunction with hand held controllers. A new brave world for extreme Virtual Reality experiences.



multi-track digital input capabilities and thus they simulate and gradually replace the sound input of the outside world. It is obvious that the hardwiring of Figure 3, image on the right, indeed resembles the beginnings of electromechanical Interfaces. Subtle operations and engineering methods take place as any malfunction or any unguided penetration may induct erroneously the electrode into the posterior semicircular.

2. **Non-Invasive:** Not so immersive, they need some training via biofeedback, and their bandwidth is rather limited. They act more like assistive devices and do not totally replace a handicapped organ or instrument.

The focus of this article lies on how commercial gadgets play the role of what instrumentation does to medical technology in terms of augmentation. As body parts are failing to function properly and restoration to a healthy state seems inefficacious, prosthetics are used to rehabilitate vital bodily functions. In the same sense, gadgets readily available to the wide public can increase the data flow from the outside

world to the brain and vice-versa. This consideration, albeit promoted with niche computing machinery, comprises the central vision for the already over \$1 billion Blue Brain Project (Markram, 2006) and the Human Brain Project in Europe (Waldrop, 2012) that promulgate medical informatics and neuromorphic computing. The equivalent project on the other side of the Atlantic is the US-financed Brain Initiative (2013). These approaches, which rely heavily on data analytics and simulations, attempt to promote brain-inspired Information Technology (Amunts et al., 2016). As a result, interdisciplinary trajectories are motivated linking Neuroscience, Brain Medicine and Computer Science in pursuit of the complex links amongst cerebral activity and behaviour (Markram et al., 2015; NSF, 2006).

At this point HCI emerges: it is the interdisciplinary field that correlates many disciplines like engineering, psychology, computer science, industrial design, ergonomics, artificial intelligence, and more recently, sociology, anthropology, art sciences, etc.

So it is the technological advances in these fields, as far as mobile, wearable and implanted devices are involved, that provide a new potential for the quality of the UI (Nielsen & Budiu, 2012). Also, a new workflow framework is introduced which further progresses the functionality of computing devices that support oral and aural communication. Under this prism, HCI becomes more central to the design and development of augmented reality machinery, investigating functionality that did not previously exist for the user or functionality that was not virtually usable.

In strict terms a Cochlear Implant (CI) is an electronic device that restores partial hearing to individuals with severe to profound hearing loss; these people normally would not benefit from a conventional hearing aid. Conventionally, as the American Academy of Otolaryngology (2015) puts it “it is surgically implanted in the inner ear and activated by a device worn outside the ear. Unlike a hearing aid, it does not make sound louder or clearer. Instead, the device bypasses damaged parts of the auditory system and directly stimulates the nerve of hearing, allowing individuals who are profoundly hearing impaired to receive sound” (Figure 3).

As stated earlier, the hardwiring of Figure 3, image far right, has a profound congruence with the origins of electromechanical Interfaces. Subtle operations and engineering methods take place as any malfunction or any unguided penetration may induct erroneously the electrode into the posterior semicircular canal damaging the facial nerve, or creating an unsupervised electrode contact within the vestibule. The implant consists of antenna, magnet, receiver stimulator in titanium casing, electrode array with electrode contacts, apical and basal, spaced at 2.4 mm intervals. The overall length of the implantable electrode array is 30 mm and its width 1.3 mm at the base and 0.8 mm at its apical end (Godara & Nikita, 2013).

Conclusively, a new generation of rather expensive gadgets transforms vigorous everyday activities: Google Glasses® consolidate with normal glasses, smart watches like iWatch™ display apart the others time and can dip into water, while contemporary fully immersive CIs disguise well with the scalp characteristics and allow their user even to swim. Either for medical purposes or for normal every day activities, computer aided infrastructures assists human senses to manipulate higher dimensional objects, which in mathematical terms leads to evading hyperspaces while in more pragmatic computer terms this directs users to virtual reality augmentations.

FROM PROSTHETICS TO BIONICS

Hearing disorders is the first pivotal point in disrupting the pipeline of proper oral and aural communication (Figure 4). They are quite common in modern societies not only due to congenital issues but also because

Figure 3. The Cochlear Implant pictorially: Left, the device, Cochlear's Nucleus Freedom™; Center: penetration and placement within the ear; Right, clinching the synapses of the audio nerve

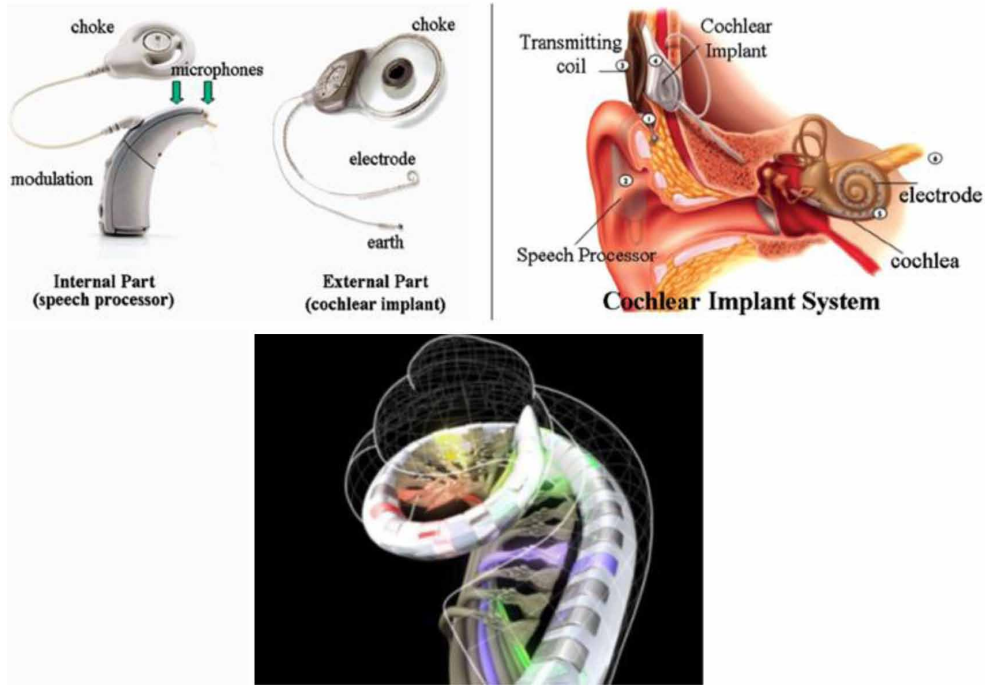
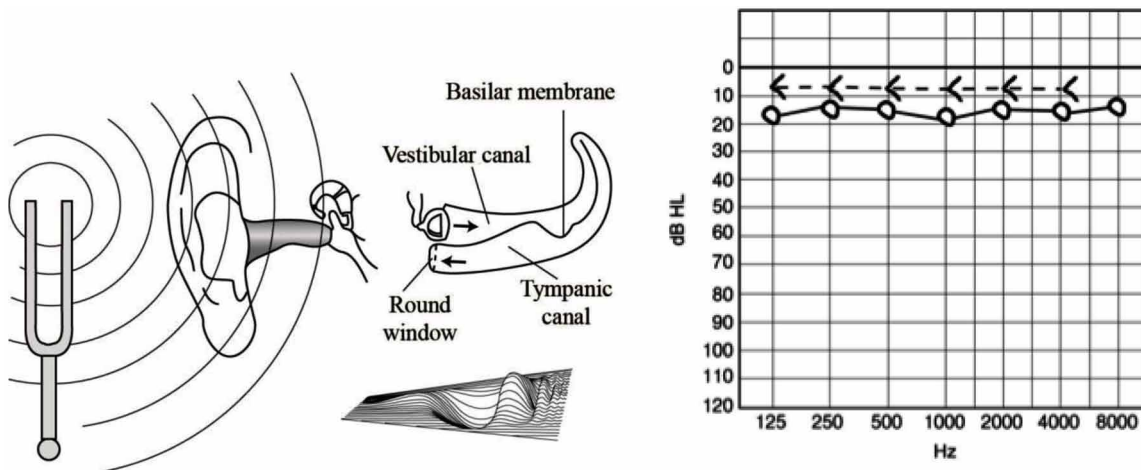


Figure 4. Left: the hearing process. Right: An Audiogram for normal hearing, in dB of Hearing Level versus frequency. air audiometry (o) and bone conducted audiometry (<) (Stavarakas et al., 2016)



diagnostic media are readily available. Hearing loss is perhaps the most common reason for visiting an ENT Department, both in the clinic and in the acute setting. As recent statistics reveal (Blackwell et al., 2014) approximately 15% of American adults (about 37.5 million) aged 18 and over, report some kind of hearing problem. 13% of the United States residents aged 12 or more (some 30 million people) have

been diagnosed after standard hearing examinations to be experiencing hearing loss in both ears. More severely, a 2% of adults between 45 and 54 suffer from disabling hearing loss. As age increases, in the slot 55 to 64, this disability affects the 8.5% of the population. For those aged 65 to 74 the percentage rises to 25%, while for the ones who are 75 and older disabling hearing loss affects the 50% of that population group. According to these figures, hearing disorders impact adversely the patient's quality of life by predominantly disrupting his oral-aural channel of communication (Stavrakas et al., 2016).

While hearing disorders directly affect the voicing mechanism, they have some smaller in extend negative influence on the way that musicians skillfully interact with their instruments in order to produce harmonic tones that bring to prominence beauty of form, harmony and emotion. Indeed, the distracted perception of musical sounds not only represses the ability of the performer to tacitly interact with his musical instrument, but is influencing the behavior of listeners who pervasively dip into oceans of digital music (Margounakis & Politis, 2011) supposedly delighting their ears. Actually, although the way that classically educated musician interact with computers has not changed in its essence the last 20-30 years, the general public has started to interact with computers, mobile devices and the sound cloud in a two-way manner that enables computer aided synthesis and composition of new sounds, recording and mixing using smartphones and laptops, distribution through on-line libraries and repositories, (live) streaming services, and ubiquitous listening to music on smartphones and other portable music players (Tzanetakis, 2016).

Despite all these sweeping advances that raise the everyday audiophile to an enthusiastic producer, people who are hard of hearing lack the harmonic understanding or have impaired perception of natural tones struggle to participate in these social networks.

Hearing loss can be divided into two main categories, depending on the affected parts of sound transmission:

1. Conductive hearing loss results from any disruption in the passage of sound from the external ear to the oval window. It can be caused by pathologies involving the external and middle ear (external auditory meatus, tympanic membrane, ossicular chain).
2. Sensorineural hearing loss results from disruption of the passage of sound beyond the oval window. Such pathologies can be located to the auditory receptor cells of the cochlea and the eighth cranial nerve.
3. Mixed hearing loss represents a mixture of both conductive and sensorineural hearing loss.

Pure tone audiometry for producing audiograms is performed in an audiometric test room, where the subject's face should be clearly visible to the tester. When the test is observed from outside the audiometric test room the subject should be monitored through a window or a TV monitor. Excessive ambient noise can affect test results, thus it is recommended not to perform the test if the ambient noise is >35dB. Both ears are tested for air conduction firstly at 1000Hz and then at 2000Hz, 4000Hz, 8000Hz, 250Hz and 500Hz. A reference level of 0dB HL conventionally represents normal hearing across the entire frequency spectrum.

Some basic thresholds are the following:

- Threshold of hearing, 0 dB
- Whisper from 1m distance, 30 dB
- Normal conversation, 60 dB

- A shout, 90 dB
- Discomfort, 120 dB

The interpretation of the audiogram provides information not only for the quality of any potential hearing loss (conductive, sensorineural or mixed) but for the level of hearing loss as well. Generally, normal hearing is considered to be >20 dB, while mild hearing loss is >40 dB. Hearing thresholds and degrees of hearing loss are summarized pictorially in Figure 5 (Stavarakas et al., 2016).

Unlike a hearing aid, CI does not make sound louder or clearer. Instead, the device bypasses damaged parts of the auditory system and directly stimulates the nerve of hearing, allowing individuals who are profoundly hearing impaired to receive sound” (Figure 6).

CIs are applicable for both children and adults with bilateral, severe to profound sensorineural hearing loss, who cannot take advantage of the use of powerful hearing aids and have not managed to improve their oral communication skills by a prescribed speech therapy. In this manner, the early stimulation of the acoustic Central Nervous System, especially in pre-school ages, may well lead to improved acoustic memory and sound discrimination.

Figure 5. Left: Conductive hearing loss with an obvious air bone gap in its pure tone audiogram. Center: Sensorineural hearing loss audiogram. Right: Mixed hearing loss. All audiograms after Stavarakas et al., 2016.

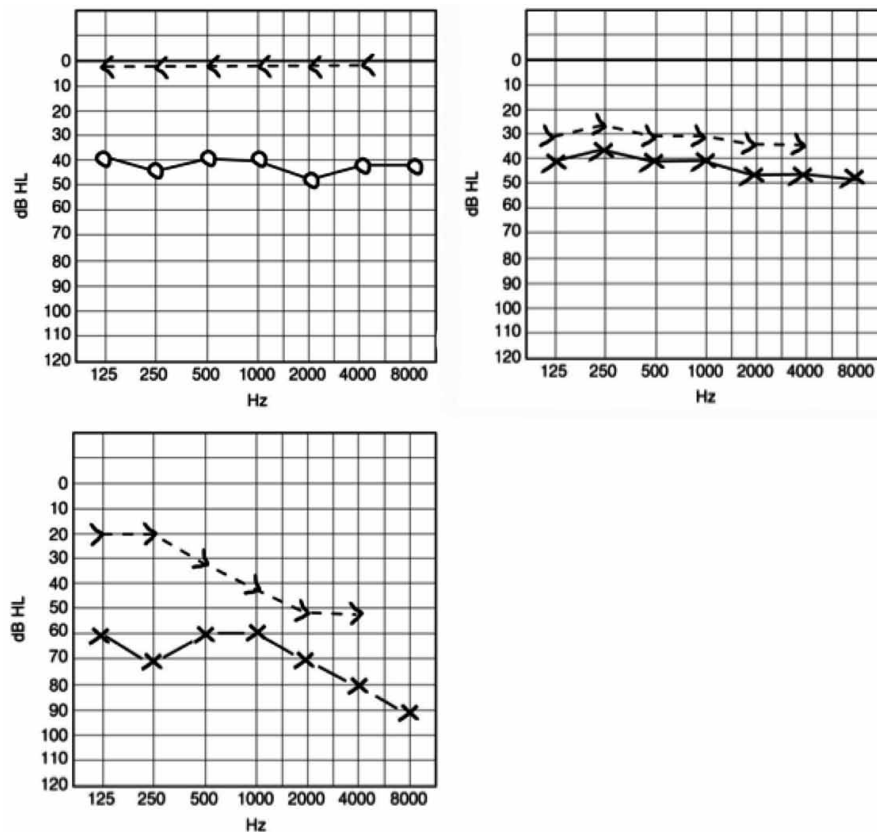
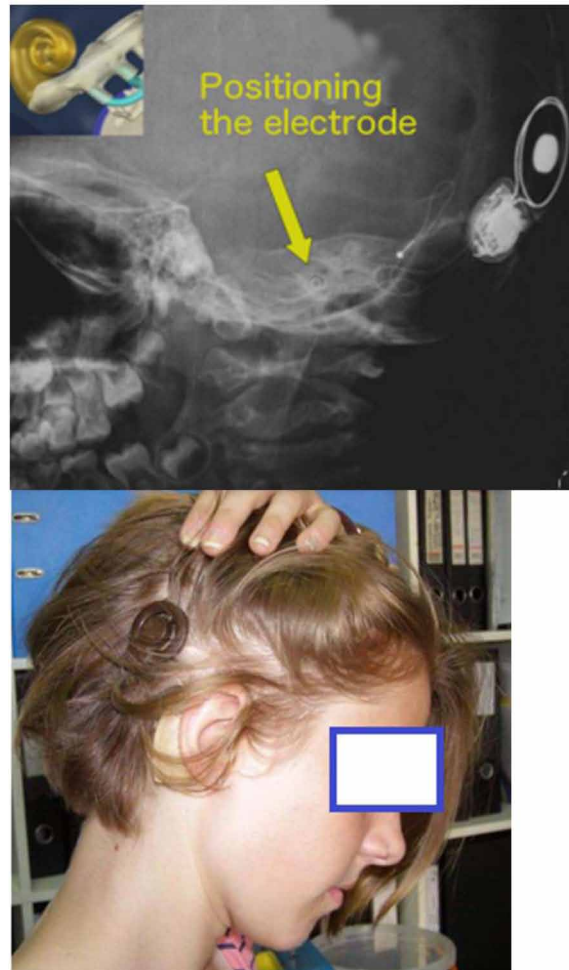


Figure 6. Applying a Cochlear Implant to a child at the AHEPA hospital, as seen with a CT head cross-section (left), and as it seen from outside (right), with an obvious attempt to camouflage the external parts of the implant.



Indications and preoperative requirements for cochlear implantation include a complete medical history and physical examination, medical valuation, audiologic examinations, CT and MRI scans to evaluate the cochlea and the auditory nerve, psychological tests, speech evaluation and enrolment in oral education program (Kyriafinis et al., 2007).

CIs do not restore normal hearing; they just provide a *representation* of sound. An inner ear problem, usually leads to sensorineural impairment or nerve deafness. In most situations, the hair cells are damaged and do not function. Even though various auditory nerve fibers may be intact and can transmit electrical impulses to the brain, these nerve fibers are unresponsive due to hair cell damage (American Academy of Otolaryngology, 2015). It is generally accepted that if severe sensorineural hearing loss cannot be put right with medical treatment, then the road towards cochlear implantation is wide open.

FURTHER RESEARCH DIRECTIONS: ESTABLISHING A BCI MODEL FOR ORAL AND AURAL COMMUNICATION

It is obvious that cochlear implantation, along with highly immersive and invasive audiovisual and kinetic devices deploy a BCI that more or less revamps the Human Processor Model (Card et al., 1986) that was first established in mid 1980's by adding a blend of virtual reality sensing.

Indeed, the situation depicted in Figure 6 can be diagrammatically explained with the computer architecture module seen in figure 7.

The initial model proposed by Card, Moran and Newell, provided a workable simulation for analysing how human cognition responds in a HCI manner with the plethora of incoming signals that test the ability to see, hear, or become aware of something through the senses.

However, prosthetics and implanted devices offer a potential that did not exist in the original 1986 model, which could not envisage the possibility of desirable future characteristics (Pesaran et al., 2006), like an "audio processor" or a "graphics processor" apart from the Central Processing Unit.

This new approach propels theories that take into account special capacities that enable individuals to display exaggerated performances and skills, which cannot be explained in depth by the theories of intellectual performance based on a person's reasoning ability.

Prosthetics, bionics and augmentation devices allow subjects to readily experience an augmented virtual reality that gives them, although handicapped and impaired in normal physiological values, the possibility to experience the production of sensual impressions stimulated by "parts" of their body, or provoked by other senses.

For instance, a patient with a CI does not use the middle and the external part of his ear at all; instead, he is able to hear through an audio processor that establishes a sensorineural channel of communication between a computer device, the speech processor, its bionic extension, which is implanted within the skull, and a BCI, the place where the electrodes are conclusively settling and clinching the hair cells of the audio nerve (Figures 3 and 6).

Indeed, all this arrangement is well described by the auditory processing channel seen in Figure 7. Furthermore, it may give the impression that the sense of hearing is completely replaced by a bionic part, and therefore the normal hearing apparatus is not contributing to the bodily function of hearing.

Therefore, if the CI's battery is uncharged, or if the subject turns off the CI, then, he may not receive or process any auditory input. However, this is not the case. If, for instance, the subject is in a music hall and he is listening to dance music, which is highly rhythmic with strong subwoofer beats, he will not be able to hear the melody, but the strong beats via the ear's auditory canal will trigger with their vibrations the vestibulocochlear nerve, attesting the sense of balance. For a deaf subject, no sound or melody will be heard, since the bionic device is turned off, but, the strong vibrations will be sensed by the vestibule, sacule, superior canal and posterior canal, and therefore the subject will have a clear sense of the rhythm, allowing him to dance in accordance (Figure 8).

This ability, to have multiple representations of sounds, is stimulating the virtualization of our senses, by intermingling perceptual processors (which can be our senses or bionic devices) with the cognitive processor, which is our cerebral processing power, responsible for the integration of complex sensory and neural functions and the initiation and coordination of voluntary activity in the body.

This approach can be somehow adequately incorporated with the theory of Multiple Intelligences (MIs).

The profiles of intelligences and their basic description defined by the MI theory are (Aleksic & Ivanovic, 2016):

Figure 7. The diagram for the revamped Human Processor Model (cropped from <https://blombladivinden.wordpress.com>)

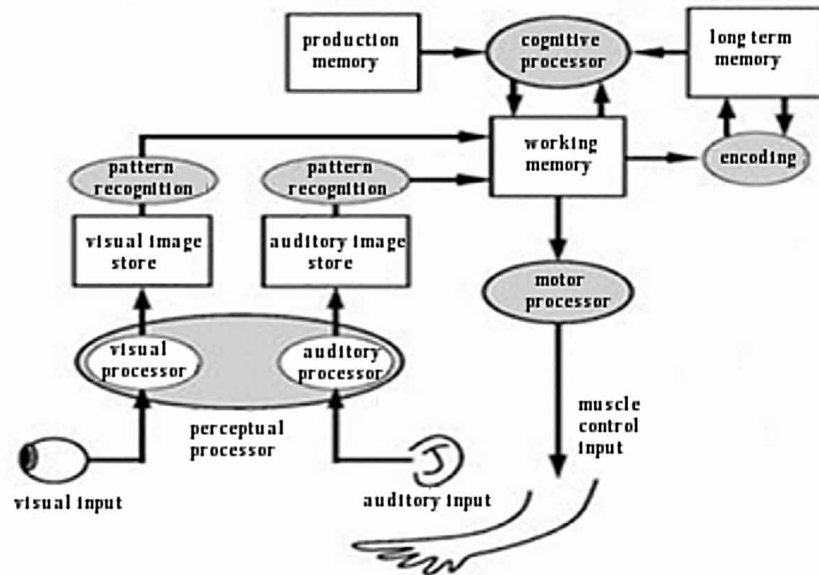
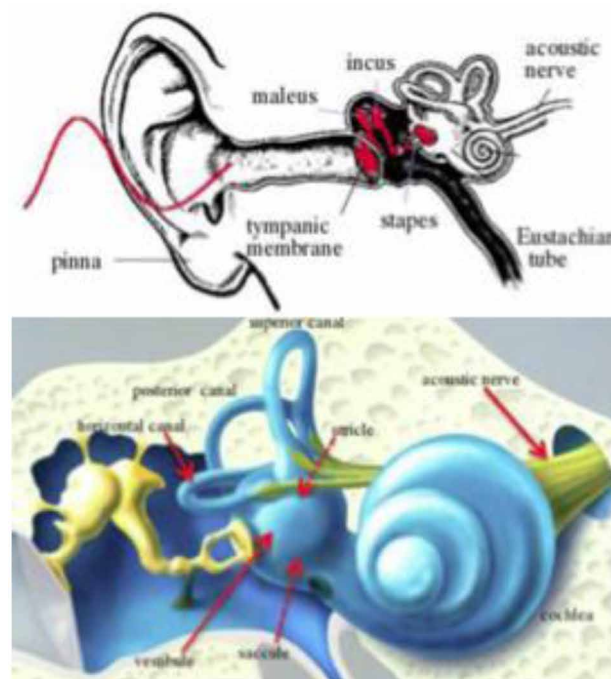


Figure 8. Left, the hearing mechanism triggered in the outer and middle ear. Right, the structures that are triggered within the inner ear.



- **Verbal/Linguistic:** Represents the primary means of communication amongst humans. It is reflected in symbolic thinking, language, reading, and writing.
- **Logical/Mathematical:** Is used for data processing, pattern recognition, working with numbers, geometric shapes.
- **Visual/Spatial:** Navigation, map making, visual arts, architecture, perspective.
- **Bodily/Kinesthetic:** Reflects the precise self-body motion control, non-verbal emotion expression, dance, fine hand-eye coordination.
- **Musical/Rhythmic:** Recognition and use of rhythmic and tonal patterns, recognition of sound, speech and music instruments. It is used to interpret and create music.
- **Natural:** Recognizing patterns in nature, classification of objects and types of wildlife.
- **Interpersonal:** The possibility of cooperation in small groups, communication with other people, individual's ability to recognize other people's intentions, mood, motivation, non-verbal signs.
- **Intrapersonal:** Recognizing own abilities, capacities, feelings, emotional reactions, self-reflection, and intuition.

Evidence of existence of a theoretical ninth (existential) intelligence has not been clearly established (Moran et al., 2006), so it will not be considered.

The theory of MIs has spread waves of enthusiasm in various educational circles since it promotes both an individualized approach and practical application in teaching. Researchers thus recognize that by supporting multiple areas of activity they may enhance the students' mindset and better exploit it, especially amplifying its verbal and linguistic aptitude. MI theory increases learning efficiency by expediting instructors to direct further assistive education (Stagiopoulos et al., 2016).

Furthermore, it can be said that as sound or music experience is a complex procedure that involves multiple human sensors intermingling with virtual instruments or virtual worlds (Tzanetakis, 2016), that a more complex scheme should be used to represent logically, mentally and mathematically the multitude of HCI and BCI events.

Several systems have been proposed in various occasions, e.g. like that of Valbom & Macros (2003), Miranda & Wanderley (2006), Graham-Knight & Tzanetakis (2015), Politis et al. (2015) that give an idea of the multitude of interaction with the world of music. New devices, new instrumentation and ample computer resources reshape the way that people either alone or en masse participate to the increasingly global music recreation (Figure 9).

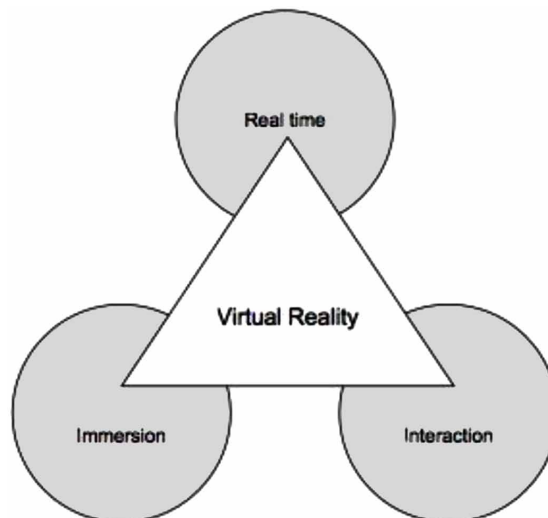
CONCLUSION

Playing a musical instrument, speaking properly a (foreign) language or being able to sing with the right tune are undoubtedly some of the most complex interactions for the convolution of oral and aural communication. All people have a lengthy experience of schooling for becoming able to handle properly their speech, language and musical communication skills. Furthermore, the ability to manipulate the multiple aspects of linguistic ability (phonation, formation of speech, structural organization, etc) characterizes the overall competence of a subject's potential for his perceived general intelligence, at least for the schooling age.

Figure 9. Interacting with musical instruments. Left, a performer playing his guitar. Center, a virtual guitar with multitouch capabilities that can be played with an iPad. Right: A new concept for multisensor music reproduction – a “virtual” compact disc surface enabling the DJ to perform cueing effects with his hand.



Figure 10. The axes for developing augmented communication skills between prostheses, implants and wearable devices



A new perspective in the management of these capacities comes with the advent of devices that offer a bionic support and augmentation in proliferating oral and aural channels of communication.

Having already presented outstanding features in supporting communication with peers, they have commenced to demonstrate impressive features in their communication with the Internet, with digital technology equipment, with devices that make sound using music robotics and ultimately with wearable devices, portable devices or prosthetics that create an everyday virtual reality experience beyond expectation.

In any case, to manage the great expectations that have been created as far as handling, programming and interaction are involved, the three pivotal points exposed in Figure 10 should be adequately balanced.

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KEY TERMS AND DEFINITIONS

BCI: The Brain Computer Interface research and development engulfs all the neuroprosthetics applications that focus in repairing, augmenting, and assisting human cognition or sensory-motor functions.

CT: Computed Tomography scans are special X-Ray tests that after being processed by computing machinery reconstruct detailed images of inner body structures and organs.

EEG: ElectroEncephaloGraphy is a monitoring methodology that gives concise measurements of the electrical activity of the brain while it performs cognitive tasks. Some 20 electrodes or more can be positioned on the skull to monitor small electric signals produced by brain functions.

GUI: By the term Graphical User Interface is denoted the integral part of computing machinery that relies on graphic representations to carry out commands. It also depicts visually the results of computer interaction establishing multimodal graphic communication between the smart device and the end user.

HCI: Human Computer Interaction is the scientific field that observes in depth how humans use all kinds of computing machinery, aiming to exploit the efficiency and effectiveness of their control potential by designing in cognitive and applicative terms new services.

MRI: Magnetic Resonance Imaging uses magnetic fields and radio waves to produced detailed images of the inner body. MRI may reveal problems that cannot be easily diagnosed by X-rays, ultrasounds or CT scans.

Senses: While computer research has put as goal to replicate the five senses, it becomes evident that machine perception can simulate, especially in gaming, some other sensations too, like vertigo, balance, equilibrium, acceleration, dizziness, magnetoception and so on.

UI: User Interface is the imminently responsive part of computable processes and structures. By it users can interact with a smart device.

VR: The synoptic term Virtual Reality refers to all the computer generated environments that create artificial worlds to feed our senses. Various devices like gloves, headsets, headphones, joysticks, eye cameras, 3D glasses, gamepads, motion controllers and similar offer to users simulated environments to “inhabit” and “wander in”.

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Chapter 33

Personalized Medicine

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ABSTRACT

This chapter discusses the issues and concerns related to the adoption of personalized medicine in modern healthcare system. In this chapter, the authors have elaborated the critical challenges while adopting this new medicare system. The changes required for this adoption have also been discussed by the authors. They have also give a glimpse of the critical success factors and consumer trust concerns along with the privacy and security threats for the successful adoption of personalized medicine system.

INTRODUCTION

Electronic Medical Record (EMR) and Personalized Medicine (PM) systems utilize new strategies for genomic diagnosis to better deal with a patient's ailment or inclination towards a sickness. PM intends to accomplish ideal restorative results by helping physicians and patients pick the disease management approaches prone to work best in the setting of the patient's genomic profile and genetic data. Such methodologies might incorporate genetic screening programs that all the more precisely analyse sicknesses and their types offering physicians the right assistance with selecting the right treatment and most appropriate drugs best suited to that genomic group of people (PMC, 2010, PMC, 2014). EMR and PM systems consist of identifying nature and contribution of genes as well as different environmental factors and preparation of personalized drugs based upon the information derived. PM system can then facilitate disease prediction, prediction and treatment by determining whether an individual runs the risk of developing a disease. Thus PM system can develop early prevention strategies. It can dragonize disease faster. Therefore, treatment can be started early. Thereby, it is possible to prevent side effects that resulted from medicines given to a patient by trial and error method using the traditional system of treatment. Thus the main merits of PM system can be summarized as follows (PMC, 2007):

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Personalized Medicine

1. In this novel system, it is possible for the medical practitioners to prevent onset of different diseases more effectively.
2. It is more time and cost effective.
3. This treatment procedure bears the potential to reduce the possibility of adverse reaction of drugs.

However, it is to be borne in mind that for successful adoption of EMR and PM systems it is very important to first identify the critical challenges (Misra and Bisui, 2014), changes required (Misra et al., 2016), and trust, privacy and security concerns in the adoption. This act of identification will significantly add to the success of the personalized healthcare system management. As indicated above, the novelty of EMR and personalized healthcare lies in the fact that it makes use of information regarding environment, genes, proteins and clinical treatment of individual patients.

BACKGROUND AND MAIN FOCUS OF THE ARTICLE

Personalized Medicine is a recently developing idea in the modern health sector. Some of the personalized drugs have been now found by the researchers. However, reception of the Personalized Medicine and EMR idea still lacks practice implementations. Despite the fact that there are a several researches about on the genomic translation and genetic interpretation by Esvelt and Wang (2012), Dreyfuss (2012), Zamft et al. (2012), Cong et al. (2013) and Mali et al. (2013) advancement of exploration on various parts of Personalized Medicine is very insufficient. Bolouri (2010) has talked about a few issues regarding personalized medicinal services. Eysenbach (2001) and Ahern et al. (2006) gave some insights about electronic healthcare. In a survey Jadad et al. (2005) and Eysenbach and Diepgen (2001) gave some direction towards the electronic medicinal services framework. There is an active promotion of e-health across the world. Several developed countries including Canada, United Kingdom and United States have a long-term plan to implement EMR. Taiwan has already adopted EMR and EMR Exchange. Canada had the goal to have EMR for all its citizens by the time of 2015. United Kingdom is building integrated IT infrastructure and systems to transmit health information safely and efficiently. United States has invested billions to encourage physicians and hospitals to adopt EMR and other applications of healthcare Information technology (HIT). Thus, the active promotion of EMR and EMR exchange is one of the important goals of health policy across the world (MRI, 2004). However, when it comes to developing countries, the success rate of the EMR adoption is not very high. Although Taiwan has implemented it, but physicians and clinics are still in a dilemma when it comes to practice implications of EMR and EMR exchange (Hwang et al., 2012, Chang et al., 2009, Chen et al., 2010). Countries like India, Netherlands and Australia are still trying to implement EMR and E-Health system. There are several challenges, trust issues, privacy and security concerns in this new technology adoption. We will try to discuss these issues further in this article.

SOLUTIONS AND RECOMMENDATIONS

While older people are more prone to drug adverse reactions because they are more likely to have multiple ailments and treatment of all the health problems need to be addressed simultaneously. Among younger generation people too, treatment by using personalized medicine is becoming increasingly attractive

after the detection of the effect of the genetic background on the disease susceptibility and response to treatments. Pharmaceutical industries also indicate that the introduction of Personalized Medicine will ease the healthcare management to a significant extent. Personalized drugs are getting popular day by day. Personalized Medicine drugs will allow companies to provide a wider variety of drugs, each targeted to a smaller and more specific category of patients. In this way, adverse reaction of traditional drugs in patients' body can be minimised. Researchers have identified some issues regarding the implementation of Personalized Medicine. For any new technical adoption several managerial needs to be accessed before practice adoption. For this new healthcare paradigm we need to identify the feasibility of the adoption in the current scenario. The critical challenges those may hinder the adoption also needs to be known. The changes are required to the current practice must be identified. Success factors of the new medicare system will give the healthcare institutions an insight about what needs to be done for a successful adoption. Several trust issues may be associated with the consumer, privacy and security of the genomic database will also be an important concern. Therefore, one need to have an insight about all these issues before actually goes for a practice adoption. In this article we have tried to portray some key aspects regarding the above issues. A brief discussion has been made on the previous researches. A direction for future researches has also been given in this article.

Feasibility of the Personalized Medicine System in the Present Scenario

There are various reasons to think whether Personalized Medicine is really needed. Often many medical practitioners and patients feel that it is just a marketing hype (Bolouri 2010). However, it is to be kept in mind that the world population is growing rapidly and older people require better healthcare support. Importantly, older people have varied health history, and therefore, have much diversified healthcare needs. They are also more prone to drug adverse reactions because they are more likely to have multiple ailments and treatment of all the health problems need to be addressed simultaneously. Among younger generation people too, treatment by using personalized medicine is becoming increasingly attractive after the detection of the effect of the genetic background on the disease susceptibility and response to treatments. Thus personalized medicine is needed by a large proportion of people.

Challenges Involved in the Adoption of Personalized Medicine

Misra and Bisui (2014) recently explored the challenges for the adoption of Personalized Medicine system within the healthcare management. The authors conjointly argue systematic and elaborate discussion on many vital aspects of personalized health care system. Within the same academic article, the authors have dwelt on variety of problems that provide hindrance to the implementation of this electronic healthcare system. The author analysed the crucial challenges from the perspective of medical physicians and common people. They have mentioned that there is a significant difference in both prospects. Some challenges include,

Genomic analysis for all individuals, High initial cost with no clear Return on Investment (ROI), Current healthcare work place doesn't have the training to administer Personalized Medicine, Present structure of medical record system doesn't have the infrastructure for Implementing Personalized Medicine, Unavailability of personalized medicine, Personalized Medicine concepts and tools have not yet been incorporated in medical school criteria, Government agreeing for the payment of the genomic tests, Complex cases where Personalized Drugs haven't yet discovered, Unawareness of doctors about

personalized medicine, Ever increasing cost of health care, Insurance companies agreeing for the payment of the genomic tests, Categorization of different genomic groups. However, common people also identified Categorization of different genomic groups and Complex cases where Personalized Drugs have not yet discovered as significant challenges in the adoption of Personalized Medicine.

Changes Required While Adopting Personalized Medicine

Several scholars have showed that there are several challenges that need to be taken care of before adopting Personalized Medicine system. Misra et al. (2016) gave us a glimpse of the changes required for this new medicare system to adopt. Their study showed that changes from reactive to efficient medical care, from trial and error to right treatment for right person at right time, from narrow mind-set to open mindedness, from open information of patients to secure information, from less emphasis on IT infrastructure to more emphasis on IT infrastructure are some of the significant changes that are necessary for implementing the revolutionary medicare system of personalized Medicine. Their research gave us more useful and more accurate information necessary for implementing Personalized Medicine systems in the future. The results from their study serve as first step in the direction.

Factors Leading to Successful Adoption of Personalized Medicine

For any technical adoption identifying the critical success factors is a key step. Once the organizations are aware about the factors that could lead to successful adoption, the manager could prepare a plan or pathway to overcome the success factors. Misra and Bisui (2014) while identifying the critical challenges gave a hint of the factors that may have an impact in the success of the Personalized Medicine system. A study in the similar area indicated that data management, team work and composition, privacy and confidentiality, mind-set, return on investment, sufficient time, R&D and alignment could be possible success factors. However, there is not any academic paper in which an attempt has been made to suggest the critical factors for the implementation of Personalized Medicine in healthcare management. Researchers could identify a multiple regression model for the consolidated dependent variable success, with the dependencies success factors as regressor.

Consumer Trust, Database Privacy and System Security in Personalized Medicine System

While receiving any new innovation the customer trust is dependably a noteworthy concern. In Personalized Medicine framework keeping up the protection and defending the security concerns will likewise assume a noteworthy part in the achievement of the adoption. As there will be a genomic database containing the patients' medicinal and individual data, therefore, keeping up the trust of the consumers will be a noteworthy test. There will likewise be numerous security concerns in regards to the information protection and utilization. Consumers and healthcare provider professionals would likewise be worried about their protection while utilizing this framework. Along these lines, there may be several trust issues could hinder or delay the success in the adoption. Before effectively receive this new medicare framework one needs to address all the trust issues that might influence the accomplishment of this progressive and

novel medicare framework. Researchers are trying to identify the issues that may regulate the trust of consumers, however, as per our knowledge there are no academic literature available in this domain. We have taken this issue up and trying to identifying the moderating effect of trust concerns in the success factors of Personalized Medicine. As trust issues are mostly related to people and organization (Robert and Seibold, 2003). Therefore we took the success factors that are directly or indirectly related to people and organization. A brief of our study on the identification of trust issues and their moderating effect on people related success factors is given bellow. Factors related to consumer and hospital system authorities are identified. These factors are the important modifiers of success. Next trust concerns of the consumers are listed. Finally the moderating effect has been checked using statistical methods. Along with trust privacy is also a major concern in this novel technology adoption. In Personalized Medicine system there will be a genomic database available in the web. This database is going to be the core of the adoption and it will contain all the genomic and personal information of the patients. Therefore, who are accessing the database will be a major concern for the patient' community. The privacy of the consumers will be directly in the hand of the database user. Therefore, common people will be very concern about their privacy. To prevent the privacy breach there will be a strong need of proper technology. Any technical glitch may leak the privacy of the consumer. Therefore, before adopting the Personalized Medicine system there is a strong need of research in the privacy concerns and their moderating effect on the success of Personalized Medicine. Similar to trust issues and privacy concerns, security will also be an important concern to taken care of. The implementation of Personalized Medicine system and E-healthcare platform is going to be very costly. Therefore, there will be high chance of security breach. Healthcare institutions and government should focus on developing policies and regulations to prevent the security breach. A proper research is needed before the practice implementation of Personalized Medicine.

FUTURE RESEARCH DIRECTIONS

Personalized Medicine system is surely to be an important enabler of the E-health system. It could shift the whole e-healthcare platform to a new level, where healthcare cost will be less, treatment time will be minimized and there will be no error in the treatment (PMC, 2007). However, Personalized Medicine system still lags research. There is not much academic study in the implementation of this novel technology. Misra and Bisui (2014, 2016) and Misra et al. (2016) have provided some business models for the critical challenges, feasibility and changes of this system. However, more work needs to be done in the area of trust, privacy, security concerns of the novel technology. Shalhoub (2006), Hwang et al. (2012) have identified different trust, privacy and security concerns for the EMR adoption. Although there are some research works available in the area of EMR adoption and E-health implementation, however, current academic still lags works in Personalized Medicine implementation. We have given a glimpse about the possible research works that can be done in this area. Personalized Medicine system surely is an important asset/discovery for our society. Therefore, researchers must have to be focused in its implementation. Several countries including United States, Canada, Australia, India, Taiwan have taken the implementation of EMR and Personalized Medicine system seriously. Therefore, these research works could be very helpful to the administrators and healthcare care providers while adopting this new medicare technology.

CONCLUSION

The research works in the area of adoption of Personalized Medicine serve as a vital step towards an essential comprehension of the rising field of Personalized Medicine framework. The conceivable purpose behind these research works is to minimize the current healthcare cost and provide our society a better and efficient healthcare system. Personalized Medicine will be a vital enabler in this. Adoption of EMR and electronic healthcare system has broadened the pathway for Personalized Medicine. Several authors and organizations Misra and Bisui (2014, 2016), Misra et al. (2016) Hwang et al. (2012), NHMRC (2011), Ginsburg and McCarthy (2001), Ong et al. (2013), PMC (2007, 2010, 2014) have started working in the practical implications of the Personalized Medicine. The outcome of the research works could serve as a noteworthy step towards the adoption of Personalized Medicine. We may hope that soon there will be an era of Personalized Medicine in the healthcare sector. Physicians, healthcare administrations and government could use these results to make new policy and regulations for the successful adoption of Personalized Medicine.

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Chapter 34

Pervasive Mobile Health

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ABSTRACT

Pervasive mobile health is mobile health that provides healthcare services that are accessible regardless of time and place where patients can continuously be connected through their smart mobile devices. It offers healthcare providers a more comprehensive perspective of patients' conditions and thus aids in achieving complex healthcare goal(s) such as building lasting relationships with patients. The service can be further extended to accommodate customers' participation in health and healthcare processes to improve healthcare services by extending roles of patients. The advancement of the web technologies, especially social networks, push e-health to embrace mobile devices (m-health) and personalize customer-centric services with a possibility to extend and improve services by enabling active participation of patients, patients' families, and the community at large in healthcare processes and personal health decision making. This chapter addresses some important concepts of m-health, challenges, future trends, and some related terminologies to provide a holistic view of m-health.

INTRODUCTION

Recent progress in mobile health (mHealth) is very encouraging as it allows healthcare services to be accessed through powerful smart mobile devices. Nowadays smart mobile devices such as smartphones and tablets support many features that can be utilized to access healthcare services conveniently. mHealth will indeed be a convenient experience to patients since there is currently a growing trend towards pervasive knowledge acquisition and management. Pervasive mHealth is an electronic health where healthcare services can be accessed regardless of time and place, and patients can continuously be connected to their healthcare services through their smart mobile devices.

According to Eysenbach (2011), healthcare services in mHealth are delivered through mobile devices. Pervasive mHealth provides services that go beyond traditional healthcare services. It provides various services accessible through smart mobile devices, including searching relevant health information, in-

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teractive discussion of healthcare matters with colleagues or friends, updating health related information from smart mobile devices, and seeking opinion through online healthcare services. Pervasive mHealth is becoming an increasingly important instrument in healthcare services for the public.

Most healthcare initiatives perceive patients as recipients of healthcare, where they hardly have roles in the process of healthcare activities and decision-making. For example, it is difficult for a patient to get access to his/her own health record or to find out his/her health history. On the other hand, the advancement of mobile technology has given customer (patients) a greater role in the process including the ability to gain access and control of information flow that fits their personalized needs. In terms of healthcare activities, many smart electronic devices have enabled patients to check their own health condition without assistance from healthcare staffs such as checking blood pressure, food hygiene Apps, mobile thermometer, mobile glucose measurement, mobile hypertension tool, etc.

In addition, the wide adoption of smartphones and tablets as well as the emerging of their utilization in healthcare raises the possibility to engage patients, patients' families, and society to participate in their own healthcare processes. For instance, social networking, which is accessible through smartphones, can provide an avenue to identify any misuse or misunderstanding in consuming antibiotics, share health information, promote positive behavior change, disseminate valid information, and explore how such tools can be used to gather real-time health data (Scanfeld et al., 2010). Pervasive mHealth can offer healthcare providers a comprehensive perspective of patient's condition and thus provide an environment in achieving complex healthcare goal(s) such as building lasting relationships with patients. The main goal of this chapter is to accommodate the concept of pervasive mHealth scenario within pervasive knowledge acquisition in healthcare systems. We propose a pervasive mHealth model that extends to multi-channel knowledge resources in mHealth. The model is designed to establish longitudinal healthcare services anytime and anywhere which in turn will raise health literacy of individuals and the community at large.

BACKGROUND

Currently almost every healthcare organization depends on information and communication technology (ICT) in every level of their activities. One of the most valued aspects of ICT is its capability to enhance processes or functions to improve consistency, accuracy, and efficiency. Similarly, efficient and effective healthcare services have become increasingly dependent on accurate and detailed clinical information, which is transferred from interrelated departments or even between organizations (Conrick, 2006). In addition, people's demands have changed because they have been empowered by the vast amount of information available and accessible to them through smart mobile devices, including mHealth related services (Anshari et al., 2013). For example, half of smartphone owners in US use their devices to get health information and one fifth of smartphone owners have health-related apps (Fox & Duggan, 2012). Despite some limitations of smartphones (Koushanfar et al., 2000), they can be used as services platform for mobile health information delivery, access and communication (Nkosi et al., 2010).

Rapid adoption of smartphones and smart mobile devices has removed the space, time and distance barriers for users, including the patients, to access information. In fact, smartphones facilitate the use of dynamic Web 2.0 and Apps allows intensive and immediate interactivity through social networks. In Web 2.0, users can collectively contribute contents and applications (O'Reilley, 2005). Web 2.0 is defined as a set of economic, social, and technology trend that collectively forms the basis for the next generation of Internet – a distinctive medium characterized by users' participation in using networks such

as *Facebook*, *Twitter*, *Snapchat*, *Instagram* and *LinkedIn*, which have indeed grown rapidly, facilitating peer-to-peer collaborations, participation and networking. The term social networks refer to the use of Web 2.0 that describes the social characteristics supporting the promotion of collaborative sharing. Web 2.0 is commonly associated with technologies such as weblogs (blogs), social bookmarking, wikis, podcasts, Really Simple Syndication (RSS) feeds (and other forms of many-to-many publishing), social software, and Web application programming interfaces (APIs) (Kristaly et al., 2008). Web-oriented applications and services use the Internet as a platform to provide unique features by engaging and providing users with rich interactive experiences (Rodrigues & Vaidya, 2010).

The widespread acceptance of the Web 2.0 services will affect the operation of future businesses. Greenberg (2009) explained these changes and that the customer's ownership of the conversation ultimately leads to organizations readjusting their business strategy. The fast adoption of smartphones has made customers or patients demand accessibility of health services through their smartphones. It is imperative for Health service providers to respond to these demands to sustain their businesses. In fact, health service providers can provide services that take advantage of smartphones' features or other mobile devices such as Web 2.0 features. The use of smart mobile devices with the Internet connection has permeated almost all aspects of our lives, creating pervasive computing.

Pervasive computing is associated with smart environments in which information and communication technologies employ intelligence and machine learning techniques to reason about, control and adapt to our physical surroundings. It focuses on sensing, interacting with and aiding humans at an individual and community level (Cook & Das, 2004). This means that pervasive computing should encompass every device worldwide that has built-in active and passive intelligence (Saha & Mukherjee, 2003). While mobile computing supports IT such as remote information access and adaptive applications, pervasive computing extends this notion to provide computing and communication capabilities that are integrated with users (Weiser, 1991).

MOBILE HEALTH

Challenges and Opportunities

As a business entity, a healthcare provider needs to have a comparable standard of customer service with other business organizations. It is a fact that customer expectations in healthcare are high, creating serious challenges for healthcare providers as they have to make an exceptional impression on every customer. In a competitive market, poor service drives customers to switch from one healthcare provider to another (Anshari & Almunawar, 2011). The adoption of mHealth will be a natural consequence of the adoption of smartphones. Hence, healthcare services must be adjusted in such a way that people can access the service through their smartphones or other mobile devices.

Most recent healthcare initiatives perceive customers (patients) as recipients of health care as they do not have a significant role in the decision-making process of their health (Anshari & Almunawar, 2015a). However, the advancement of Web 2.0 offers patients to have a greater role in the decision-making process related to their health. This is because they can be provided with the ability to access and control some personal information that fits with their personalized needs, which allows them to actively participate in the decision-making process related to their health.

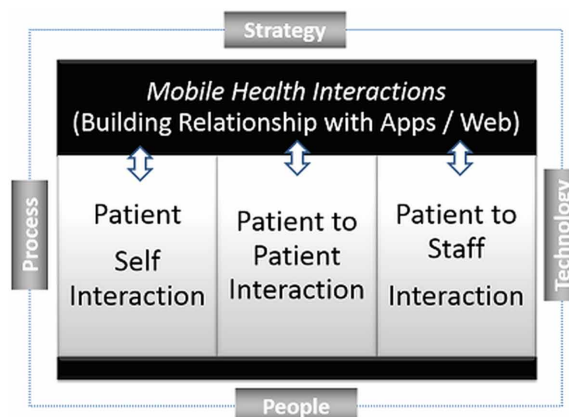
Web 2.0 tools have brought a possibility to extend e-health by enabling patients, patients' families, and the community at large to participate more actively in the process of health promotion and education through a social networking process (Almunawar, Anshari, & Younis, 2015). Embedding Web 2.0 in healthcare is a challenging task in order to provide a new meaning in building relationships between patients and healthcare organizations within a social network platform. In addition, social network applications that exist in smartphones can be utilized to facilitate interactions between patients and their healthcare providers (Anshari & Almunawar, 2015b). Furthermore, the impact of Web 2.0 technologies for health continues to grow, and the term Medicine 2.0 has entered popular categorization. Hughes et al., (2008) mentioned that the terms of Medicine 2.0 and Health 2.0 were found to be similar and categorized into five major notable cores:

1. The participants involved (doctors, patients, etc.);
2. Its impact on both traditional and collaborative practices in medicine;
3. Its ability to provide personalized health care;
4. Its ability to promote on going medical education; and
5. Its associated methods and tool related issues, such as potential inaccuracy in end user-generated content.

However, discussion on Medicine 2.0 needs further investigation to map the relationship model of patient-patient interactions, and patient-healthcare provider interactions. This chapter proposes that the role of patients in mHealth services can be extended into an individual health actor, a social health agent through social networks, and a medical care partner.

Managing interactions in any business organization requires proper concepts, business process, tools, people, and strategies. Therefore, mHealth model must provide a mechanism that have the ability to broaden service beyond its usual practices. Three aspects of interaction in mHealth can be considered (Figure 1). First, *patient-self interactions* with the system, which is the ability of a patient as an individual to actively utilize mobile healthcare services provided by the healthcare provider. For instance, patient-self interaction enables the patient to view his/her medical records through his/her mobile phone, or request for a consultation. Secondly, *patient-to-patient interactions*. This allows patients to interact

Figure 1. Interactions scenario in mHealth



among themselves, share information, concerns, and experiences. For example, the system facilitates social networks for patients with similar conditions to make conversation and share their experiences. Thirdly, *patient-to-staff interactions* provide online interaction between patient and healthcare staff.

Finally, the development of the Internet of Things (IoT), big data, and massive medical software applications (apps) has supported the generation of pervasive knowledge including mobile health devices. Mobile health devices have empowered patients to use care tools such as drug references, healthcare references, diagnostic aids, medical calculators, etc. Whenever mobile health devices connects with mHealth system it can generate information that enriches personal health records. For instance, a blood pressure tool measures a patient's blood pressure and instantly updates the record of his/her blood pressure in the mHealth system. The focus of pervasive mHealth is recognized in different areas of data and information management, including accessibility, collaboration, information utilization, integration, and process automation of mHealth data.

Solutions and Recommendations

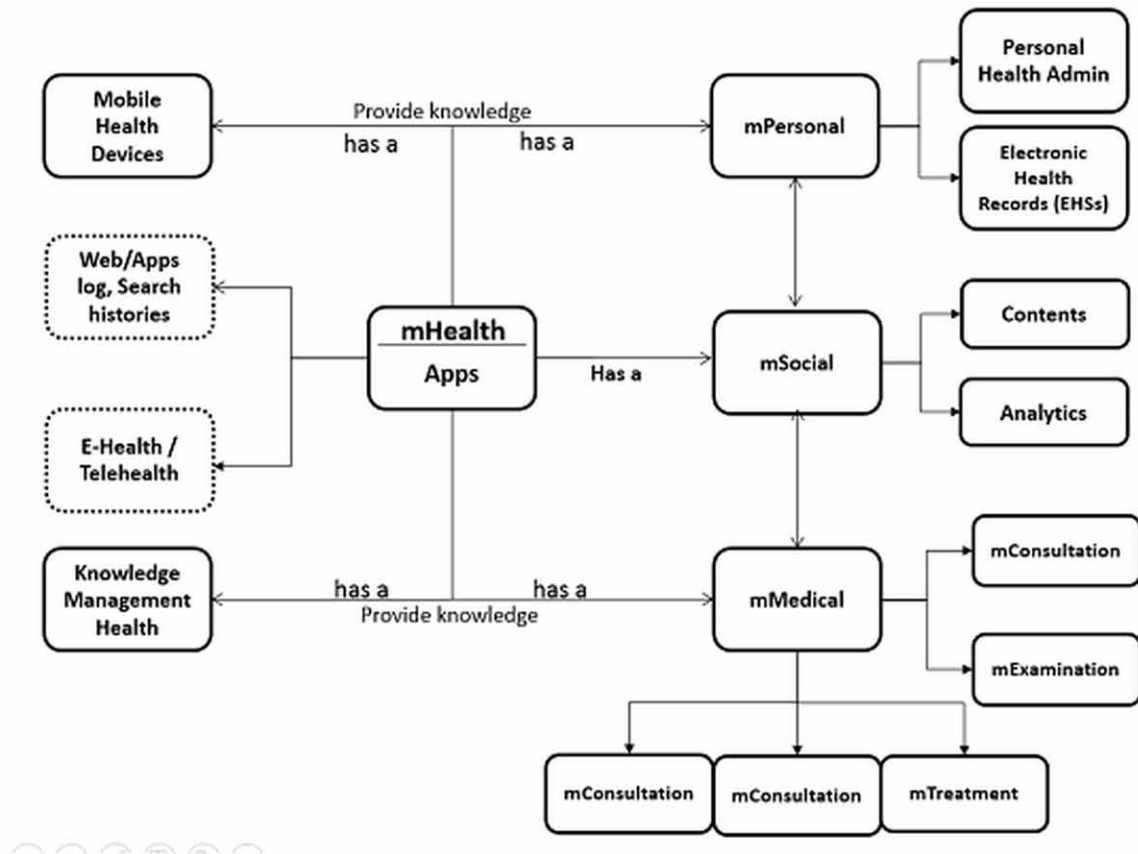
Active role of patients through mobile services is delineated as the embodiment of future mHealth, with the hope to make the system more reliable, effective and efficient in addressing patients' demands. The model addresses multi levels interactions to provide online information access, consultations, information sharing, and other services through smart mobile devices. The model is expected to lay the perspective for pervasive knowledge management in which mHealth provides service for improving healthcare literacy and building relationships among all the parties involved (a healthcare organization, patients, and the community at large).

Understanding a business process helps healthcare organizations to deliver the strategic plan in providing proper mHealth services. The model combines social networks, mobile health devices, and knowledge health database (Figure 2). It is important to examine each business process as a layer of value to the patients. Patients place a value on these services according to the quality of outcome, service, and price. The value of each layer depends on how well they are performing. If the processes do not correspond to the strategy, the value will be significantly diminished. For example, the value of mHealth is reduced by any delayed responses to patients' queries or healthcare staffs' poor communication skills.

Figure 2 depicts the model of pervasive mHealth with features of social networks, pervasive knowledge management, and mobile health devices. Mobile health devices support personalized healthcare anywhere and anytime in delivering healthcare service to users. Social network has enabled patients to dynamically enrich their personalized information. Conventional systems have relied solely on static information provided by the service provider. However, they are now empowered with the ability to conduct conversations with other patients to share and exchange experiences through discussions in social networks.

Pervasive mHealth offers patients a greater role in active healthcare processes by empowering them with the ability to control and generate flow of information that fits with their personalized needs. Pervasive knowledge in mHealth is proposed to enhance all actors in the system (patients, healthcare staffs, automate smart mobile devices, etc.) to generate content with relevant knowledge from various channels. The concept of pervasive knowledge in the model is to enable multi-channel knowledge that is available in the Internet. Knowledge health database can link information across different online sources to form a more comprehensive knowledge to support synchronous lecture, asynchronous study, online consultation, knowledge sharing in social networks.

Figure 2. Proposed model of pervasive mHealth



In addition, the model accommodates the three dimensions of mHealth: *mPersonal*, *mSocial*, and *mMedical*. *mPersonal* refers to patient-self interaction. *mPersonal* derives functions of personal health activities that cover all personal health related activities in mHealth services as an individual (patient) which can directly or indirectly affect their health conditions. Activities in this category may include personal Identity (ID), personal Habits of patient (HB), Exercise activities (EX), Spiritual and Emotional activities (SE), personal Health Plan (HP), personal Account information (AC), and so on. For instance, ID consists of personal information in the mHealth system such as name, address, phone no, email address, login ID, and password, where the information solely belongs to personal and a patient (patient-self) is in control of the data. HB stands for daily habits of the individual which may consist of eating, sleeping, and any other habits that can affect personal health. The EX is routine exercise activities of the individual that may be beneficial when they are recorded in the system. *mPersonal* will replace the conventional approach; instead of the health staffs entering personal information into the system, the customers themselves will do it on their own, empowering them.

Secondly, *mSocial* refers to managing patient to patient interactions through social networks. The social networks refer to the social networks applications such as Facebook, Twitter, LinkedIn, and Instagram, or social networks that are operated, managed and maintained within the healthcare's infrastructure which patients may belong to. This is targeted towards patients/families within the same interest or health

problem/ illness to converse between each other. For example, patients with diabetes will be motivated to share his/her experiences, learning, and knowledge with other diabetic patients. Constructive conversation and information from external or internal social networks should be captured as it is an excellent, innovative strategy to improve services. mSocial enable individuals and the community as social health agents for others in mHealth systems. mSocial accommodates the concept of social network within mHealth services. Some activities in this category include conversations (CS), chatting, updating status, forums, wikis, blog, knowledge management (KM), group knowledge and asking for specific services (RS). Nowadays, people constantly use social networks in their daily lives. Updating status in social networks trigger conversation among circles of friends. Bringing this scenario into mHealth services is both interesting and challenging. For instance, patients with the same condition like diabetes may share their experiences with other patients in social networks. Sharing in social networks may become a virtual supporting group that can enrich and strengthen their motivation to fight for better health. In fact, social networks also affect the relationship between the healthcare provider and customers (patients). Therefore, embedding mSocial in mHealth is imperative.

Finally, mMedical refers to the interactions between healthcare/medical staffs with patients. In fact, mMedical is the core activity of mHealth, because it is where patients raise medical concerns through mobile devices and are responded by dedicated medical staffs managing mHealth services. mMedical proposes that patients can be involved in the medical care processes and medical decision-making in the mHealth scenario. Any medical queries from patients can be facilitated through the module available in mMedical. mMedical's module may consist of examination (XM), mAppointment (MA), mPrescription (MP), and mTreatment (MT). XM is online consultation between patients and medical staffs which can lead to the generation of electronic medical record (EMRs) for the patients. It is a common service in many e-health initiatives; however, when there is empowerment or participation from patients in these processes of medical activities, the result of consultation can be accessed by patients directly, anytime and anywhere. For instance, many healthcare providers prevent patients from accessing their EMR. In fact, those patients are not in the position to track their medical history themselves; whenever the patient needs consultation, the diagnosis will start from the beginning. mMedical should enable patients to have access over their medical records regarding their health status, condition, and history anywhere-anytime. The MP is another subset of EMR, another area in which customers need to be empowered. Empowerment in MP will speed up the process of managing prescription, and customers will know how to consume their medication appropriately, as they are able to access and learn anytime-anywhere. In summary, participation and empowerment in mMedical can shift the role of a patient from a recipient of care, to a partner of care. Access to knowledge and contents (EMR) will make patients more knowledgeable on their health conditions and issues.

FUTURE RESEARCH DIRECTIONS

The advancement of pervasive mHealth is expected to improve interactions of all actors. Those interactions range from patient-patient, patient-healthcare provider, patient-community, healthcare-community, and smart mobile health-patient. Meanwhile, there are a lot of opportunities for broad arrays of research in developing smart mobile health devices that will integrate all data into a single platform of mHealth. In addition, empowerment in mHealth will continue to grow in three subdomains; *mPersonal*, *mMedical*,

and *mSocial*. *mPersonal* can be the first module to be tested for deployment since the data generated is less complex, involving data on personal health habits. Secondly, *mSocial* encourages patients to share and support other patients with their knowledge and experiences. From an organizational perspective, *mSocial* can be an effective marketing tool to promote services to customers. *mSocial* can also be utilized as a place to capture ideas from customers. Further studies in developing listening tools will help healthcare organizations to better understand their customers' needs. Thirdly, *mMedical* is the core of the mHealth's system because critical data is stored in this module. It is important to decide which data can be shared with patients and which cannot. This issue needs to be carefully studied, including any related legal aspects. Although this study covers a broad-spectrum of issues across multiple domains, the four primary potential target groups for this study are:

1. Customers (patients / patients' family) who need to be informed, empowered, educated, and connected with others to encourage information or knowledge sharing.
2. Healthcare providers that are seeking innovative ways to improve their customer relationship, loyalty, trust, customer satisfaction, market leader, and any state of interactions.
3. Government and policy makers who seek innovative healthcare solutions through mHealth services with less budget for their citizens.
4. The researchers who need to fully understand the concept of healthcare business processes, technology, and the issues of each domain.

CONCLUSION

Pervasive knowledge is generated from various channels and tools. It can come from smart mobile health devices, social networks, Internet of Things (IoT), and knowledge health database. Integrating all the resources will provide personalized service in pervasive mHealth scenario. Pervasive mHealth extends multi channels sources and interactions from all actors. Those actors are patients, healthcare providers, social networks, mobile health devices, and knowledge health database. Pervasive mHealth covers three domains of patients' empowerment to ensure interactivity and participation in the healthcare processes. Finally, accommodating the advantages of each model above will give the opportunity to improve the mHealth services that are expected to meet users' demand which is the concern of this study.

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KEY TERMS AND DEFINITIONS

Electronic Health (E-Health): According to WHO (2005) is a cost effective and secure use of ICT in support of health and health related fields, including healthcare service, health surveillance, health literature and health education, knowledge and research.

Health Information System (HIS): Refers to any system that captures, stores, manages or transmits information related to the health of individuals or the activities of organizations that work within the health sector. This definition incorporates things such as district level routine information systems, disease surveillance systems, and includes laboratory information systems, hospital patient administration systems (PAS) and human resource management information systems (HRMIS).

Healthcare: Refers to the diagnosis, treatment, and prevention of disease, illness, injury, and other physical and mental impairments in humans. Practitioners in medicine, optometry, dentistry, nursing, pharmacy, allied health, and other care providers deliver health care. It refers to the work done in providing primary care, secondary care, and tertiary care, as well as in public health.

Healthcare Business Process: Refers to a set of activities which activity adds value to the customer. These are registration, patient care, discharge, marketing, and service.

Mobile Health (mHealth): mHealth is an extension of electronic health (e-health) in which health-care services can be accessed through smart mobile devices. The scope of mHealth is mobile personal (mPersonal), mobile social (mSocial), and mobile medical (mMedical).

Patient Empowerment: In healthcare is a principle to give patients more power in making decisions related to their health and to give them required authority to access or produce information related to their health.

Pervasive Computing: Refers to an embedding microprocessor in device (mobile) to connect and communicate in the networks.

Pervasive Knowledge: Refers to a massive knowledge generated from multi sources of information such as social network, smart mobile devices, and structure knowledge management database.

Smartphone: Refers to a mobile phone built on a mobile operating system, with more advanced computing capabilities and connectivity than feature phones.

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Chapter 35

Radio Frequency Identification Technologies and Issues in Healthcare

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ABSTRACT

One of the most compelling cases for RFID-embedded technologies in the healthcare field has been made by documenting increased efficiency in supply chain performance measurements, which generally consist of financial and non-financial indicators. The chapter suggests that patient flows and safety are key measures of hospital operation efficiency. Process bottlenecks in hospitals can delay discharge times and lead to higher costs and lower quality of service, which in turn affects the overall performance and business of the hospital. Hospitals have struggled to control costs, and RFID-embedded technologies should allow management to prioritize their technology spending and reduce total cost of suppliers and operational expenses.

INTRODUCTION

Barcoding and RFID-Related Technologies in the Services Sector

Barcodes and related identification technologies have been used to control inventory and supply chain management (SCM) for some time, especially in retail and purchasing applications (Aldaihani & Darwish, 2013; Azadeh, Gholizadeh, & Jeihoonian, 2013; Bhamu, Khandelwal, & Sangwan, 2013). Barcoding equipment is fairly inexpensive and easy to use as compared to other AIDC technologies (Smith, 2011; Smith, Smith, & Baker, 2011; Smith & Rupp, 2013; Visich, Li, Khumawala, & Reyes, (2009; Wilson, 1995; Wyld, (2006). However, certain limitations create the need for a new approach to increase efficiency (Drejer & Riis, 2000; Dutta, Lee, & Whang, 2007; Fisher & Monahan, 2008; Fumi, Scarabotti, &

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Schiraldi, 2013). Barcodes are only accurate if items are continuously scanned in and out as they move along the supply system. An employee must ensure an item is scanned at each stage, or entry and exit point. An example of this would be a delivery driver that scans packages as a truck is loaded and scans the package at the delivery point. If the package is not scanned, the action is not accurately recorded. Barcodes require an employee to physically inspect the item for scanning purposes to ensure inventory accuracy and determine the product's location, while Radio Frequency Identification (RFID) conveniently tracks products through radio waves, designed to improve operational efficiency.

RFID technologies helped Walmart to control its inventory and track product movements along its supply chain (Tarofdor, Marthandan, Mohan & Tarofdor, 2013). Furthermore, RFID has been used in the identification of stray pets, which is known as chipping and in transportation, in addition to sports. Experimentation with RFID in soccer may soon allow a visually impaired player to participate in the game by integration of computers and video cameras, along with an active RFID tag to signal to the player through a set of audio headphones (Zare, McMullen & McCune, 2014).

DISCUSSION

RFID in the Healthcare Industry

Anand and Wambaa (2013) performed a case study to evaluate how RFID can be applied in healthcare settings. The authors suggested that there are significant benefits for both patients and healthcare organizations in the application of such technology. Adoption in the healthcare industry is not widely spread because of the initial high cost associated with equipment and technology implementation. One argument against the investment emphasizes that the technology primarily focuses on tracking and implies that the costs outweigh the benefits (i.e., compared to the cheaper alternative of barcodes). However, Anand et al. compared the evidence collected from 39 hospitals and analyzed the costs and benefits of RFID implementation over the long run. Their findings indicated that RFID-embedded systems can save time and reduce waste.

Hence, RFID-related technologies can help reduce costs associated with the medical supply chain (e.g., pharmaceuticals and medical supplies) or in patient tracking and management. For example, high-valued supplies, such as blood can be equipped with RFID tags that can ensure that the right type of blood is being administered to the right patient (Winters, 2010). When associated with patient tracking, RFID can be used to track patient history as well as hospital admittance, transfer, and discharge. Advantages also include reducing redundant work and time consuming processes by making certain that the correct blood is drawn from storage. This allows healthcare providers to concentrate on patient care and service (Dominic, Goh, Wong, & Chen, 2010; Tarofdor, et al., 2013). RFID-related technologies can also reduce errors and waste by assuring that the accurate drug or medical product, ordered from the appropriate supplier is used at the proper time for the correct patient in the suitable dose.

RFID is an acceptable way to automate and improve the tracking of medical products and pharmaceuticals. Patients gain from RFID-related technology because of the reduction in errors when healthcare providers are prescribing or fitting medical products to them. As suggested by a number of researchers (Smith, 2012, 2013a, 2013b, 2013c; Ting, Kwok, Tsang, & Lee, 2009; van der Togt, Jan van Lieshout, Hensbroek, Beinat, Binnekade, & Bakker, 2008; Wickboldt & Piramuthu; Zang, & Fan, 2007), the experimentation of RFID in a variety of fields [i.e., sports, SCM, operations management,

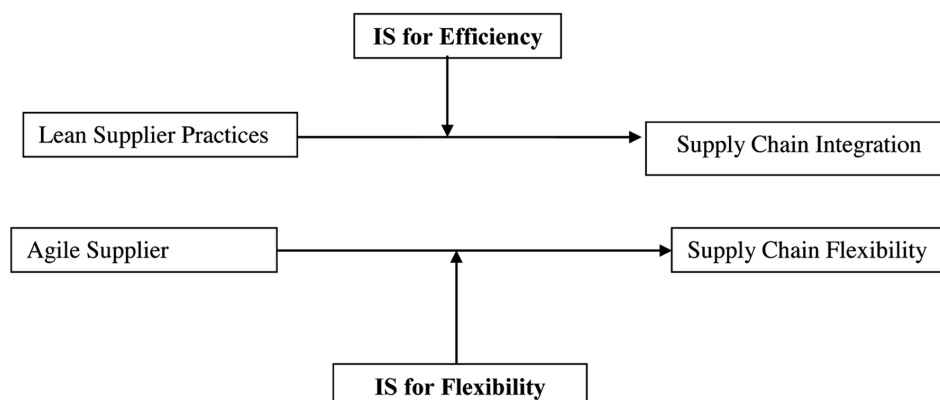
lean manufacturing] may lead to new discoveries and other applications (Hu, Wang, Fetch, & Bidanda, 2008; Ifinedo & Nahar, 2009; Jain, Benyoucef, & Deshmukh, 2008; Johansson & Sudzina, 2008; Jones, Riley, Franca, & Reigle, 2007; Ketikidis, Hayes, Lazuras, Gunasekaran, & Koh, 2013; Koong & Lin, (2007). The application of RFID technology on the soccer field, for example, may also be applied to patients in the emergency room setting or soldiers on the battlefield; the range of active RFID tag can easily reach 300ft. and can detect direction and motion (Zare, et al., 2014). Emergency room specialists can analyze the information from RFID to track patient movements.

Implications for Medical Supply Chain Management

RFID utilizes radio waves to communicate, track, and trace products along the supply chain with the goal of helping to boost efficiency through enhanced data communication, counterfeit reduction, and drug quality insurance. There are many studies that point to the obvious operational efficiencies and reduction in waste and errors associated with the implementation of RFID-embedded systems (Aldaihani & Darwish, 2013; Azadeh, et al., 2013; Bhamu, Khandelwal, & Sangwan, 2013; Chen, Wu, Su, & Yang, 2008). For example, one main cost for any firm is a lack of knowledge of supply chain integration and how to manage a company's inventory, especially in promoting vendor-managed inventory system and the use of virtual asset trackers (VAT). A company does not want to order as many products as they can and expect it to empty its shelves instantly. By using certain IS applications [automatic identification and capture systems (AIDC) like barcodes, smart cards, touch memory, RFID] aligned with supplier practices, a company can have an improved supply chain performance well into the future ("Healthcare IT outsourcing ...," 2016).

Qrunfleh, Tarafdar, & Ragu-Nathan (2012) provided an empirical based study of how the alignment between supplier management practices and information systems strategy provides a positive association with supply chain integration goals. From their research, as illustrated in Figure 1, IS for efficiency refers to a strategy that is oriented toward operational support of intra- and inter-organizational efficiencies and that the ultimate goal of supplier management practices is to achieve better performance in the supply chain. Ultimately, healthcare organizations have asked their decision makers in strategic positions

Figure 1. Using Information systems of increased supply chain efficiencies and flexibilities (partially adapted from Qrunfleh, et al., 2012)



to evaluate hospitals' need to find ways to support IT and operational functions to deliver high-quality patient care and increase the proficiency of its operations and finances (Devaraj, Ow, & Kohli, 2013). Bottlenecks such as overages in time for surgery, emergency room inflow, and scheduling errors need to be reduced in order to achieve an even and swift process flow.

The above exhibit illustrates some of the interrelationships and interdependencies of supplier practices and different IS strategies that directly affect the supply chain performance of a company. Lean supplier practices consist of activities aimed at creating the most cost efficiency in the supply chain by reducing the inventory and focusing on improving the quality in the supply chain by eliminating waste.

Compared to the alternative of using barcodes, RFID has multiple advantages, which include enhanced traceability and transparency that result in increased operational efficiency (Wambaa, et al., 2013). Moreover, the exchange of data, access to real-time information, and "external and internal coordination of material flows" (Chircu, et al., 2014, p. 738) are key factors to improved efficiency within the supply chain. The collaboration of the manufacturer, wholesaler, pharmacies, and hospitals adds value to the supply chain by reducing errors, and as a result, costs are also lowered. One of the many problems facing the pharmaceutical industry is the persistence of generic and counterfeit drugs as companies try to successfully deal with competition that strategically leverages lower prices. Proper use of RFID technology in supply chain integration issues may offer an alternative to solve these pricing issues. Although using barcodes is cheaper and easier to affix to products, they are not tamper-proof, and it is not possible to read them in bulk, which are two advantages of RFID labels. Ultimately, any transition to new technologies will incur costs. Combining RFID with electronic documents (i.e., e-pedigree) that summarize data about a drug is useful to all supply chain participants. Essentially, it is vital for any organization within any industry to operate as efficient as possible and to search for new ways on how to add value to its processes. RFID can be the solution.

In healthcare settings, RFID can be utilized to manage medication and materials for complex procedures that previously were time consuming and subject to human mismatching errors. One adoption decision was made by Integra's to overcome waste. The use of RFID saved US\$111,500 in lost and missing products and US\$223,000 in expired products (Anand & Wambaa, 2013). Healthcare professionals, for example, may use RFID readers to access information about medications that can be displayed conveniently on a computer screen.

IMPLICATIONS IN THE HOSPITAL SETTING

Multiple Implications for RFID Technologies in Healthcare

There are multiple implications for RFID technologies in healthcare outside of SCM and supplier integration and performance (Lee & Shim, 2007). In hospitals' workflows in the areas of scheduling, admitting, discharging, and operating can be improved with the implementation RFID. RFID tags planted in patient bracelets can accommodate information about the patient, such as his or her location, medical history, allergies, age, weight, blood results, diagnosis, living will, and religious preferences. Those bracelets can be utilized in different ways to increase patient safety, operate leaner, and offer improved service (Revere, et al., 2010). For example, RFID bracelets can reduce errors in the billing process. Portable scanners can be used by hospital personnel to scan the patient's bracelet and enter medications administered and

services provided. Updated and stored in a database, this information is later used by the billing department to bill the patient. This accuracy leads to faster payments and improved customer satisfaction.

According to one recent study (Southard, Chandra & Kumar, 2012), medical errors lead to a significant amount of deaths. The number ranges between 44,000 and 98,000 per year. Medical errors result in a cost of about US\$2 billion annually. Information on RFID tags in patient bracelets can be used to reduce errors in the administering of drugs by comparing patient information on the bracelets with information on the medication. This reduces errors involving administering the wrong medication or the wrong dosage. Whenever medication is dispensed, the technology can be utilized to manage inventory levels electronically. Another implication to increase patient safety involves the tracking of operating supplies and materials to avoid surgical tools being “left inside a patient” (Revere, et al., 2010, p.30).

The tracking of patients also results in the reduction of waiting time and an increased efficiency of capacity usage by optimizing bed turnover. As soon as a patient is being discharged from the hospital, an automatic alert can be send out to housekeeping to prepare the room for a new patient (Revere, et al., 2010). Another improvement concerning time efficiency can be achieved by automatically syncing the computer displays of examination rooms with current patient information as soon as the patient walks through the door. These advances should help reduce miscommunication between physicians and nurses. As the results of the case study concluded, there existed quantitative evidence of the benefits of implementing RFID in healthcare processes by examining surgical processes (Southard, et al., 2012). In one example, it was estimated that nurses typically were spending an average of 15 to 20 mins. per shift trying to locate the proper equipment. Moreover, hospitals waste about US\$50,000 monthly on rental charges because of misplaced or lost equipment. Resulting in about US\$20,000 annually wasted on human resource costs to search for the lost equipment. Other than increased costs, further negative implications include medical equipment missing routine maintenance. In these situations, implementation of RFID can improve the coordination of hospital processes and enhance visibility.

One hospital spent only US\$35,000 on software and US\$50 per active RFID tag. Moreover, it used existing Wi-Fi infrastructure and did not acquire any readers (Southard, et al., 2012). The benefits, transparency and prevention of errors of RFID, outweigh the costs. Again, RFID has two main advantages over barcodes. RFID tags do not have to be physically close to the reader to be read and multiple “pieces of information” can be stored on the tag. This is useful in the supply chain of pharmaceuticals when tracking and controlling information about temperature, movement, and tampering is important (DesRoches, et al., 2008; Ludwick & Doucette, 2009).

Usage, Application, and Adoption Issues

The usage and application of RFID tags are spreading rapidly and are increasingly spreading into the healthcare industry (DesRoches, et al., 2008; Smith, 2012). Perhaps, the first step in successful implementation of RFID is to perform an initial analysis and needs assessment of how supplier management practices and IS integration strategy tied together to help a company with their supply chain performance practices. The adoption of the RFID-related technology in the healthcare industry has historically lagged behind as compared to other industries in the manufacturing and retail industries, perhaps due in part to certain ethical dilemmas. Many leaders and decision makers of the healthcare industry have begun to realize the role that this technology can positively benefit the industry by maintaining focus on quality care, while doing so by meeting the pressures from competition and achieving business and performance

goals (Smith, 2010). The introduction of information technology (IT) into the healthcare industry led to more efficient tasks and processes, a higher quality of healthcare services, and increased accessibility to healthcare providers (Jones, Bekeris, Nakhleh, Walsh, & Valenstein, 2009; Kjøs, Botten, & Romøren, 2008; Palmon & Sudit, 2009; Santouridis, Trivellas, & Reklitis, 2009; Sauerland, 2009; Scanlon, Swaminathan, Lee, & Chernew, 2008; Smith, Casey, Hurst, Fenton, & Scholefield, 2009).

The organizational level of the IT adoption research focuses on the understanding of the diffusion and adoption process. There have been numerous studies that have tried to include as many distinctive characteristics of context as possible in the development phase of organizational IT adoption theories (Dominic, Goh, Wong, & Chen, 2010; Kapur, Gupta, Jha, & Goyal, 2010; Keramati & Behmanesh, 2010; Kim & Tadisina, 2010). Also, researchers have tried to identify the impacts of key categories (i.e., individual, technical, structural, environmental factors, task-related factors) in the adoption process. A number of the previously cited studies that have been done have found that the characteristics of organizations are very significant of the IT adoption process. Another force driving the decision to adopt the RFID process is the environmental factor, “environmental uncertainty, competitive pressure, industrial pressure, and government policy all serve as pressures on organizations (Lee & Shim, 2007, p.714).” Another concept used when deciding whether to adopt the RFID process is the concept of technology-push/ need-pull (TP/NP); “the technology-push model is based on the view that a new scientific discovery will trigger events ending with diffusion or application of the discovery” (Lee & Shim, 2007, p. 714).

The likelihood of total adoption RFID-related technologies within healthcare organizations is unclear but, it is looking up. Research has showed that RFID is still in the early stages of adopting in the healthcare industry. In a survey done out of 126 organizations (Kumar, Swanson, & Tran, 2009), only 4 are currently using the RFID systems and almost half of those are still planning to evaluate their situation. Also, the results of the survey showed that the adoption rate of the RFID technology is expected to increase since 22 out of 23 that have evaluated RFID processes would adopt it. Applications of RFID-related technologies are inherently very valuable, but some managers feel it is at a great cost to integrate it into a business, at least during their tenure as manager. Healthcare organizations may reap important benefits from RFID application, since it automates the tracking of medical equipment, patients, medical supplies, nurses, and drug usage. These benefits should result in the increase of RFID technology to more than US\$2.1 billion in 2016 (“Healthcare IT outsourcing market ...,” 2014).

Challenges in RFID Application in Healthcare

Even though there are many benefits that should encourage the implementation of RFID technologies in healthcare organizations, the total cost consists of multiple factors that management has to consider before introducing the new system. Adoption and implementation, in addition to maintenance and the training of employees, incur costs. According to a recent case study, the cost of each aspect varies among supply chain partners (Chircu, et al. 2014). RFID-related applications in healthcare involve several benefits; however, there are several challenges that are faced with such a complicated system. Perhaps the most influential challenge are the various costs put into the system, in fact, the high costs of implementing the system into healthcare is what kept the system away from healthcare for so long and kept within commercial applications (Mehrerdi, 2010, 2012; Smith, 2010).

The concern in the long-term investment is the chance of failure after the expenses have been incurred. It is more likely in RFID for healthcare, but the payoff in RFID is never guaranteed, which is a major

concern in adoption in other fields (Erdem, Zeng, Zhou, Shi, & Wells, 2009; Wickboldt, et al., 2012). Mehrjerdi (2011) stated that products that are US \$15 or less may not be worth the costs or return on investment because of the unpromising performance a product would deliver at that low of a price. Infrastructure can also be complex which delays a process that requires patience that some may not think is worth it, since technology is constantly changing and systems are continuously being altered as more information is compiled.

Patient privacy and security is a major challenge in applying RFID to healthcare. Consumer protection programs such as CASPIAN are being implemented because of the possible invasion of privacy to patients (Kapoor, et al., 2009). Patient information is embedded deep within systems; therefore, patients may be left with a sense of insecurity of their personal information and skeptical of buying into the system. Not only is patient information vulnerable, but also the data concerned with the organization must ensure safety (Wickboldt, et al., 2012). On-the-other-hand, there is a challenge faced with those in control of the RFID trust the system more than the patient, even when that should not be the case. A trusting relationship whether it be between a person and systems, such as patients and physicians trust in RFID renders themselves “vulnerable” (Entwistle & Quick, 2006). Once a healthcare provider has earned the trust from a patient, it is vital that the provider should work even harder to provide the patient with the safety he/he deserves (Entwistle, McCaughan, Watt, Birks, Hall, 2010). Those serving patients with RFID assistance must buy-in to the system; however, the trust must be rational and suitable. Certain situation information is most accurate when it comes from the patient, and if trust is placed in the wrong place, a situation where a patient can contribute the most effectively to their own safety, may be overlooked.

Such as an RFID “VeriMed” system can be thought to attain the “most accurate information” about a patient; however, if the system interpreted information incorrectly such as medications and allergies and the provider trusts the system more than the patient, they may not give it a second look (Monahan, et al. 2011, p.373). Even though a healthcare provider can be well educated and pertain all qualifications for their position there can be differences in the knowledge of the person and the system. Varied abbreviations could be used in a particular organization, and if a provider does not realize that a new system uses a different abbreviation for a medication, it could lead to an overdose or delivery of an incorrect medication (Entwistle, et al., 2006). Therefore, if a doctor trusts the technology to an extent that information within the system is never questioned, then there is the potential for serious medical errors (Fisher & Monahan, 2010).

CONCLUSION

Hopefully, after reading through this chapter, the reader will receive a better understanding of the role that an IS-based strategy, utilizing RFID, and various healthcare supplier management practices do play a significant role on the supply chain performance for a company. Healthcare organizations need to partner and integrate such technologies and medical suppliers in order to strategically leverage each other's strengths to improving the supply chain and better healthcare delivery and related outcomes. A supply chain manager may be very knowledgeable about operational and technological practices to help a company save money by inventory control and production planning, but with the help of RFID-embedded technologies, it has the potential to make the healthcare system operationally run more efficient and effective.

FUTURE DIRECTIONS

Overall the outlook for RFID acceptance is very positive when contemplating the use in supply chain management of medical supplies and pharmaceuticals. Pertinent patient information could prove to be the biggest obstacle to overcome in taking steps of implementation. Managers, healthcare providers, and IT professionals must keep patient concerns in mind when making decisions, conducting training, and processing information. Patients must also be open to the use of RFID in order to reduce medical errors. The reduction of these errors can be critical and life-saving. The use of these case studies will continue to provide evidence supporting the use of RFID in healthcare.

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KEY TERMS AND DEFINITIONS

Automatic Identification and Data Capture Technologies (AIDC): Types of AIDC-related technologies to leave the human element out of the data collection and storage functions of information derived from manufacturing, integrated through the manufacturing process, types of authentication concerns and/or e-security strategies, and relationship links to customer profiles.

Barcoding Technology: A long-term and very reliable type of AIDC technology, it is known for its very accurate and economical approaches to identity products and machine readable information from a variety of manufactured goods and services. Most barcodes use a type of standardized bars and spacing coding or symbology that is certified by an international standards body (GS1 System).

Ethical Dilemmas: There are a number of ethical theories that are appropriate for dealing with healthcare issues concerning automatic identification. These theories involve both individual and group behaviors that are grounded in moral philosophy, especially in the concepts of consequentialism or deontology ethical philosophy.

Healthcare Service Strategies: When it comes to the healthcare industry, an overall strategic goal is to provide affordable coverage and quality service to all citizens that need such services at affordable costs.

Operations Efficiency: Improving efficiency and reducing waste is a major challenge for hospitals and other patient care facilities looking to lower the cost of providing healthcare services.

RFID-Embedded Technologies: RFID technologies are types of automatic data capture techniques that use a combination of active and passive senders and receivers to collect and store codified information for further uses.

Supply Chain Management/Performance: In basic terms, supply chain is the system of organizations, people, activities, information and resources involved in moving a product or service from supplier to customer. The configuration and management of supply chain operations is a key way companies obtain and maintain a competitive advantage.

Vendor-Managed Inventory Systems (VMI): VMI-based systems are designed to transfer the control of inventory and its planning activities to a manufacturer or distributor in order to provide a beneficial relationship to promote a more transparent and seamless flow of goods and services at lower costs.

Virtual Asset Trackers (VAT): VAT is a type of application of active RFID tagging that allows healthcare practitioners to enhance security to patients, residents, and hospital staff while providing better patient and resident-care services.

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Chapter 36

Social Telerehabilitation

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ABSTRACT

Social telerehabilitation, which focuses on solving limitations and social issues associated with health conditions, represents a further specialization in telerehabilitation. Both telerehabilitation and social telerehabilitation are grounded in the delivery of rehabilitation services through telecommunication networks, especially by means of the internet. Essentially, telerehabilitation comprises methods of delivering rehabilitation services using ICT to minimize the barriers of distance, time, and cost. One can define social telerehabilitation as being the application of ICT to provide equitable access to social rehabilitation services, at a distance, to individuals who are geographically remote, and to those who are physically and economically disadvantaged.

INTRODUCTION

In a relatively short time, information and communication technologies (ICT) have spread worldwide, from defense and space exploration to large industrial applications, and to the worlds of commerce, education, and entertainment. ICT is changing people's daily lives, the way they work, buy, sell, and learn, and also the way that services are run in the healthcare sector. Consequently, *e-health*, *telehealth*, and *telemedicine* are now terms that are commonly used in this sphere, encompassing three main computer-assisted areas in healthcare, namely: clinical assessment, diagnosis, and therapy. E-health comprises the monitoring of patients' health, the promotion of good practices, and the prevention and treatment of health conditions by electronic means, as well as the provision of online access to literature and medical knowledge. One of the first reviews of telehealth is that provided by Winters (2002), who identified two major subsets of telehealth: telemedicine (i.e., delivery of clinical services) and telehealthcare (i.e., management of disability and health).

Nowadays, there is a progressive specialization within the field of e-health, and the specificity of the different branches appears to be increasingly sharp.

Telerehabilitation is a recent emerging field in telehealthcare area and this chapter presents social telerehabilitation, a new specialized sector of telerehabilitation.

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BACKGROUND

Before to deal with social telerehabilitation, the more general notions of rehabilitation and telerehabilitation ought to be introduced.

In fact, social telerehabilitation, which focuses on solving limitations and social issues associated with health conditions, represents a further specialization in telerehabilitation. Figure 1 shows the position of social telerehabilitation within the general framework of telehealth.

It has to be noted that social telerehabilitation results from a change in the concept of rehabilitation, which has seen a shift in view point away from a predominantly medical one, towards an increasingly complex one in which psychological and socio-cultural aspects are deemed to be of equal importance (Brown & Hughson, 1993; Wade & de Jong, 2000; Altman, Swick, Parrot & Malec, 2010; Karkou, Martinsone, Nazarova & Vaverniece, 2011).

The Notion of Rehabilitation

In general, rehabilitation encompasses any services or providers that are directed to the reduction of impairments, activity limitations, or social participation restrictions experienced by an individual (Figure 2). The World Health Organization describes rehabilitation for people with disabilities as being a process aimed at enabling them to reach and maintain their optimal physical, sensory, intellectual, psychological, and social functional levels.¹

Generally, two different forms of rehabilitation can be distinguished: *medical* and *social*, or, in the latter case, also referred to as *vocational*.

Both forms are aimed at developing the functional and psychological abilities of the individual and, if necessary, his/her compensatory mechanisms, in order to enable him/her to attain self-dependence and lead an active life. The main difference between them is that medical rehabilitation is more restricted to curative medicine, and involves intensively trained clinicians and different health professionals, especially physiotherapists, whilst social rehabilitation focuses more on the individuals' social sphere, and includes services such as rehabilitative nursing, occupational therapy, speech and language therapy, audiology, dietetics, prosthetics and orthotics, podiatry, art therapy, music therapy, and social work. However, although social rehabilitation is directed, for example, at overcoming barriers for people to

Figure 1. Social telerehabilitation within the telehealth general framework

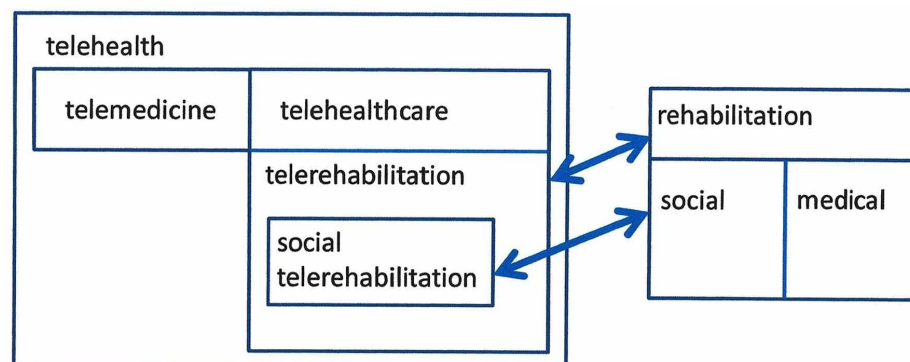
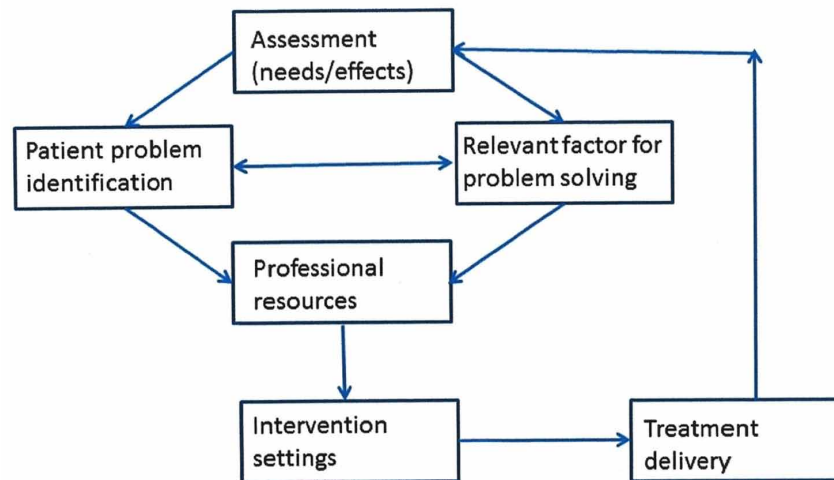


Figure 2. The rehabilitation process



access, maintain, or return to employment or other useful occupations (ILO, 2008; Kuoppala & Lamminpää, 2008), it substantially differs from strategies and policies aimed at promoting and developing the inclusion of people with disabilities in the work place. Offender rehabilitation (Robinson & Crow, 2009) and addict rehabilitation (Wilson *et al.*, 2012), for example, are considered to be forms of social rehabilitation that focus on the development of practices and programs for helping individuals to retake their place in society.

Many social scientists and policy makers share the opinion that community-based rehabilitation practices are a part of general medical care (Haig, 2013). As a consequence of this, it is not always possible to trace a line of demarcation between clinical and social rehabilitation, and sometimes there is an overlapping relation between these two forms of rehabilitation. A case in point is the *Report on Disability* (WRD) of June 9th 2011, published by the World Health Organization (WHO) and World Bank (WB), which outlined concrete actions that befit both medical and social rehabilitation.

Such concrete actions intended to help overcome barriers to the provision of rehabilitation services (WHO & WB, 2011) include:

- Increasing human resources for rehabilitation (training, retaining, and retention of rehabilitation personnel);
- Expanding and decentralizing service delivery;
- Increasing the use and affordability of technology and assistive devices.

It has been observed that the WRD report presents a challenge to medical rehabilitation (Bethge, von Groote, Giustini & Gutenbrunner, 2014) and, although it doesn't provide a fixed definition of rehabilitation, its description of the concept represents a valuable frame of reference that can help to foster a common understanding of the rehabilitation scope and rehabilitation services (Meyer, Gutenbrunner, Bickenbach, Cieza, Melvin & Stucki, 2011). In fact, many authors cite in their works the WRD definition of rehabilitation, that being: "a set of measures that assist individuals who experience, or are likely

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to experience, disability to achieve and maintain optimal functioning in interaction with their environments” (Meyer et al., 2014; Lynggaard, May, Beauchamp, Nielsen & Wittrup, 2014; Gibson, 2016).

It is important to note that the WRD definition recalls that of Article 26, entitled *Habilitation and Rehabilitation*, of the United Nations Convention on the Rights of Persons with Disabilities (CRPD, 2006):

[...] appropriate measures, including through peer support, to enable persons with disabilities to attain and maintain their maximum independence, full physical, mental, social and vocational ability, and full inclusion and participation in all aspects of life.²

The above definitions fit well with both medical and social rehabilitation, as well as with telerehabilitation that includes social telerehabilitation.

Telerehabilitation

The term “telerehabilitation” is a relatively new one, although it has been observed that the first experiment with remote medical interventions dates back to the 1880s, following the invention of the telephone (Scalvini, Vitacca, Paletta, Giordano & Balbi, 2004).

Until a few years ago, telerehabilitation applications were considered within the wider field of e-health, and only recently telerehabilitation has been assumed to have an autonomous, separate, and parallel identity under the telehealth umbrella, within telehealthcare (Schmeler, Schein, McCue & Betz, 2009).

Essentially, telerehabilitation comprises methods of delivering rehabilitation services using ICT to minimize the barriers of distance, time, and cost, and, more specifically, has been defined “as the application of telecommunication, remote sensing and operation technologies, and computing technologies to assist with the provision of medical rehabilitation services at a distance” (Cooper *et al.*, 2001).

Social Telerehabilitation Definition and Scope

Both telerehabilitation and social telerehabilitation are grounded in the delivery of rehabilitation services through telecommunication networks, especially by means of the Internet. Likewise, one can define social telerehabilitation as being the application of ICT to provide equitable access to social rehabilitation services, at a distance, to individuals who are geographically remote, and to those who are physically and economically disadvantaged.

The scope of social telerehabilitation is vast, since it faces challenges related to both medical and community care settings (Hill, 2010). Social telerehabilitation aims at helping people regain their psycho-physical functions and improving their daily quality of life through the use of ICT and mobile technologies (Reeder, Chung & Stevens-Lapsley, 2016; Kamwesiga, Tham & Guidetti, 2016). In this regard, research has underlined the potential and effectiveness for social media, mobile phones, and the Internet in general, to improve social rehabilitation processes.

Expanding and Decentralizing Rehabilitation Services

Telerehabilitation and social telerehabilitation share the same goal: to expand and decentralize rehabilitation service delivery.

In fact, both medical and social rehabilitation services are generally located in urban centers and health care structures, and this hinders their access by people with disabilities or those living in rural areas. In many cases, the burden of transportation, as well as the mobility assistance for persons with temporary or chronic diseases, represents a serious barrier that limits the advantages of rehabilitation services. Parking, distance, or transportation difficulties can significantly interfere with the receiving of treatments. In fact, the more frequent the treatments are, the more the mobility burden increases.

Furthermore, in the majority of cases, rehabilitation, either medical or social, involves multidisciplinary professional competence and expertise (Neumann et al., 2010; Stanos, 2012; Malladi, 2015). This means that the planning activity and the actual treatments involve teams of professionals (physiotherapists, psychologists, social educators, etc.) who must work together in order to achieve common and complementary goals. Their activity is directed to resolving the patient problems, following an iterative, active, educational, and problem-solving process that focuses on the patient's behavior and adapts to it (Marzano, Lubkina & Rizakova, 2015). The most common goals of the rehabilitation process are:

- Maximizing the participation of the patient in his/her social setting;
- Minimizing the pain and distress experienced by the patient;
- Minimizing the distress of, and the stress on, the patient's family and caregivers.

Accordingly, telerehabilitation is particularly useful when the coordination of rehabilitation service delivery requires the improvement and expansion of the availability of coordinated multidisciplinary rehabilitation in an effective care framework.

Both social and medical telerehabilitation services are generally provided on an outpatient basis, usually at home and under the supervision of at-a-distance professionals. Experts check patient evolution through regular online meetings or by analyzing data from sensors and equipment. Depending on the telerehabilitation programs, there are many kinds of assistive devices whose cost is lowered by mass production, e.g. there are many very affordable teleconference systems, and mobile phones are used for remote data collection, control of equipment, and telemonitoring. Supervisors can help the patient to perform exercises during the day-to-day rehabilitation sessions, suggesting the correct execution.

In the last few years, many researchers and practitioners have argued the importance of social telerehabilitation services for patients, caregivers, and public institutions, for instance in regard to services for children suffering from physical handicaps and emotional disturbances (Nilsson & Nilsson, 2011b), alcoholics (Simpson, T. L., Kivlahan, Bush & McFall, 2005; Rose, Skelly, Badger, Naylor & Helzer, 2012), and for patients with affective disorders, such as depression and manic-depression or bipolar disorder (Sachpazidis & Sakas, 2008; Acampora, Cook, Rashidi & Vasilakos, 2013).

Research has underlined the potential for social media, mobile phones, and the Internet in general, to improve mental and physical health, treat addictions, and also to help individuals experiencing homelessness (Quan, Joseph, Keller & Arch, 2011; McInnes, Fix, Solomon Petrakis, Sawh & Smelson, 2015). Furthermore, Artificial Intelligence is discovering new opportunities to overcome the limitations of the computational approach and, consequently, making possible new advanced healthcare applications, especially in the social-healthcare (Pravettoni, Folgieri & Lucchiari, 2015).

Application of Social Telerehabilitation

It has been underlined that social telerehabilitation tackles some issues that set it apart from the broader telehealthcare arena. For example, it has been observed that one challenge is that social rehabilitation is often provided across both medical and community settings, often with different funding structures and rehabilitation protocols in place (Scaffa & Reitz, 2013; Camicia, Black, Farrell, Waites, Wirt & Lutz, 2014).

From the analysis of the literature, three principal areas of interest emerge in terms of the development of social telerehabilitation services:

1. The psycho-physical area;
2. The social-communication area;
3. The behavioral area (e.g. behavioral addictions).

Applications are available for health education and counseling programs, many of them offered to myocardial infarction patients during and after hospitalization. During hospitalization, the interventions consist of individual counseling sessions and group health education sessions focusing on medication, healthy habits, and anxiety and depression. After discharge from hospital, patients are checked at home by telephone or via the Internet, and are encouraged to perform exercises and physical activity. Social telerehabilitation programs demonstrate their effectiveness in the areas of decreasing unhealthy eating habits, cessation of smoking, and treating anxiety and depression of patients following a stroke (Beatty, Fukuoka & Whooley, 2013; Varnfield et al., 2014).

A Typical Social Telerehabilitation Service for Elderly Who Need Physical Exercises

To better understand how social telerehabilitation processes operate, we can illustrate a typical example of a telerehabilitation service that concerns physical exercises for elderly people.

The first step is the identification of needs and the recognition of related problems: the social rehabilitators' team performs the evaluation of the elderly person conditions in order to verify his/her capability to benefit from the service. Professionals engaged in the rehabilitation program use teleconference and/or phone communication to discuss the case and define the rehabilitation program, and to generate its electronic workflow. Following this, the trainer demonstrates exercises to the patient, and answers his/her queries and clears his/her doubts. This step can be performed either at a distance or face-to-face. The trainer then conducts videoconferencing sessions for the progression of exercises, supervision of program completion, additional demonstrations, and consultations. As may be the case, exercises might include flexibility, strength, endurance, and other types of active motion activities. For videoconferencing, a professional videocamera and Skype software with a broadband internet facility can be used. The patient is regularly engaged in exercises and followed by the same trainer, who will give him/her instructions, e. g. in order to adjust the video camera for each exercise, number of repetitions, etc.

Online delivery of social rehabilitation services encourages the rethinking, reorganization, optimization, and extension of the current social rehabilitation services that fall under face-to-face treatments and protocols. Of course, this can require the retraining of rehabilitators

In general, a social telerehabilitation system should provide patients and caregivers suitable mechanisms to interact with each other as if they were meeting face-to-face. Furthermore, patients should have at their disposal all the information about the schedule of the rehabilitation plan, a full description of the rehabilitation activities, and real-time feedback about their performance. For rehabilitators, the system should gather information about the fulfillment of the program, and the correctness of the patients' performance. This will allow a quick and ubiquitous assessment of the patients' evolution, and an adjustment of their rehabilitation program if necessary.

A social telerehabilitation system includes:

- Computers and other general-purpose devices (i.e. tablets, laptops, videocameras, and so on), for both patients and rehabilitators, which are used to run the applications.
- Different types of sensors used to monitor the patient's performance; the simplest of them being low-cost wearable motion capture devices (e.g. accelerometers that gather values of linear acceleration along three perpendicular axes (x , y , z)).
- Specific software application, e.g. for social-cognitive exercises, speech therapy, etc.

FUTURE RESEARCH DIRECTIONS

The idea of exploiting ICT in psychosocial care is not a novelty. Eliza, the computer program created by Weizenbaum between 1964 and 1966 (Weizenbaum, 1966), can be considered to have been a primitive attempt at social telerehabilitation. It was a tongue-in-cheek application, which emulated the responses of a Rogerian non-directional psychotherapist during an initial psychiatric interview. Since then, much progress has been made to the point that social telerehabilitation now represents a topical field of research.

Almost 50 years have passed between the creation of the Eliza program and the appearance of the recent programs designed for rehabilitation services. The difference between the two is that Eliza was one of the first experimental programs in the field of natural language processing, whilst the new electronic applications are able to utilize the achievements made in natural language processing for communicating with patients. The focus is now on programming machines for empathy emulation and ethical therapeutic activities. One of the next future challenges is to provide robotic caregivers for social rehabilitation purposes.

In fact, thanks to the investigations that have started in the last fifteen years on different forms and roles of affection in virtual agents and robots (Scheutz, 2011), some researchers are now considering the employment of robots in social rehabilitation services (Tickle-Degnen, Scheutz & Arkin, 2014). The new robots could provide moral functionalities that enable them to establish therapeutic human relationships, for example in the context of occupational therapy and Parkinson's or Alzheimer's disease (Salichs, Encinar, Salichs, Castro-González & Malfaz, 2015). At the simplest level, a robot could ensure basic functional elements of interpersonal communication. On a more sophisticated level, they could act as *observers* that accurately detect and prioritize people, objectives, and context attributes relevant to reasoned and ethical therapeutic interaction (Arkin, Scheutz & Tickle-Degnen, 2014).

Furthermore, the applications of wearable technology to monitor older adults and subjects with chronic conditions at home and in community settings are multiplying, while the integration of wearable and ambient sensors is expected to make relevant progress (Patel, Park, Bonato, Chan & Rodgers, 2012).

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Finally, behavior-based caregiver robots represent a social telerehabilitation new advanced research area that presumes interaction among a machine and a human patient. The keystone concepts behind the artificial behavior-based caregivers are showed in Figure 3.

However, at next future, we are left with some as yet unresolved questions concerning social telerehabilitation:

1. To what measure can social telerehabilitation replace traditional face-to-face social rehabilitation therapies?
2. Which are the priority sectors for intervention?
3. Is social telerehabilitation in these sectors really economical?
4. What is the educational effort and cost that would be required to diffuse knowledge about social telerehabilitation practices?

A broad, coordinated, research effort will be needed to provide answers to the above questions.

CONCLUSION

The use of computers to deliver traditional social rehabilitation services cannot be a sufficient condition for transforming them into effective social telerehabilitation services: to make these services really effective, it is often necessary to both rethink them in the light of the opportunities offered by the new technologies and, at the same time, to carefully analyze the impact that they have on the persons involved in the process. In many cases it is worthwhile to verify the impact on the organization which delivers social telerehabilitation services, e.g. considering the requalification of personnel, the reliability of the computing services, the costs, and so on.

Internet-based applications can be realized not only for follow-up communications between caregiver-doctor-patient after a therapy, which is the most common use of ICT in the rehabilitation process, but also for improving the quality of the traditional rehabilitation therapies, or for realizing services that are entirely new.

Figure 3. Future caregiver robot

Future caregiver robot	
Key characteristics	
• Embodiment • Representation independent • Situadness (social behavior) • Emergent complexity (collective action of different agents) • Real time responses	

The aim of developing new types of services is shared by social innovation. Another common point between social innovation and social telerehabilitation is that both entail cutting across organizational, sectoral, or disciplinary boundaries of expertise. Furthermore, social innovation looks towards technology as a means to create new social relationships between previously separate individuals and groups.

Social innovation and social economy are closely related: both pursue the same goal of creating solutions that can generate a positive impact, not only on the economic but also on the social development of people and their communities. The basis of social economy is the creation of services that focus on specific target groups who need to be sustained and assisted (e.g. services that complement core hospital staff, employment counseling, vocational training, education/rehabilitation for addict/misfit people, and so on), or that satisfy a general public need (e.g. nurseries, care services for the elderly, shelters for the homeless, integration for the disabled, and so on).

Social telerehabilitation can primarily be useful in the above-mentioned sectors, especially in the scope of social rehabilitation applications related to the labor sector. In this case, social telerehabilitation needs to be underpinned by an integrated approach and by a strong collaboration among different subjects, namely: rehabilitation structures, employers, and workers. Education institutions play a crucial role in the implementation of social telerehabilitation services since the different subjects involved in them need to be educated. More generally, though, telerehabilitation and social innovation necessitate training and retraining activities for both the providers and users of services.³

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KEY TERMS AND DEFINITIONS

Artificial Intelligence: Is a branch of computer science that aims to improve machine behaviour in tackling complex tasks that are specific of human beings.

Behavior-Based Robots: Are implemented following an approach that focuses on exhibiting in a robot complex-interactive behaviors in given environment.

Caregiver: Is someone who (paid or unpaid) takes care of another person who is either sick or disabled; a caregiver is most commonly used to address impairments related to old age, disability, a disease, or a mental disorder.

Occupational Therapy: Helps to solve the problems that interfere with an individual ability to do the things that are important to them; it can also prevent a problem or minimize its effects.

Problem Solving Process: Consists of using methods, in a methodical and organized manner, for finding solutions to problems.

Social Educator: Is an independent and recognized professional figure linked to the area of social professions; he supports and guides a person with developmental disabilities in making his or her own choices and implementing their decisions.

Wearable Technology: Consists in incorporating in clothing computer and advanced electronic technologies.

World Bank (WB): Is an international financial institution that provides loans to developing countries for capital programs.

World Health Organization (WHO): Is a specialized agency of the United Nations that is concerned with international public health.

ENDNOTES

¹ <http://www.who.int/topics/rehabilitation/en/>; last accessed 7.06.2016.

² <http://www.un.org/disabilities/documents/convention/convoptprot-e.pdf>; last accessed 06.06.2016.

³ See the Latvian National Research Program. "Innovative solutions in social rehabilitation in Latvian schools in the context of inclusive education" ("Inovatīvi risinājumi sociālajā telerehabilitācijā Lat-

Social Telerehabilitation

vijas skolās iekļaujošās izglītības kontekstā – VPP INOSOTEREHI”). VPP INOSOTEREHI is a three-year multidisciplinary project (2015-2017) in the field of social telerehabilitation focused on social inclusion; it is being conducted by four Latvian Universities (Rezekne Technology Academy, Latvia University, Riga Technical University, and Liepaja University), and investigates the use of mobile technology in the scope of social rehabilitation (<http://telerehabilitation.lv/>).

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Chapter 37

A Validation Study of Rehabilitation Exercise Monitoring Using Kinect

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ABSTRACT

In this chapter, the authors present their work on a validation study of using Microsoft Kinect to monitor rehabilitation exercises. Differing from other validation efforts, the authors focus on a system-level assessment instead of the joint-level comparison with reference motion capture systems. They assess the feasibility of using Kinect by examining the enforceability of a set of correctness rules defined for each exercise, which are invariances of each exercise and hence independent from the coordinate system used. This method is more advantageous in that (1) it does not require coordinate system transformation between those of the reference motion capture system and of the Kinect-based system, (2) it does not require an exact match of the Kinect joints and the corresponding external marker placements or derived joint centers often used in reference motion capture systems, and (3) the correctness rules and their mapping for Kinect motion data analysis developed in this study are readily implementable for a real motion monitoring system for physical therapy.

INTRODUCTION

In rehabilitative health care, a carefully designed physical exercise plan could be instrumental to the recovery of a patient provided that the patient. Exercise programs are prescribed to address specific problems, and are often individually tailored by a clinician due to the presence of co-morbidities and additional impairments. It is critical that the patient perform the proscribed program correctly and with

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adequate practice repetitions (in the range of thousands) (Kleim and Jones, 2008), otherwise, the exercise may be ineffective, or even dangerous (Escamilla et al., 2009; Tino & Hillis, 2010).

Correct adherence to supplemental home exercise is essential for safe, effective, and efficient care. The lack of correct feedback during independent in-home exercise is therefore a serious concern. The use of simple counting devices helps verify the exercise repetitions. However, such simple, commercially available devices cannot fully capture all the required movements beyond the most simple, such as counting steps or recording overall amounts of activity (Wagner et al., 2012; Yang & Hsu, 2010), and are, therefore not useful for most prescribed home exercises.

The release of the Microsoft Kinect sensor, which is equipped with a depth camera capable of measuring 3 dimensional positions of the objects in its view, has triggered tremendous interest in its use to monitor in-home physical therapy exercises (Chang et al., 2013; Chang et al., 2012; Garcia et al., 2012; Gibson et al., 2012; Guerrero & Uribe-Quevedo, 2012; Huang, 2011; Zannatha et al., 2013; Pastor et al., 2012). A Kinect-based system could facilitate proper performance of the exercise or fitness program, increase patient accountability, allow the clinician to correct any errors in exercise performance, and allow program modification or advancement as needed. Hence, the Kinect sensor based system could potentially provide sufficient feedback and guidance to patients performing clinician prescribed in-home exercises, significantly minimizing costly and inconvenient trips to outpatient centers, and improving the effectiveness and outcomes of courses of treatment.

Many existing clinical trials with Kinect-based systems appear to have proceeded without comprehensive validation tests (Chang et al., 2013; Chang et al., 2012; Garcia et al., 2012; Gibson et al., 2012; Guerrero & Uribe-Quevedo, 2012; Huang, 2011; Zannatha et al., 2013; Zhao et al., 2014; Tamei et al., 2015; Ebert et al., 2015). Other studies have aimed to characterize the accuracy of the Kinect sensor; however, these validation studies have focused primarily on the movements within the frontal plane for a subset of the joints or segments (Clark et al., 2013; Obdrzalek et al., 2012; Mobini et al., 2013). In this article, we report our validation study on using a Kinect-based system for physical therapy exercise monitoring. Instead of comparing the joint positions or angles formed by key segments with respect to a (usually far more expensive) reference system, we take a completely different approach by focusing on the feasibility of using such a system to assess the correctness rules for a few common exercises in physical therapy. The correctness rules are readily implementable in a computer program for real-time motion tracking and feedback.

Due to space limitation, we only present results for two exercises, namely hip abduction and toe touch. In the standing hip abduction exercise, one leg is moved into hip abduction without any additional sagittal plane hip flexion/extension or transverse plane hip rotation. The pelvis, knee, and ankle remain stationary. In the standing toe touch exercise, the trunk bends forward and the arms reach to touch the floor. Motion occurs primarily as sagittal plane spine and hip flexion with concurrent shoulder flexion. When done correctly, there is minimal movement of the elbows, wrists, knees and ankles. We show that, although the Kinect-based system is capable of assessing many correctness rules for these exercises, it fails in the presence of significant self-occlusion, especially for the toe-touch exercise.

BACKGROUND

Microsoft Kinect was initially released as an add-on device for the Xbox 360 game console. Kinect enables a person to interact with a game using gestures and voice commands via what is referred to as

the Natural User Interface. In early 2011, Microsoft released an official driver for Kinect and a software development kit (SDK). The most useful feature of the SDK is skeletal tracking, via which, an application can receive pre-processed frames containing up to two skeletons each with 20 joints for Kinect v1, and up to four skeletons each with 26 joints for Kinect v2 (Lun and Zhao, 2015). Also very useful in the Microsoft Kinect SDK are its floor clipping application programming interfaces (APIs). Each skeleton frame includes a floor clipping plane vector containing the coefficients of the floor plane equation. Based on the floor clipping plane vector, we can calculate the vertical height off the floor clipping plane of each joint. In our study, we exploited the APIs to assess the correctness of some of the exercises.

VALIDATION STUDY

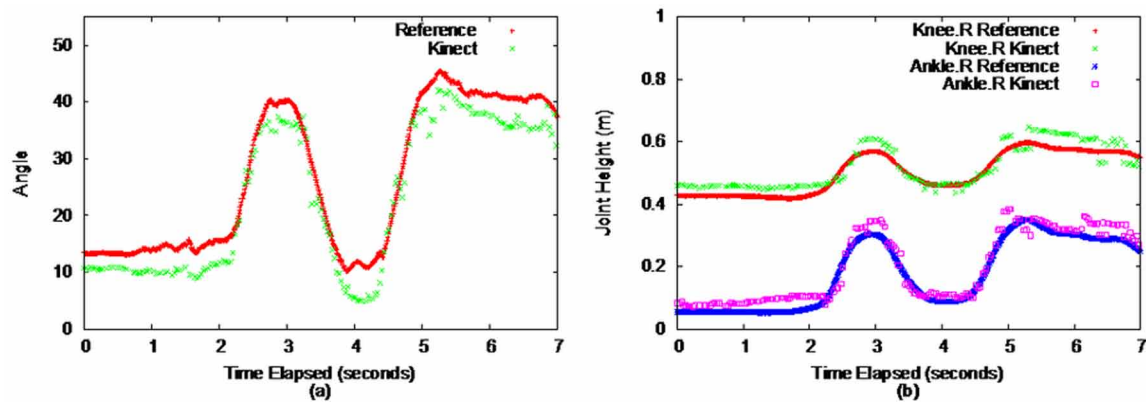
To validate the use of Microsoft Kinect for rehabilitation monitoring, we compared the skeletal joint results obtained from Kinect to those obtained concurrently by a Cortex motion capture system (Motion Analysis Corp, Santa Rosa CA) (2010). The subjects wore a full Helen Hayes marker set and each exercise was recorded by 8 cameras. The Cortex motion results were used to establish the ground truth for the study according to its established accuracy.

Our study has gone through three phases. During the initial phase, we attempted to carry out a mechanical point-to-point comparison between the two systems based on coordinate transformation. This proved to be difficult because it would require the Kinect sensor to be placed in a known location and a known tilt angle to the Cortex system. In the second phase, we attempted to focus on the comparison of relative movement between joints and the angles formed between adjacent segments during the movement. This effort was partially successful because it did not require coordinate transformation. However, a comprehensive comparison was still difficult because the positions of the markers used in the Cortex system did not correspond strictly to the joint positions reported by the Kinect sensor. Figure 1 shows a partial comparison of results we obtained in the first two phases for the hip abduction study. By exploiting the floor clipping plane APIs, we managed to compare the height of the knee and ankle during the hip abduction motion (i.e., right knee and right ankle) reported by the Kinect sensor and that captured by the Cortex system. As shown in Figure 1(b), the Kinect results were fairly close to those captured by the Cortex system. Figure 1(a) shows the angle formed by the two legs as reported by Kinect and the Cortex system. Again, we can see that the Kinect results were very close to those captured by the Cortex system.

Although the early results proved promising in using Kinect for therapeutic exercise monitoring, they were far from comprehensive. After all, the correct angle or the correct trajectories of particular joints do not necessarily mean an exercise is done correctly. We needed to perform a system-level assessment of Kinect's feasibility. We believe the most appropriate way to examine whether Kinect can be used to tell if a patient is doing an exercise correctly is based on a set of pre-defined correctness rules. Such rules establish a set of invariance for each exercise with appropriate error bounds. We argue that this approach is far more practical compared with the mechanical point-by-point based assessment:

- The point-by-point based approach would require: (1) a coordinate systems translation between the Kinect coordinate system and that used by the reference motion capture system; and (2) the reference system joint positions derived from external marker placements to match those reported by the Kinect SDK. In our experiences, neither is trivial.

Figure 1. A comparison of the Kinect measurement and that from the reference motion capture system in early stages of this study. (a) The angle formed by the two legs in hip abduction. (b) The height of the right (abducting) knee.



- Typically, prescribed therapeutic exercises allow a range of movement speeds and trajectories according to predefined correctness rules. As such, even if the joint positions reported by Kinect contain error, they might be adequate to assess whether or not the rules have been followed by the patient. Furthermore, some rules are more strict than others. A 5 cm error in Kinect measurement for a particular joint might not impact the assessment of the correctness for one exercise, but might blur the correctness boundary for another. Therefore, what matters ultimately is whether or not we can use a Kinect based system to distinguish correct exercises from wrong ones.
- Similarly, self-occlusion happens frequently during an exercise when a single Kinect camera is used. The positions for the occluded joints are estimated in Kinect. Hence, such joint positions are inevitably inaccurate. However, whether or not a large error for an occluded joint matters depends on the correctness rules for each exercise. The point-by-point based validation approach cannot give us a definitive answer as to whether or not Kinect is useful because such validation is without context.

In the following subsections, we report our experimental validation results for two typical physical therapy exercises, namely, hip abduction and toe touch.

Hip Abduction

For the hip abduction exercise, typically the following 7 rules are used to evaluate if a patient is doing the exercise correctly. Throughout, we assumed that the left leg is stationary and the right leg is the abducting leg:

Rule 1: Weight shift onto the left leg prior to abducting right leg.

Rule 2: The left leg is straight and leans slightly left after the weight shift and during right leg hip abduction.

Rule 3: Upper body shifts to the left side over the left leg after the weight shift and during right leg hip abduction.

Rule 4: Arms are held out in the frontal plane.

Rule 5: The right leg stays in frontal plane during hip abduction.

Rule 6: The right foot remains pointing forward during hip abduction.

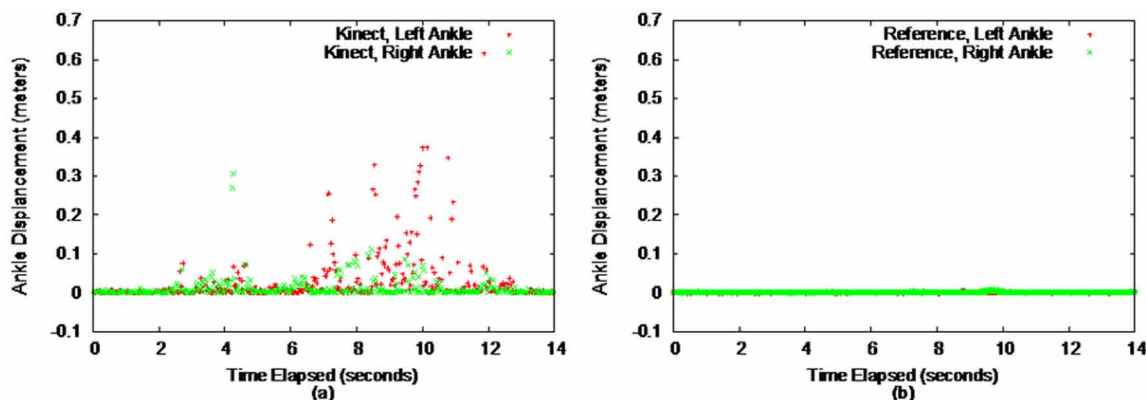
Rule 7: The pelvis stays stable after weight shift and motion occurs only at the hip joint.

To assess the rule 1 conformance, we measured the angle formed by the following two vectors: (1) a vector from the left ankle to the left hip joint *obtained in the initial pose*, and (2) a vector from the left ankle joint to the center of mass of the patient. Ideally, the angle should be reduced to 0 when the weight is completely shifted to the left leg. As can be seen in Figure 2, the angle calculated from the Kinect measurement clearly shows a gradual reduction from about 4.5 degrees to less than 1 degree, and it is very consistent with that measured by the Cortex system, although noticeably more noisy.

Rule 2 has two components: (1) the left leg must remain straight, and (2) the patient leans slightly left. Component (1) can be easily assessed by measuring the angle formed between the left knee to left hip segment and the left knee to the left ankle segment (referred to as left knee angle), and component (2) can be characterized by a leaning angle defined as the angle formed between the left hip to the left ankle and the vertical line from the left hip to the floor. Ideally, the left knee angle should remain at 180 degrees and the lean angle should change from 0 to a small value.

During our experiment, the subject performed 5 iterations of hip abduction with the first 3 iterations performed correctly and the last 2 intentionally violating rule 5 (the very last iteration is partially captured). As shown in Figure 3(a), the left knee angle as measured by Kinect stays within 170-180 degrees. The measurement result from the Cortex system reveals slightly larger variations (from about 160-180 degrees). The leaning angle indeed starts from about 0 degrees to an average of about 8 degrees for both the Kinect and Cortex measurement results as shown in Figure 3(b). However, the Kinect data are much noisier than the Cortex results. Nevertheless, the results showed that with appropriate error bounds, the Kinect based system can be used to assess rule 2 conformance.

Figure 2. A comparison of the weight shift angle for hip abduction



Rule 3 is evaluated by measuring the angle formed between the shoulder center to hip center vector and the same vector at its initial position. This upper body shift angle should start at 0 and increase to a moderate angle. In between two iterations of the hip abduction, the angle should reduce to a smaller angle. As can be seen, this was indeed the case as measured by both the Kinect and the Cortex systems as shown in Figure 4. The maximum shift angle as measured by the Cortex system was clearly bigger than that measured by the Kinect based system, indicating a systematic error in the Kinect measurement. Fortunately, this systematic error is relatively small, about 2 degrees for correct iterations and as large as 6 degrees for incorrect iterations. We believe such small error is acceptable for assessing rule 3.

Rule 4 is concerned with the placement of the arms during hip abduction. There are two components to the rule: (1) both arms must remain in the frontal plane, and (2) both arms must move out. To assess this rule, we must first establish the frontal plane, accomplished by using the following two vectors: (1) hip center to the left shoulder, and (2) hip center to the right shoulder. More specifically, the frontal plane was established by using the two vectors obtained in the *initial* T-pose. We calculated the out-of-frontal-plane angle of each arm. Ideally, the angle should remain 0. When an arm is moved out, it would form a 90 degree angle with respect to the torso (represented by a vector from shoulder center to the hip center). Due to the weight shift and leaning during abduction, the angle would oscillate around 90 degrees.

As shown in Figure 5(a), both arms remained within about 10 degrees from the frontal plane according to the Cortex system. As measured by the Kinect based system, the left arm indeed stayed within 10 degrees of the frontal plane; however, the right arm appeared to deviate from the frontal plane by as much as 25 degrees. This indicated that we would need a fairly generous error bound to assess rule 4 using the Kinect based system. As shown in Figure 5(b), the arms deviated from 90 degrees by as many as 10 degrees according to the Cortex system. While the arm-to-torso angles measured by the Kinect based system showed smaller deviations from 90 degrees, they were apparently systematically larger than

Figure 3. A comparison of the left knee angle and leaning angle for hip abduction rule 2 assessment

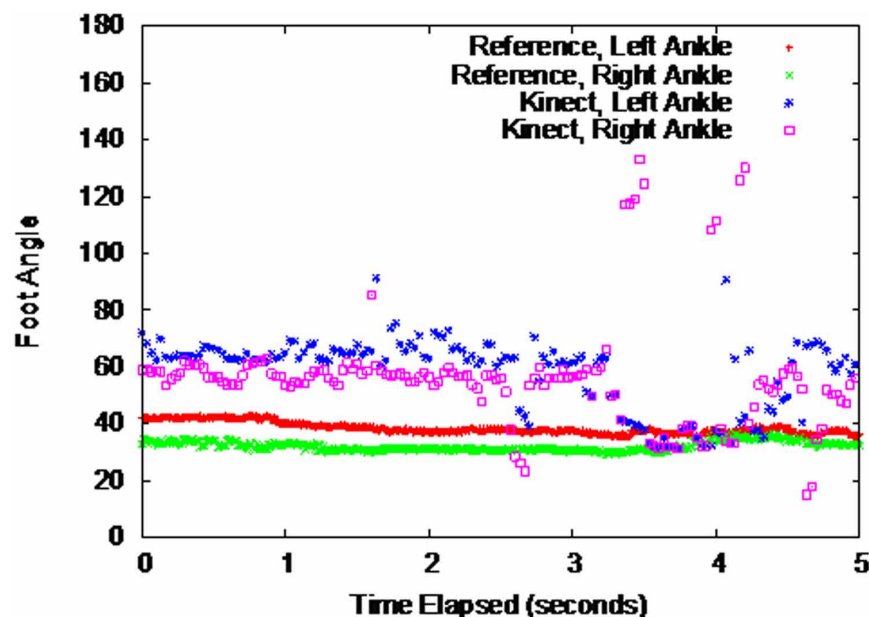


Figure 4. A comparison of the upper body shift angle for hip abduction hip 3 assessment

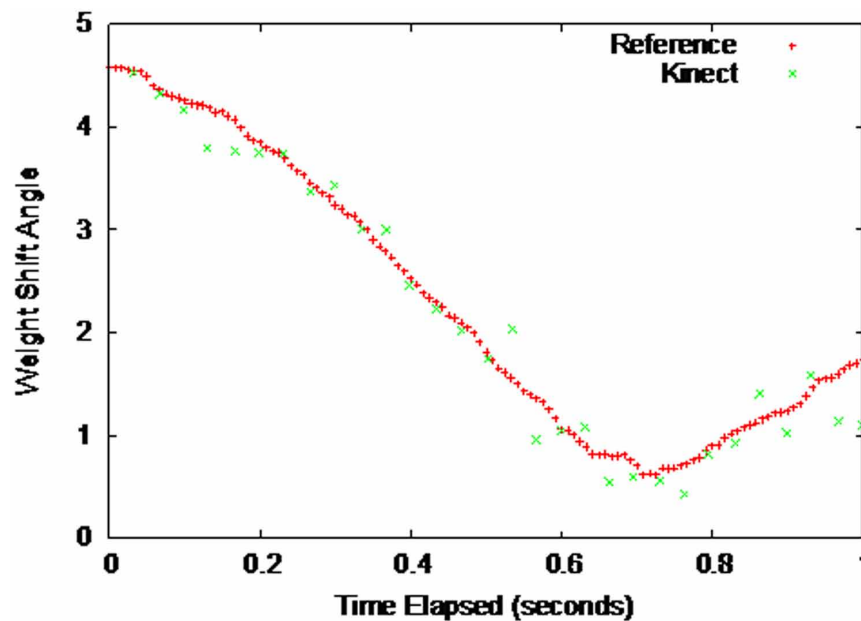
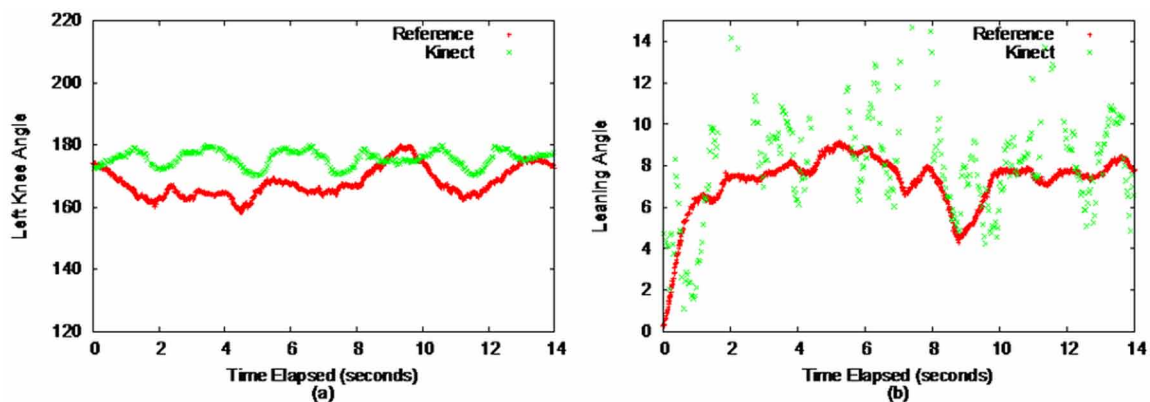


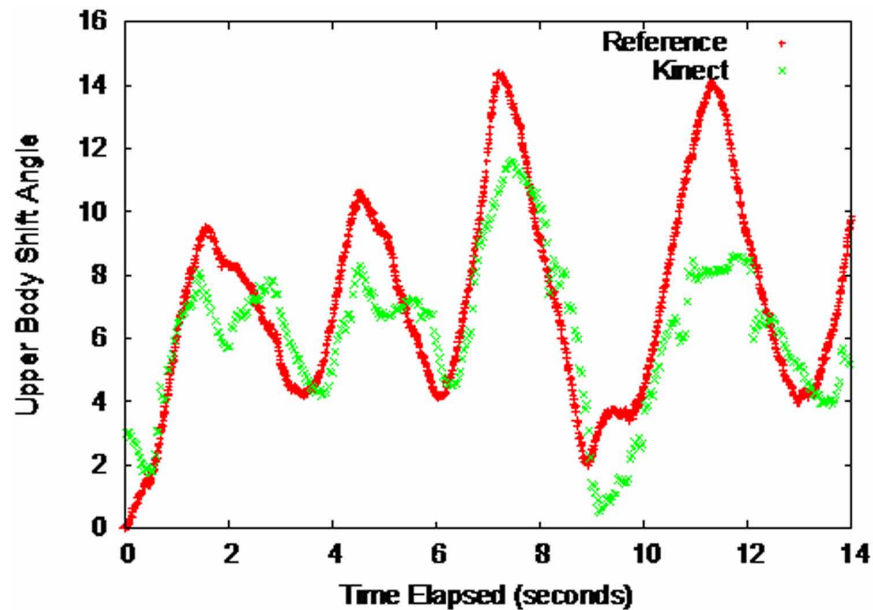
Figure 5. A comparison of the upper body shift angle for hip abduction rule 3 assessment



those measured by the Cortex system by approximately 10 degrees. Nevertheless, this systematic error does not appear to limit the use of Kinect to assess the second component of rule 4 for hip abduction.

Rule 5 can be assessed very similarly to the first component of rule 4. We calculated the out-of-frontal-plane angle formed between the right leg and the frontal plane. For correct iterations, this angle should be near 0 degrees, and should have significant non-zero angle values for the incorrect iterations. As can be seen Figure 6, according to the Cortex system, the out-of-frontal-plane angle for the right leg oscillated slightly around 5 degrees with an amplitude of about 5 degrees for the 3 correct iterations, and increased to over 30 degrees off the frontal plane for the incorrect iterations. The Kinect data showed that the oscillation was around 8 degrees (instead of Cortex's 5) for correct iterations and the amplitude about 8 degrees (instead of 5). This error in Kinect measurement can be easily overcome by setting slightly

Figure 6. A comparison of the angle between the right leg and the frontal plane for hip abduction

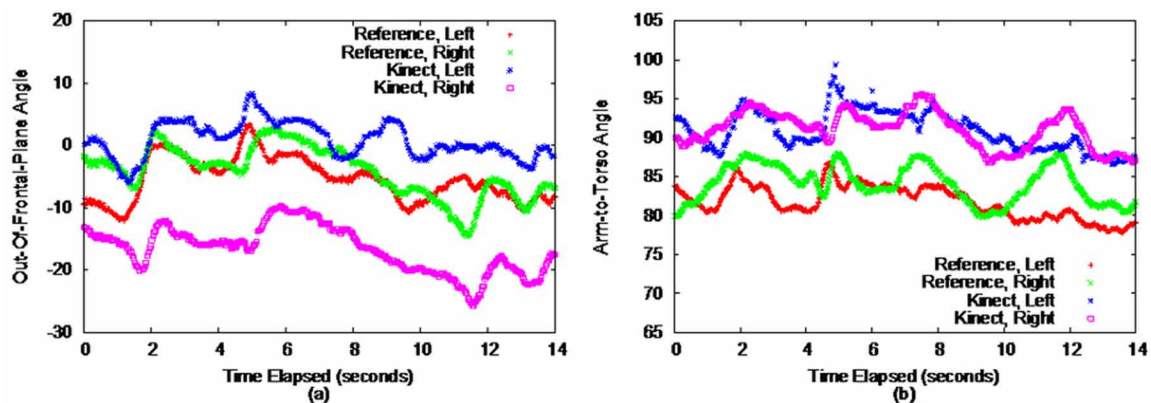


larger error bounds when assessing the hip abduction exercises in practice. For the wrong iteration, the highest angle captured by Kinect was very consistent with that measured by the Cortex system at about 32 degrees. Hence, it is clear that Kinect is capable of detecting the violation of this rule.

For rule 6, we measured the angle formed between the ankle-to-foot vector and a forward-pointing vector. The forward-pointing vector was perpendicular to the frontal plane and can be easily derived from the cross product of the hip-center-to-left-shoulder vector and the hip-center-to-right-shoulder vector. If the foot is indeed pointing strictly forward, the angle should be 0.

As shown in Figure 7, the right foot is, in fact, not even close to 0 degrees. According to the Cortex system, the foot angles varied around 30 degrees. The Kinect data showed very large variation, between 20 and 70 degrees. Our experiments clearly show that Kinect is not capable of assessing this rule due to the inaccuracy of the measurement for the foot segment.

Figure 7. A comparison of the angle between the right leg and the frontal plane for hip abduction



Rule 7 is not assessable by the Kinect based system because the current Kinect SDK does not provide APIs to capture the motion of the pelvis.

In summary, the majority of correctness rules can be assessed by a Kinect-based system. However, we note that rules for subtle movements, such as the foot alignment and pelvis movement, cannot be evaluated by Kinect. If these movements are critical for some physical therapy exercises, either the Kinect's capability has to be expanded and improved, or other motion capture systems would need to be used.

Toe Touch

For the toe touch exercise, typically the following 4 rules are used to evaluate if a patient is doing the exercise correctly.

Rule 1: Both knees are extended, i.e., the legs are straight.

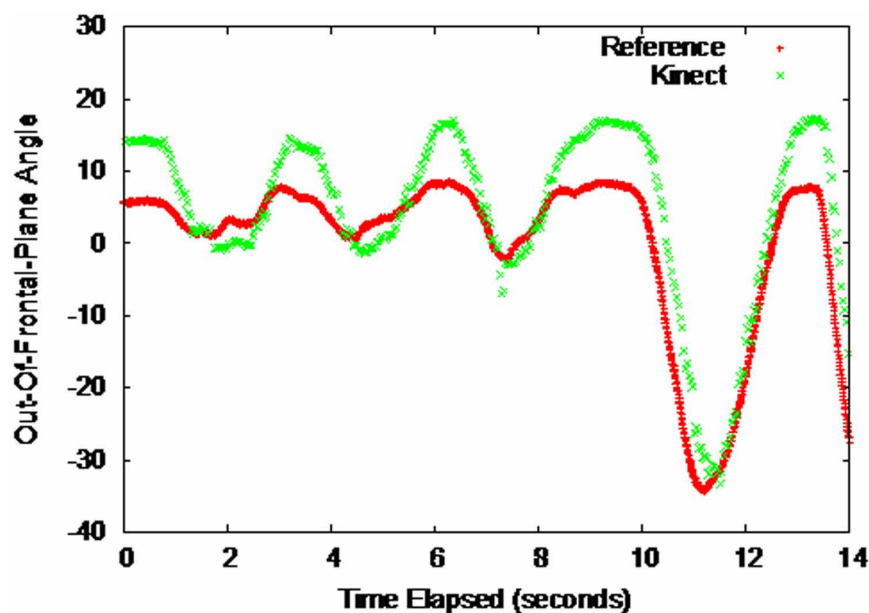
Rule 2: The torso should not rotate as the fingers reach for the floor.

Rule 3: Ankles should not move.

Rule 4: Feet are pointed forward.

We can assess rule 1 by measuring the angle formed by the upper leg and the lower leg. If the legs are straight, then the angle should be at 180 degrees. As shown in Figure 8, for a toe touch run with two iterations, according to the Cortex system, both legs were indeed fairly straight as the knee angle stayed very close to 180 degrees. Unfortunately, the angles calculated from the Kinect data were far off 180 degrees when the subject's torso occluded the legs when his fingers reached for the floor. This clearly shows that we cannot use Kinect to properly evaluate rule 1 conformance before the self-occlusion problem is resolved.

Figure 8. A comparison of the knee angles for toe touch



When the torso does not rotate during the movement, the left and right shoulder should move within the sagittal plane in parallel. Hence, the traveled distance from its initial position should be the same for the left or right shoulder joint. Therefore, we assessed the rule 2 conformance by measuring and comparing the distance travelled relative to the initial position (in T-pose). If the torso does not rotate, the distances for the left and right shoulders should be the same. As can be seen in Figure 9(a), this was the case for a correct iteration of toe touch. For an iteration with torso rotation, the distances were different, as revealed in Figure 9(b).

Note that there were apparent discrepancies in the distance measurement results between the Kinect based system and the Cortex system. As shown in Figure 9, the discrepancy can be as large as 0.2 meters when the subject's fingers are reaching for the toe. This large measurement error in the Kinect system apparently will not prevent us from using Kinect to assess rule 2.

We can assess rule 3 by measuring the displacement of the ankles with respect to their initial positions. If the ankles do not move, the displacement should be close to 0. As can be seen from the Cortex system data shown in Figure 10, indeed this was the case. However, the Kinect data exhibited large displacement during toe touch, probably due to self-occlusion. This clearly shows that we cannot use Kinect to assess rule 3.

We can assess rule 4 by measuring the angle formed by the foot and a forward vector, in exactly the same way as that for hip abduction rule 6. If the feet are pointing forward, the angle should be 0. As shown in Figure 11, this was not the case as revealed by the Cortex system measurement (with an angle around 40 degrees). The angles measured by Kinect were significantly larger (about 60 degrees) and varied significantly in the presence of self-occlusion. Hence, we conclude that we cannot assess rule 4 using a Kinect based system.

Figure 9. A comparison of the distances between the two shoulder joints with respect to their initial positions for toe touch

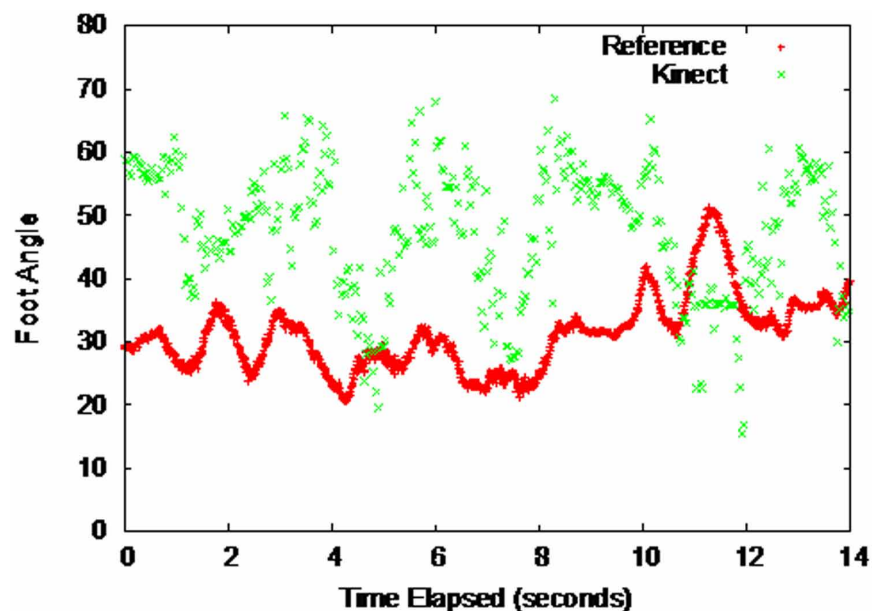


Figure 10. A comparison of the ankle displacement for toe touch

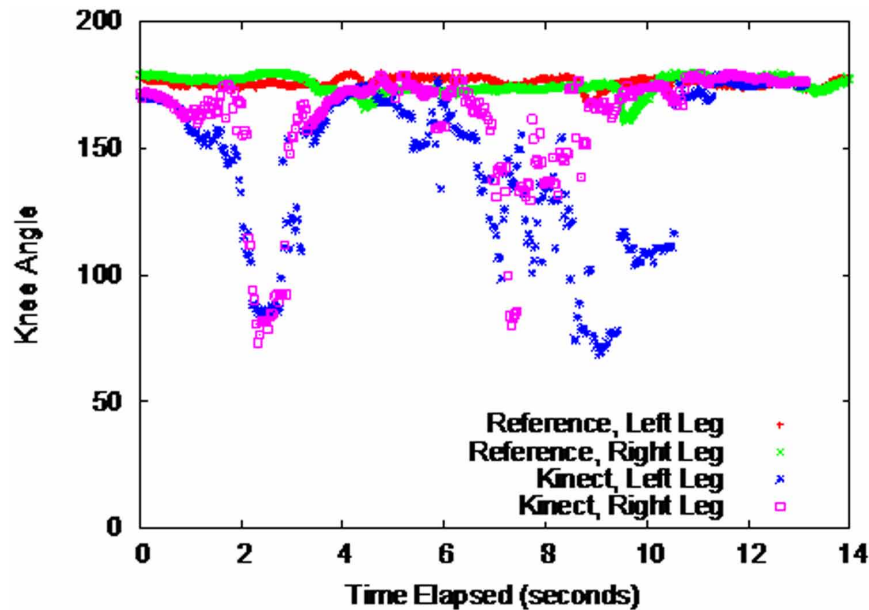
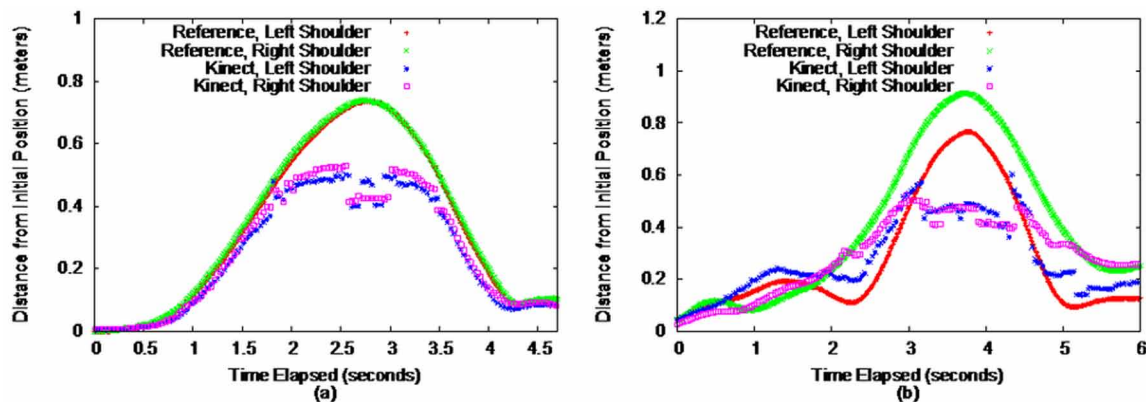


Figure 11. A comparison of the foot angle for toe touch



In summary, only one of the four correctness rules can be assessed by a Kinect-based system for the toe touch exercise. Hence, we cannot use such a system to evaluate the correctness of the toe touch exercise and provide meaningful feedback to the patients before the self-occlusion problem is addressed by the Kinect research community.

FUTURE TRENDS

The current Kinect SDK has two obvious limitations: (1) it captures only 20 joints in Kinect v1 and 26 joints in Kinect v2, and (2) the joint positions often contain large errors in the presence of occlusion.

As we have shown in our feasibility study results presented in the previous section, the limitation of the joint set prevents us from monitoring subtle pelvis movement, and the large errors in joint positions in the presence of self-occlusion make it impossible for us to use Kinect to evaluate some correctness rules, especially for exercises that involve self-occlusion predominately. There have been intensive research and development efforts to address the two issues (Han et al., 2013). For example, a Kinect based motion capture system for finger tracking was designed, implemented, and thoroughly validated in a very recent work (Metcalf et al., 2013). The self-occlusion problem has been tackled by using sophisticated machine learning methods with constraints (Shen et al., 2012), by incorporating the reliability estimation on the selection of kinematically valid postures (Shum et al., 2013), and by using multiple Kinect sensors (Asteriadis et al., 2013).

CONCLUSION

In this article, we presented our work on a validation study of using Microsoft Kinect to monitor rehabilitation exercises. Differing from other validation efforts, we focused on a system-level assessment instead of the joint-level comparison with reference motion capture systems. We assessed the feasibility of using Kinect by examining the enforceability of a set of correctness rules defined for each exercise, which are invariances of each exercise and hence independent from the coordinate system used. This method is more advantageous in that (1) it does not require coordinate system transformation between those of the reference motion capture system and of the Kinect based system, (2) it does not require an exact match of the Kinect joints and the corresponding external marker placements or derived joint centers often used in reference motion capture systems, and (3) the correctness rules and their mapping for Kinect motion data analysis developed in this study are readily implementable for a real motion monitoring system for physical therapy.

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KEY TERMS AND DEFINITIONS

Floor Clipping Plane: As part of the Microsoft Kinect SDK, each skeleton frame contains a set of parameters that can be used to determine the floor plane as seen by the Kinect sensor.

Frontal Plane: Using a three-dimensional (x-y-z) coordinate system, this is the plane dividing the front and back half of the body; movement in the frontal plane is typically viewed from an anterior or posterior perspective; an example of movement in this plane is hip abduction where the lower extremity is moved out to the side of the body from the midline.

Microsoft Kinect: A sensor produced by Microsoft that is equipped with a Webcam, a depth camera, and a microphone array. It is designed to facilitate a natural user interface.

Natural User Interface: A natural user interface enables users to interact with a computer or game console via gestures and voice commands instead of keyboard, mouse, or game controller.

Occlusion: An occlusion occurs when a joint or more is hidden from the camera. Self-occlusion means that one body part hides another part.

Sagittal Plane: Using a three-dimensional (x-y-z) coordinate system, this is the plane dividing the left and right sides of the body; movement in the sagittal plane is typically viewed from a lateral perspective; an example of movement in this plane is shoulder flexion where the upper extremity is moved from the side to up in front of the body.

Software Development Kit (SDK): A set of libraries that offer software developers the access of a set of application programming interfaces.

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Chapter 38

Virtual Reality as Distraction Technique for Pain Management in Children and Adolescents

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ABSTRACT

For a growing number of medical procedures, patients remain awake during the procedure, they feel pain during the medical procedure, and they remember the pain after the procedure is over. Inadequately controlled pain during medical procedures using pain medications alone for pain control is a worldwide medical problem. Having patients conscious and feeling pain during medical procedures is especially problematic in children who need repeated medical procedures, such as pediatric patients with large severe burn injuries. Because pain has a strong psychological component, a number of unhelpful psychological factors can unintentionally amplify how much pain, fear, and anxiety children experience during painful medical procedures. Fortunately, psychological treatments can be used to help reduce pain and anxiety. Virtual reality is one promising adjunctive analgesic. There is a growing literature showing the potential of immersive virtual reality as a psychological pain control technique that can be used in addition to traditional pain medications the patient is already receiving. The current chapter reviews a number of studies on virtual reality analgesia in pediatric patients, towards the goal of helping reduce excessive pain in children during medical procedures. The current chapter evaluates the effectiveness of VR during several painful procedures in pediatric and adolescent patients, its applicability, and the potential for wider dissemination of VR analgesia in clinical settings. The current review considers factors involved in the effectiveness of VR analgesia, such as the quality of the VR system used.

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INTRODUCTION

The problem: uncontrolled pain during medical procedures. For many medical procedures, patients remain awake during the procedure, they feel pain during the procedure, and they remember pain and unpleasantness they experienced, long after the procedure is over. These memories for the painful experience(s) can influence the patient's attitudes towards receiving healthcare, increases avoidance of medical visits that could help prevent medical problems. For example, a child who has a very painful or anxiety provoking dental procedure is more likely to become avoidant of dentists. The consequences of avoidance can be expensive. Many dental problems that could be easily prevented or corrected early on with regular checkups (e.g, filling a cavity), become much more expensive and painful problems, as the disease progresses untreated (e.g., root canal and tooth extraction) for patients who refuse to visit the dentist. Excessive pain during medical procedures is a worldwide problem, and affects a wide range of patient populations. For example, patients with a wide range of medical problems often get intravenous (IV) ports inserted "incanulation". Once inserted, healing medications, nutrients and fluids can be administered into the patient's bloodstream through the IV port. But the initial implantation of the IV port (e.g., sticking the IV port into the patient's arm) is often surprisingly painful. The same painful port insertion procedure is used with cancer patients, burn patients, patients being prepared for surgery, and a long list of other medical problems. And IV port placement is just one of large number of medical procedures where excessive pain is common.

Some medical procedures sound fairly painless, but patients' fears and anxiety associated with the procedures can amplify the patient's negative experience. For example, with blood draws, a fairly large percentage of people faint during blood draws, despite the short duration of the procedure.

A number of psychological influences can amplify or increase how much pain patients experience during medical procedures. High anxiety can increase sensitivity to pain. Some patients must receive medical procedures repeatedly. For example, children with large severe burn injuries receive several painful medical procedures per week, often daily wound cleaning and painful physical therapy skin stretching exercises, and the most painful segments of the wound care procedures often last 25 minutes or longer. If the patient has an extremely high pain during wound care, their memory for previous painful wound care sessions can increase their subjective experience of pain during subsequent wound care procedures, and make it harder to control the patient's pain using pain medications alone. There are concerns that repeated painful medical procedures can be made worse if the patient has pre-existing psychological problems such as depression or PTSD. These conditions can reduce the effectiveness of opioid analgesics. And repeated painful medical procedures during hospitalization may increase patients' risk of developing chronic pain or chronic PTSD. There has lately been a growing realization in the medical community for the need for more effective non-pharmacologic pain control during medical procedures. Use of higher doses of pain medications may increase analgesia, but also increase undesirable medical side effects of the pain medications such as nausea, delirium, constipation, urinary retention, sleeping through meals, and interference with sleeping at night. Diversion of pain medications is another concern. On the streets of the U.S.A., addiction to opioids has become a major medical problem in itself. According to the CDC, overdose deaths involving prescription opioids have quadrupled since 1999, and set a new record high in 2014 (CDC, 2016).

Because pain has a strong psychological component, in theory, psychological interventions can be used to help counteract some of the negative psychological influences. In other words, there is growing interest in using psychological techniques to help reduce pain. Typically, psychological techniques can

be used in addition to traditional pain medications, adjunctively (Stinson, Yamada, Dickson, Lamba & Stevens, 2008; Koller & Goldman, 2012). Distraction is a familiar technique. Parents frequently distract children to help get them to stop crying (using a rattle toy). Music is widely used to help patients during dental procedures. According to a Cochrane meta-analysis, listening to music resulted in a statistically significant reduction in pain, but on average, music only reduced the amount of pain by around 5% reduction (not a clinically meaningful reduction from listening to music). A stronger distraction is needed for acute pain during medical procedures.

Recently Virtual Reality (VR) has emerged as a new unusually effective distraction technique, allowing the user to be immersed in a computer-generated environment. Patients look into virtual reality goggles that block the patient from being able to watch their wound care, and earphones and computer generated sound effects and music from VR hinder the sounds of the real environment, (Hoffman et al., 2000). The user can interact with the virtual environments using a mouse or a head-tracking.

Hoffman and Patterson and colleagues co-originated the technique of using immersive virtual reality analgesia during acute procedural pain (Hoffman, 1998; Hoffman et al, 2000). Two adolescents with severe burns used immersive virtual reality during burn wound care: staple removals. Both children reported large reductions in their pain during wound care while using immersive virtual reality, compared to when the same children played a Nintendo video game during the same wound care sessions (Hoffman et al., 2000). Several controlled studies support VR efficacy in reducing pain but most of them investigated its effects on adults, in particular during procedural pain in burn patients (Hoffman, Patterson, Magula, Carrougher, Zeltzer, Dagadakis & Sharar, 2004; Maani, Hoffman, Morrow, Maiers Gaylord, McGhee & DeSocio, 2011) and during dental procedures (Bentsen, Svensson & Wenzel, 2001; Hoffman, Garcia-Palacios, Patterson, Jensen, Furness III & Ammons, 2001; Furman, Jasinevicius, Bissada, Victoroff, Skillicorn & Buchner, 2009; Wiederhold, Gao & Wiederhold, 2014).

The aim of the chapter is to review the use of VR for pediatric and adolescent pain management and its applicability in clinical settings. Between December 2011 and September 2015 some of the most important psychological and medical databases were consulted (PubMed, ScienceDirect and Scopus), including studies in which VR was used with children and adolescents as a distraction technique for procedural pain management. Studies with only adults or that applied VR for non-procedural pain, such as chronic pain, or during non-painful procedures were excluded. Search terms included combinations of “virtual reality”, “distraction”, “analgesia”, “pain”, “children”, “adolescents”.

BACKGROUND

Although the mechanisms by which VR reduces pain are still under investigation, according to Hoffman et al., 2006, the logic of how VR reduces pain can be explained by applying the Attention Pain Theory by Eccleston and Crombez (1999). People need attention in order to feel pain. VR is very attention demanding, leaving less attentional resources available for the brain to process incoming pain signals. As a result, patients report lower pain levels during VR, they spend less time thinking about their pain, and report higher levels of fun while in VR. The essence of immersive VR is the patients' illusion of going inside the 3D computer generated world, as if it is a place they are visiting. This illusion of “presence” or “feeling present” in the virtual world helps make VR unusually attention grabbing and unusually effective as distraction.

Slater and Wilbur (1997) made a distinction between the *immersiveness* of the VR system (e.g., the objectively measurable field of view of the VR goggles) and *presence*, the psychological illusion of going inside the computer generated world and feeling present in the virtual world. In laboratory studies, wide field of view VR goggles were significantly more effective at reducing pain than narrower field of view goggles ($p < .05$) (Hoffman, Seibel, Richards, Furness III, Patterson & Sharar, 2006). Moreover, another laboratory study with young adults (college students) showed that an interactive VR system was significantly more effective at reducing pain than passive VR ($p < .005$) (Wender, Hoffman, Hunner, Seibel, Patterson & Sharar, 2009). In some studies, patients with a strong illusion of going inside the computer generated world were also the patients who reported greater reduction in their pain during VR, and patients who reported a less compelling illusion of going into the virtual world reported less pain reduction during VR (Hoffman, Doctor Patterson & Carrougner, 2000; Hoffman, Sharar, Coda, Everett, Ciol, Richards & Patterson 2004). Manipulating the objective *immersiveness* of the VR system has been shown to affect the magnitude of VR analgesia in predictable ways, even though the illusion of presence was not significantly higher for the high immersion VR system than for the low tech VR system ($p > .05$) (Hoffman et al., 2006; Wender et al., 2009). In other words, in some studies, increasing the *immersiveness* of the VR system significantly reduced pain, but did not significantly increase patients' presence ratings.

VR effects on brain activity during painful stimuli have been demonstrated by Hoffman et al. (2004) in a study with adult healthy volunteers. Pain-related brain activity was measured using fMRI. During their brain scans, healthy volunteer participants received brief thermal pain stimulations during VR and during No VR. Participants reported large reductions in pain during VR, and the fMRIs showed large reductions in pain-related brain activity during VR. In another study, Hoffman et al. (2007) used pain ratings and functional magnetic resonance imaging to measure how much pain participants reported experiencing, and measured pain-related brain activity in adults undergoing thermal pain stimulation and receiving opioid analgesia and/or VR distraction. Results indicated that opioids alone significantly reduced subjective pain unpleasantness ratings and significantly reduced pain related-brain activity in the insula and thalamus; VR alone significantly reduced both worst pain and pain unpleasantness and significantly reduced pain related-brain activity in the insula, thalamus and SS2, but the lowest pain scores and largest reductions in pain related-brain activity were obtained when subjects received both opioid and VR distraction. These results support that notion that VR should be used adjunctively, in addition to traditional pain medications.

VIRTUAL REALITY ANALGESIA FOR CHILDREN AND ADOLESCENTS

Applicability and Effectiveness in Clinical Settings

VR has been used with children and adolescents between 4-19 years, mostly with burned children during bandage/dressing changes, wound cleaning or physical therapy (Hoffman 1998; Hoffman et al., 2000; Hoffman, Patterson, Carrougner & Sharar, 2001; Das, Grimmer, Sparnon, McRae & Thomas, 2005; Chan, Chung, Wong, Lien & Yang, 2007; Sharar, Carrougner, Nakamura, Hoffman, Blough & Patterson, 2007; Van Twillert, Bremer & Faber, 2007; Hoffman, Patterson, Seibel, Soltani, Jewett-Leahy & Sharar, 2008 Schmitt, Hoffman, Blough, Patterson, Jensen, Soltani, Carrougner, Nakamura & Sharar,

2011; Kipping, Rodger, Miller & Kimble, 2012; Faber, Patterson & Bremer, 2013; Hoffman, Meyer III, Ramirez, Roberts, Seibel, Atzori, Sharar & Patterson, 2014; Jeffs, Dorman, Brown, Files, Graves, Kirk, Meredith-Neve, Sanders, White & Swearingen, 2014; Hua, Yao, Zhang & Chen, 2014). Others evaluated VR analgesia for cancer with children undergoing venipuncture, lumbar puncture or port access (Sander Wint, Eshelman, Steele & Guzzetta, 2002; Gershon, Zimand, Lemos, Rothbaum & Hodges, 2003; Gershon, Zimand, Pickering, Rothbaum & Hodges, 2004; Wolitzky, Fivush, Zimand, Hodges & Rothbaum, 2005). Other studies evaluated VR effectiveness with a cerebral palsy patient during physical therapy (Steele, Grimmer, Thomas, Mulley, Fulton & Hoffman, 2003), with patients undergoing fluoride therapy and primary mandibular molar restoration (Aminabadi, Erfanparast, Sohrabi, Oskouei & Naghili, 2012) and with patients with unknown disease during intravenous placement (Gold, Kim, Kant, Joseph & Rizzo, 2006).

VR reduced pain more than an interactive video game distraction during dressing change in a 16-years boy and in a 17-years boy (Hoffman et al., 2000), and during port access placement in a 8-years child (Gershon et al.; 2003). In a pilot study, Gershon et al. (2004) randomly assigned children undergoing subcutaneous port access to three groups: VR distraction, PC screen-based distraction and no distraction. Nurses rated children in the VR and PC condition as experiencing less pain than those in control condition ($p < .05$), but no differences emerged from children reports. Similar results emerged from a study on burn children (Kipping et al., 2012).

Hua et al. (2015) found that children, their caregivers and nurse involved in the wound care reported significantly less pain levels during the dressing change in VR group compared to the standard distraction group ($p < .05$). In a randomized controlled trial study, Van Twillert et al. (2007) demonstrated that children undergoing dressing change reported significantly less pain during VR than during other forms of distraction ($p < .01$). Van Twillert et al., (2007) found that VR was somewhat superior to TV, but was not significantly more effective than watching TV.

Jeffs et al. (2014) reported that participants in the VR group reported significantly less procedural pain during VR compared to the passive distraction group (watching a movie on TV) and burn patients reported less procedural pain compared with standard care group ($p < .05$).

Seven studies also revealed significant differences between pain in the VR condition compared to a no distraction condition (Das et al., 2005; Wolitzky et al., 2005; Sharar et al., 2007; Hoffman et al., 2008; Schmitt et al., 2011; Aminabadi et al., 2012; Hoffman et al., 2014). VR continued to be effective when used for multiple treatments (Hoffman et al., 2001; Faber et al., 2013). Using relatively narrow (40 degree field of view) VR goggles, and a small sample size (ten children per group = 20 patients total), Gold et al. (2006) did not find a significant difference in pain reduction between VR and control condition, but Gold et al.'s patients receiving VR distraction during intravenous placement were significantly more satisfied with their pain management than children in the control condition ($p < .01$). Steele et al. (2003) used VR with a 16-year-old patient with cerebral palsy undergoing physiotherapy: he reported that his pain was lower during adjunctive VR distraction than pharmacological analgesia alone.

VR Systems

The most frequently used software was "SnowWorld" an interactive virtual environment where the patients glide slowly through a 3D icy canyon and shoot snowballs at snowmen, igloos, penguins, woolly mammoths and flying fish. SnowWorld was specifically designed for burn procedural pain management

and it was used also by adults in several studies about VR pain management (see reviews by Malloy & Milling, 2010; Li, Montaña, Chen & Gold, 2011). “The ice-cream factory” game, is another VR software created for children burn pain management, where subjects goal was to scare a fox away the factory by shooting it with ice-cream (Chan et al., 2007). Helmets and VR goggles used in studies varied in quality and in some cases the field of view was not mentioned in the publications.

SOLUTIONS AND RECOMMENDATIONS

On the basis of the evidence reported in the literature, VR analgesia appears to be effective for children and adolescents without side effects during dressing changes, physical therapy, lumbar puncture and port access placement. The most important medical contraindications for the use of VR regard the localization of the wound, if this doesn't allow the patient to wear the helmet, and a diagnosis of epilepsy, because the use of VR could expose children to possible epileptic seizure. These contraindications are the same as those found in adult patients (Maani et al., 2011). In pediatric burn patients, adjunctive VR reduced pain more than a Video Game distraction. VR reduced pain more than watching an age-appropriate movie, more than other distraction techniques and adjunctive VR consistently reduced pain compared to standard pharmacological analgesia. However, we must consider that in four of these studies included both children and adults, the mean age of the sample was more than 19 and the generalizability of those results to children should be interpreted cautiously for those four studies (Hoffman et al., 2001; Van Twillert et al., 2007; Hoffman et al., 2008; Faber et al., 2013). Results exploring the use of VR with cancer patients indicate a significant VR analgesic effect during port access and a non-significant pain reduction during lumbar puncture. The lumbar puncture study (Sander Wint et al., 2002) was an early study using a passive, non-interactive VR system. Patients watched videos in a pair of low resolution VR glasses (virtual i-o glasses). VR effectiveness was likely limited by the lack of interactivity, and the narrow field of view. As mentioned earlier, Wender et al, 2009 showed that VR was significantly more effective at reducing pain when participants could actively interact with the virtual world, and Hoffman, Seibel et al (2006) showed that VR was significantly more effective at reducing pain when a wide field of view VR goggles were used (compared to narrow field of view goggles, such as those used by Sander Wint et al., 2002). Future studies using more immersive VR systems (e.g., with wide field of view VR goggles and that allow patients to actively interact with the virtual world) may get stronger results during lumbar punctures.

Because most studies didn't report helmet quality, a complete analysis on the role of this aspect wasn't possible. However, five of the six clinical studies reporting a significant pain reduction in VR condition compared to control condition, used helmet with a diagonal field of view of 50-80 degrees field of view (Hoffman et al., 2000; Hoffman et al., 2001; Sharar et al., 2007; Hoffman et al., 2008; Schmitt et al., 2011). Hua et al, 2014 used a 40 degress FOV helmet. In two others, the helmet quality was unknown (Das et al., 2005; Aminabadi et al., 2012).

Hoffman et al. (2008) reported that pain levels were significantly lower when presence scores were higher. In contrast, Sharar et al, (2007), evaluating the differences in pain perception between adults and children/adolescents, indicated that, although children report higher levels of presence and realism than adults, there was no difference in pain reduction between the pediatric and adult age groups.

FUTURE RESEARCH DIRECTIONS

Until recently, the cost of a wide field of view VR system was tens of thousands of dollars more expensive than the narrow field of view VR goggles. In 2016/2017, the cost of a wide field of view VR system with approximately 90-110 degrees diagonal field of view, and very high resolution dropped in price from \$35,600 (not including head tracking) to approximately \$800 for one pair of wide field of view VR goggles. The \$800 helmet already includes head tracking as well as position tracked hand control input devices. There aren't any studies that describe the lifespan of a VR system, however, on the basis of our experience we can affirm that it can be considered a good investment: VR requires very low maintenance costs (mainly battery charging and cleaning gel) and, changing the VR software, it is possible to get a different VR environment and so a new distraction instrument. Moreover, most VR goggles can be adjusted on the base of inter-ocular distance and head dimensions, and it is suitable for children, adolescents and adults too.

Hoffman and colleagues recently developed a portable water-friendly VR system with a robot-like arm goggle holder (Maani et al., 2011). The custom made robot-like arm holds the goggles near the patient's eyes, and the VR goggles do not even touch the patient. This system uses the more expensive battery powered VR goggles by NVIS MX90 VR goggles. Researchers have also been able to use a robot-like arm goggle holder with the new Oculus Rift Developers Kit Version 2 (DK2), for a patient undergoing physical therapy skin stretching exercises, with a patient who was able to tolerate having the goggles lightly touch his face (Hoffman et al., 2014).

In the U.S.A., the National Institutes of Health (NIC) are particularly interested in research on "novel therapies for pain treatment", with a specific attention to VR as demonstrated by the dozens of the funded projects using this distraction technique (Thomas, 2014). For the future, the availability of inexpensive but highly immersive VR goggles (e.g., Hoffman et al., 2014) will increase dissemination of VR studies on pain management also in other countries, including developing countries. As indicated by Hoffman et al. (2011), there is a need of more research on pediatric population, because the large numbers of children severely burned each year, but also for other kinds of painful procedures. Moreover, the importance of VR hardware and software tailored to the needs of the patient is essential to obtain a better analgesia. Recently Bidarra et al., (2013) reported that during dental procedures the patients have to reduce their movements, and created a specific software for children to use during dental procedures (Bidarra, Gambon, Kooij, Schutjes & Tzouvara, 2013). Similarly, SnowWorld, the first VR world specifically designed for pain control in burn patients, (www.vrpain.com) is specifically designed to encourage patients to sit still during wound care (e.g., as the wound care nurse uses tweezers to remove staples from an open burn wound).

CONCLUSION

More studies exclusively conducted on children (without mixed data between children and adults) are needed to evaluate the potential of VR analgesia for helping control pediatric pain in several medical settings.

In 2017, major companies such as Facebook, HTC VIVE, Sony, Magic Leap, Microsoft and others, are investing a total of several billions of dollars into developing immersive (and also augmented) virtual reality, and are mass marketing VR systems to the general public. Highly immersive VR systems are becoming more widely available, increasing the availability of immersive VR for pain control. More research using these highly immersive VR systems is needed.

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KEY TERMS AND DEFINITIONS

Attention: The cognitive process that let to select information from the environment in a specific moment.

Distraction: The action to draw of attention away from the primary task to another stimulus.

Pain: Unpleasant experience connected with an actual or potential tissue damage, or described in terms of such damage.

Presence: The subjective perception of being in a virtual environment and living a realistic experience.

Procedural Pain: An acute pain caused by medical-diagnostic procedures.

Snow World: The first virtual reality environment created for virtual reality analgesia with burn patients.

Virtual Environment: An artificial 3D world, that reproduces real objects or generates new ones, with which users can interact at different levels.

Virtual Reality Analgesia: Psychological technique based on distraction, used to reduce pain in adults and children.

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Rosapia Lauro Grotto has a Degree in Physics, a Degree in Dynamic Psychology, and a Ph.D. in Cognitive Neurosciences, and she is Professor of Dynamic Psychology and Group Psychodynamics at the Department of Health Sciences of Florence University (Italy). She is member of the Italian Association of Psychology, of the International Sandor Ferenczi Society and of the Italian Society of Historical, Philosophical and Social Studies of Biology and Medicine. Her actual research interests are focused on two interrelated fields: the modellization of psychodynamic

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Hunter Hoffman, Ph.D., is Director of the Virtual Reality Research Center at the University of Washington in Seattle. Hoffman is research scientist in Mechanical Engineering, and affiliate faculty in Radiology and Psychology. He conducts research at the University of Washington, Seattle Shriners Hospitals for Children Galveston, and Effat University in Jeddah Saudi Arabia. His graduate education was in Cognitive Psychologist specializing in human learning/memory and attention, and is one of the early pioneers applying virtual reality technology to difficult medical and psychological problems such as pain, phobias, and Post-Traumatic Stress Disorder. Hoffman and Patterson co-originated the technique of using virtual reality pain distraction for severe burn patients. Hoffman has designed several virtual worlds (e.g., SnowWorld pain distraction, part of the Smithsonian Cooper-Hewitt National Design Museum Triennial), and he has designed and developed a number of custom original hardware technologies, such as photonic fiberoptic magnet-friendly VR goggles that can be used during fMRI brain scans. Hunter Hoffman was named one of the top "fast 50" innovators of the next 10 years (http://www.fastcompany.com/fast50_06/index.html).

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About the Contributors

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