A Predictive Theory of Mental Evolution and Its Consequences

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CHAPTER I

INTRODUCTION

Introduction

The topics explored in these collected articles follow logically and rigorously from a single observation—the external world can be known only as an internally constructed model. They include the details of sequentially constructing such a model and its resulting expression as a theory of mental evolution with verified predictions. In addition to its integrated description of the mind and its predictions of the archaeology of human phylogeny, the theory has consequences for the nature and temporal origin of consciousness and language, the commonalities of alternate intelligences, the nature of mathematical forms, and the origin and nature of time. It also has implications for the limits of scientific knowledge and modern research in neurology and neuroscience.

The articles present an ordinal and predictive theory of mental evolution and its consequences. The theory is ordinal because the position of each stage of mental development is determined by its relation to its predecessor and successor. Specifically, each stage is an explicit generalization of the one that precedes it, and the theory is ordered by the sequence of these generalizations. Consequently, each level is defined exclusively in terms of levels already defined, so that the resultant precision and clarity allow specific verifiable and falsifiable predictions for each stage of evolution. The theory is unique in many ways, but most importantly, it is scientific. The subject of the mind has traditionally been within the purview of philosophy where the lack of unambiguous definitions prevents recognition of an evolutionary sequence of mental capacities and the possibility of verifiable or falsifiable predictions.

Not only are philosophical ideas such as consciousness undefined but there seems to be little recognition that a definition is useful. Yet without such definitions there can be no coherent discussion about the origin of mental capacities and how they are related. This theory attempts to remedy that situation, and in the process, reclaims territory for science that previously has been ceded to philosophy. At the very least, it offers axioms and unambiguous definitions with which to disagree.

Investigations at the convergence of science and philosophy can create difficulties from both perspectives. As a general rule, natural scientists dismiss philosophical inquiry and its traditional foci as imprecise and non-heuristic. On the other hand, readers theoretically most interested in this theory of mental evolution likely share a philosophical perspective of the mind and asking them to reject their own frame of reference and adopt a scientific system may prove problematic. There is a natural tendency to dismiss ideas critical of one's own and to be skeptical of different approaches to problems at the core of one's discipline. I maintain, however, that when possible, a scientific explanation of a phenomenon is preferred and hope that even those most committed to a purely philosophical view of the mind will at least seriously consider this innovative approach with an open one. This flexibility—scientific and philosophical—may be rewarded with novel solutions to scientifically ignored and philosophically unanswerable questions.

This introduction describes the axioms, definitions, and method for a theory of mental evolution and the rationale and nature of the research that engendered it. It does not include references or significant elaboration, since the arguments with documentation appear many times in the following articles. The repetition will, I hope, gradually increase familiarity with, and understanding of, this novel theory.

Despite the clear and concise definitions, rigorous organization, and logical structure of internal reconstruction and its associated theory of mental evolution, there are at least three elements that may contribute to an initial difficulty in grasping it. First, although the ideas of mental evolution are simple, this does not necessarily mean they will be easily understood on first exposure. The simplicity of the stages of evolution, and their implications, is due to their unambiguous definitions and resultant clarity, but this clarity can be obscured by the competing common, imprecise, and unexamined use of many of the terms.

In addition to a possibly unfamiliar usage of common words, this theory introduces a novel key idea—that of a concept-space—which is simply the place where concepts exist. Since we know of concepts in only one form, as ideas in our minds, it is difficult to separate form and content. However, the precise definition of a concept used here is part of an increasingly sophisticated process of defining categories of objects. As such, it is independent of any representation and can exist in many forms. This, then, is the second difficulty. The increasing complexity of the description of categories and the representation of concepts that form the stages of evolution involve subtle distinctions that are difficult to perceive because they require an unfamiliar perspective and a precise focus on detail.

The final problem in understanding mental evolution is that we do not experience it personally. As infants we are guided rapidly over the developmental stages by fully-evolved adults, leaving no trace in memory. Only when the theory's structure is viewed phylogenetically, with the stages extended over thousands of years, do the subtle changes that form the evolutionary levels clearly emerge.

The rigor and precision this theory applies to a system of mental evolution is what makes it unique and useful. However, our linguistic preconceptions, the subtle distinctions among novel ideas, and the shift from a personal to a phylogenetic perspective can present a challenge. Although synonymous in common usage, *simple* and *easy* are antonyms when applied to most abstract topics.

Internal Model Versus External World

Contrary to the title, and despite the majority of the topics explored, the assembled articles originated neither in a research project whose goal was a theory of mental evolution, nor in an attempt to engage in discussions about neuroscience or the nature of consciousness. My interest initially was in the form of physical laws, i.e., why do they appear as they do and what exactly do they describe? It seemed reasonable then—and still does—to begin at the beginning, with the seemingly unarguable observation that a physical organism can know the external world solely as an internally constructed model. For this reason, I thought of the investigation as an attempt to create a rigorous description of internal reconstruction. By carefully following this process, it should be possible, I thought, to separate and identify aspects of the internal model that may be consequences of physical structure, thereby clarifying the nature of those aspects that are independent of it.

There are at least two reasons to suspect that the nature of the internal model may be influenced by the mechanism and circumstances of its construction. First, the physical structure of any organism requires that sensory information—the raw data of internal reconstruction—be significantly altered and degraded. The essentially continuous external world must be discretized, sampled through a coarse filter (e.g., the senses), and converted into a common form (e.g., bioelectric impulses) before it can be reassembled. Second, the internal machinery of reconstruction reflects adaptations to idiosyncratic geologic, ecologic, and phylogenetic changes. The resulting internal model would be expected to reflect these unique occurrences.

It seems likely that these two factors may limit the correspondence of the internal model with external realities and may have consequences that can be identified by a careful examination of the reconstruction process. But this limitation itself has a profound astrobiological significance: any rigorous consequences that are derived from physical structure necessarily apply to all sentient species that share those structures. These, then, were my thoughts at the outset of this project and the motivation for its pursuit.

Surprisingly, the question of whether the internal model and the external world may be different is not one that has previously been asked by natural scientists, or as far as I am aware, even recognized. The only explanation must be an implicit assumption that the two do not differ. This could be true, however, only if the external and internal worlds are either equivalent—more rigorously, isomorphic—or identical. Clearly it is *prima facie* impossible that they are identical, so the assumption must be that they are isomorphic. An isomorphism is a mapping between two sets that maintains the relationships among their elements. This means that it maps every element of one set to a unique member of the other, and that every element of the second set is the result of such a mapping.

Because of this "one-to-one and onto" nature, each isomorphic function must have an inverse, and isomorphisms are also known as bijective maps. As such, all elements, structures, and laws of the internal model would be seen as functionally congruent to those of the external world. But this cannot be. Technically, the functional relation between external and internal is a composition of two maps—decomposition and reconstruction. If an isomorphism did exist, by definition, there would be an inverse map from internal to external that would consist of an inverse reconstruction map followed by an inverse decomposition map. But since the latter is not one-to-one it cannot have an inverse, and therefore an isomorphism cannot exist.

Though the internal model and external world are demonstrably not identical or isomorphic, this demonstration does not identify the specific nature and significance of their difference. In theory, there is no constraint on how they may differ, but practical survival necessities impose significant extrinsic limitations on the degree to which the two may diverge. For example, miscategorizing a speeding car as a palm tree will expunge the person's genes from the gene pool. Thus, biological evolution "fine tunes" the model through natural selection. But this process has no influence at an abstract level of description where selective pressures do not directly operate (e.g., a mathematical description of the dynamical system of the person and speeding car). The only way to identify a consequence of reconstruction that affects the structure of the internal model—and therefore is relevant to the internally reconstructed laws of natural science—is by a careful and detailed analysis.

The focus on internal reconstruction has two immediate consequences. First, the stepwise construction of the model clearly defines the origin and nature of its constituent elements. Since the fundamental components of the theories of natural science all have their analogs in this internal model, these foundational scientific principles, as we know them, must originate as a consequence of internal reconstruction. This positioning of biology as fundamental to physics inverts the traditional order of basic sciences. For example, scientists and philosophers have discussed the nature of time and the integration of its scientific and experiential characteristics for millennia without resolution. Careful examination of the internal origin of time, however, reveals a natural hierarchy that integrates the different types of time and effectively eliminates contradictions.

Second, the structural exigencies of any physical organism result in a necessary congruence of internal models. These similarities establish commonalities of diverse sentient species that previously have been purely speculative, but now become amenable to rigorous investigation.

The Study of Mind

Despite the origin of this investigation in a question about the nature of physical laws, as I learned more about diverse disciplines, it became clear that the investigation of internal reconstruction could be described from the perspective of more familiar fields, thereby enhancing its understanding and also resolving important open questions. The two most significant of these applications are to the foundations of neurology and neuroscience and to the archaeologic record of human phylogeny.

In the rest of this section—based on the origin of neurology and neuroscience as derived by John Hughlings Jackson—I interpret many of the classic issues of the mind and brain using the theoretical structure of internal reconstruction to establish an infrastructure for mental evolution. These include a) the specific types of logic that characterize mind and brain functions; b) an interesting complementarity, or dual structure, demonstrated by the logical characterization; and c) the relationship of mental processes to electrical activity of the brain. I then describe how this analysis differs from a traditional philosophical approach and suggest significant strengths of the former and limitations of the latter.

The Science of Neurology

There are many potential definitions of science. For the present purposes, I will define science as a circumscribed body of knowledge that is organized by a predictive and reproducibly testable theory and includes explicit axioms and methods. By these criteria, the science of neurology began with the pioneering work of John Hughlings Jackson, a Victorian physician. He created a new science of the brain using an evolutionary structure inspired, in part, by the currently discredited ideas of Social Darwinism promulgated by Herbert Spencer. The relevant parts of Hughlings Jackson's formulation use the most general characterizations of evolutionary systems, however, and are not related to the objectionable parts of Spencer's work.

Hughlings Jackson's circumscribed body of knowledge is the human nervous system, his tripartite method is explicit, his axiom is that the nervous system is exclusively sensorimotor, and his reproducibly testable and predictive theory is weighted ordinal representation. His method is explained and referenced in the included papers but is relevant to the current discussion only in that it establishes neurology as a science. His axiom, that all functions of the nervous system are sensorimotor—though, at the highest levels, extraordinarily complex—limits the scope of neurology to clinically observable events. And this restriction, after millennia, finally expunged the variable and irreproducible aspects of the mind and soul that had prevented the emergence of a predictive and reproducible neurological science.

His theory of weighted ordinal representation states that the nervous system is a hierarchy of three functional levels—representing, re-representing, and re-re-representing the physical body. Each element of each level contains an entire copy of the preceding stage—an organization that is, by definition, ordinal.

Two principles underlying this theory are that 1) the stages of evolution demonstrate increasing complexity, increasing definiteness, and increasing interconnections, and 2) higher levels exert an inhibitory control over lower levels. The practical clinical consequence of this evolutionary hierarchy is that pathological states of the nervous system are characterized by two types of observable symptoms—positive and negative. Negative symptoms are due to loss of a higher function and positive symptoms result from release of a less organized lower level from inhibitory control. The increasingly complex, integrated, and interconnected levels mean that the afferent function of the nervous system is the creation of a similarly structured sensory map of the external world.

Although Hughlings Jackson excluded the mind from the purview of neurology, he clearly recognized that mental functions exist. He posited a parallel structure of three levels with a correspondence between the brain and mind that he termed the doctrine of concomitance in which the brain and mind are completely correlated but causally unrelated, i.e., each brain function correlates with a mental function, but is not its cause.

He did not explicitly discuss the functional relationship between these parallel systems of nervous system and mental evolution. However, his perspective is consistent with my assertion that the afferent function of the nervous system is to create an increasingly complex, ordinally structured sensory map of the external world, and the role of the mind is to interpret this structure.

Hughlings Jackson thought that the highest level of mental function—correlated with the highest level of brain function—was consciousness and predicted the existence of subconscious mental functions concomitant with the two lower levels of nervous system evolution. Being a rigorous and intellectually honest scientist, when he could not find any evidence of lower mental functions in comatose (i.e., non-conscious) patients—the positive symptoms predicted to appear as lower levels emerge from inhibitory control—he rejected his evolutionary structure for the mind. As described in the following articles, this rejection was based on a simple technical error, and when corrected, a suitably adjusted interpretation of his ideas is identical to this theory.

Hughling Jackson's description of the relationship between mind and brain is general and nonspecific, though it is seminal, and helps explain my decision to demonstrate the process of internal reconstruction as one of mental evolution. Still, two additional levels of description are needed to complete his analysis—a logical or functional level and its implied consequence, and a structural or physical level.

Logical/functional observations

The explicit functions of mind and brain emphasize their antipodal differences and dual nature. The brain, as a sensorimotor machine, operates deductively, while the mind operates inductively. In fact, intelligence—as a measure of mental function—can be succinctly defined as the facility of induction. The greater the intelligence, the more rapidly and accurately general conclusions can be drawn from specific instances. As will be seen in this theory of mental evolution, the inductive character of the mind is explicit, as each stage is formed by an equivalence identified in the preceding stage, and identification of an equivalence—or generalization—constitutes induction.

An analogous characterization of the brain as a sensorimotor machine is that it is governed by reflex action throughout. In fact, Hughlings Jackson's axiom is the culmination of the extended development of an idea known as the Law of Reflex Action. A reflex can be expressed as a syllogism as follows: if "afferent x" occurs then "efferent y" follows; given "x," therefore "y." In classic logic this is known as *modus ponens,* the defining feature of deduction. The nature of the afferent and efferent processes become incredibly complex at higher levels of brain structure, but their nature as sensorimotor, and therefore deductive, is assured by the axiom upon which all neurology and neuroscience is based.

Complementarity

An interesting consequence of the (respectively) inductive and deductive natures of mind and brain is that they are dual structures, or complementary in the rigorous sense of the term—like heads and tails, night and day, or particle and wave. Complementary pairs are mutually exclusive yet reflect a unity at a higher level of abstraction. That is, heads and tails are unified by the structure of the coin, night and day by the rotation of the earth, and particle and wave by the solutions of the wave equation. The complementarity of brain and mind, or deduction and induction, indicates an abstract unity whose exact nature is interesting to contemplate, but one I have not been able to resolve.

Physical/structural observations

An important practical question that immediately arises when discussing a relationship of brain and mind is a structural one, i.e., how do the processes of the mind, whatever their specific nature, relate to the patterns of electrical activity that form the sensorimotor structure of the brain? Although the exact nature of this physical relationship is not relevant to this theory because internal reconstruction is functional and independent of any specific instantiation, I personally believe—and there is some experimental evidence—that the mind is an emergent property of the brain. Although the term *emergent* is found in many fields and with many meanings, I will use its general description from solid state physics, which consists of three defining features: an emergent system 1) cannot be predicted by a microscopic description of the substrate from which it emerges. In other words, it cannot be described reductively, 2) is substrate-independent, and 3) is characterized by long-range correlations.

Identification of an emergent mind can only be experimental. There has been some direct evidence that suggests this, but other, less direct, data also are consistent with this conclusion. For example, a long-range correlation is found in low-frequency global brain electrical activity that appears to be associated with transfer of information from short-term to long-term memory. Also, even within an individual, the substrate of the mind, i.e., the physical structure of the brain, varies due to atomic and molecular replacement over time while mental processes are unaffected. Although it is uncertain if, or to what degree, brain cells are replaced, their components definitely are, and, in this limited sense, the mind must be substrate-independent.

If the mind is emergent according to these criteria, at least two important and interesting consequences arise. First, since the mind's substrate is the brain, it cannot be explained—by definition—through any microscopic description of brain structure. This is a reason to be skeptical about explaining consciousness in terms of the physics of the brain, as mentioned below. Second, if the mind is substrate-independent, mental processes are not caused by the specific human brain structures from which they emerge. Therefore, there is no restriction on the potentially diverse forms of astrobiological intelligences, that are otherwise precluded if mental functions are seen merely as a reductive consequence of activity of the human brain (or an identical structure).

Viewing the mind as an emergent property of the brain may be an attractive and intuitive proposition, but it is important to note that this characterization is not essential to any part of internal reconstruction or mental evolution. The critical relation between mind and brain is a functional one, and the physical correlation of cerebral and mental processes is inconsequential. Though an emergent relation seems the most rational explanation for the dual logical structures described above, the specific manner in which their complementarity arises is not relevant. The theory itself is unaffected by the physical or structural relationship of mind and brain, whatever its exact nature.

Beyond Philosophy

The study of the mind traditionally has been within the purview of philosophy, and possibly the major innovation of this theory is that its approach is purely scientific—i.e., it is axiomatically based, it is unambiguous and clearly defined, and it makes verifiable (or falsifiable) predictions. This means that the theory places the study of the mind in a context that can be rationally discussed and argued, and from which progress can be made. Since the nature of mental capacities has traditionally been a subject of conjecture, not a topic of scientific study, a clear and unambiguous definition of the current final level of mental evolution, i.e., consciousness, has not been possible. And without such an unambiguous definition, it is not possible to suggest axioms and generate a hierarchy of well-defined capacities from which consciousness emerges—in short, to derive a continuity of evolving mental abilities. Conferences and symposia on consciousness and the mind rarely offer such definitions or even recognize their usefulness. Any proposed explanations are *a posteriori*, consisting of a collection of characteristics of consciousness or the mind, and are inadequate to form rigorous definitions amenable to scientific or evolutionary analysis.

One potential method of resolving some of the ambiguity in the purely philosophical approach has been an attempt—especially in recent years—at integrating philosophy of mind and physical science. Unfortunately, this attempt at grafting rigor onto ambiguity cannot clarify the underlying lack of understanding of either mind or consciousness. A rigorous description of how consciousness occurs in the human brain is theoretically possible, but only if the nature of consciousness is first clearly understood. An example that has generated an entire academic industry is the attempt to explain consciousness as a quantum process. The rationale for such investigations seems to be based on a questionable syllogism: consciousness is mysterious and seems *sui generis*; quantum mechanics is mysterious and seems *sui generis*; therefore, quantum mechanics must have something to do with consciousness. Of course, the relevance of a quantum description of consciousness based on shared incomprehensibility is neither heuristic nor convincing. A more serious objection, however, is that, if the mind is an emergent property of the brain, which seems likely, it is by definition impossible for it to be explained by a microscopic or reductive description of the substrate from which it emerges—including any quantum brain processes.

Mental Evolution

The following sections describe the terms and axioms underlying the theory of mental evolution, construct its ordinal stages, explain its predictions, and show how the predictions can be verified. Finally, I preview three significant consequences of the theory emphasized in the collected papers—the nature and temporal origin of consciousness and language, and the limits of knowledge that are implied by these novel explanations.

As a science, this theory of mental evolution consists of a circumscribed body of knowledge—the mind—three explicit axioms, a method of ordinal generalization, and a reproducibly testable and predictive theory of internal reconstruction. The theory begins with clearly stated axioms and progresses so that each element of each stage is an equivalence class of elements in the previously defined level. This ordinality provides unambiguous definitions of mental capacities and a clear description of how these capacities are related and how they arise. The theory, which is based on a single observation—any organism can know the external world solely as an internally constructed model—culminates in a rigorous and unambiguous definition of consciousness.

Definition of Terms

The following terms have specific meanings in this theory of mental evolution: *concept, concept-space, recognition,* and *definition*.

Concept—a collection of attributes that determines membership in a category, is independent of its representation, and so, can exist in many forms. That is, a concept is an explicit equivalence relation and can be thought of as a category itself, independent of its members.

Concept-space—the place where concepts exist. This idea may initially seem unnecessary since the concepts of modern humans exist in an abstract mental space, and their form and content seem inseparable. But the abstract mental space itself is a product of evolution, and before it existed, concepts were embodied in a modified physical object—a physical concept-space. For example, a carved stone displaying the physical characteristics of an animal is the concept-space of an Upper-Paleolithic-Age concept.

Recognition—a process that involves comparison, as differentiated from definition.

Definition—a process that involves specification. For example, recognition of an object as a horse requires a mental comparison between it and previously encountered horses. Recognition does not require awareness of the characteristics that define a horse, or even that such characteristics exist. In contrast, definition of a horse requires specification of those characteristics that delineate "horseness."

Axioms

This theory is based on three axioms—the first is global, the second applies to the function underlying mental evolution, and the third is required to validate (or falsify) the predictions of the theory.

Axiom 1—The external world of any physical organism can be known only as an internally constructed model. It seems inconceivable that this is not true, but it is assumed and not proven.

Axiom 2—The function of the mind is generalization, or the mind is an inductive machine. A strong rationale for this idea is based on the science of neurology, which is possible only if the brain is seen as a purely sensorimotor machine. Because higher brain functions are increasingly complex, integrated, and interconnected, the afferent function of the brain is the construction of an increasingly complex sensory map of the external world. I posit that the function of the mind is to interpret this construction, and that these internally constructed sensory maps provide the substrate for mental evolution.

Since increasing mental capacity is most generally characterized by increasing inductive facility—the ability to identify equivalence—this axiom states that the specific function that interprets the brain's sensory maps is generalization. The elements of internal sensory maps are generalized and re-generalized in the mind, producing an increasingly complex, ordinally structured hierarchy of mental functions.

Prediction of a sequence of archaeologic artifacts from the hierarchy of evolutionary mental functions requires three corollary assumptions that together form the third axiom: mental capacities 1) can be correlated with a phylogenetic sequence; 2) are reflected in archaeologic data; and 3) are expressed as soon as they arise.

Axiom 3—The minimum mental capacity necessary to produce an artifact is the capacity indicated by the archaeologic appearance of that artifact.

The Process of Mental Evolution

The process of mental evolution proposed in this theory results from the instantiation of the abstract sequence of internal reconstruction in human phylogeny. The first two stages of internal reconstruction—sensory transduction at an organism's boundary surface, or the conversion of diverse external input to a common internal mode, and the identification of separate objects and the origin of time—are the most unfamiliar and may be the most difficult to understand. In addition, although they are arguably the most significant from a purely scientific perspective, they offer no observable predictive consequences. For this reason, the following discussion assumes that separate objects already have been identified within the sensory maps. I will discuss these first two steps of internal reconstruction later in this introduction and in the articles presented in the appendices, trusting that the explanation of the rest of mental evolution will help clarify these more abstract precursors.

The sequence of mental evolution consists of two parts. The first is an ordinal hierarchy that begins with objects and categories of objects and ends by defining a concept that explicitly describes what it means to be a member of the category—the category's equivalence relation. With objects identified as equivalence classes among separate global patterns of activation, the first stage of a predictive process of mental evolution begins. Each stage results from an equivalence identified in the previous level and, therefore, is defined exclusively in terms that already have been defined. This ordinality and precision provide clarity and rigor that previously have not been applied to mental processes.

The second part of the mental evolutionary sequence follows the introduction of the innovative idea of a concept-space, the place where concepts exist. As mentioned earlier, since we know of concepts only as ideas in our minds, form and content seem synonymous. However, this definition of a concept does not include any reference to how it is represented, and so it can exist in many forms. The increasing complexity of an ordinal sequence of concept representation—culminating in the abstract concept-space of consciousness—then forms the final phase of mental evolution.

Although the ordinality of the theory determines its scientific nature and is probably its most significant contribution, it also can complicate understanding. The lack of ambiguity that results from each stage of evolution being defined in terms of the previous one also means that once a higher level is achieved, its predecessors are subsumed and become functionally obsolete. In essence, the stages are erased as they are superseded. Consequently, from the perspective of a fully evolved (conscious) human, it is extremely difficult to perceive the subtle steps that are required to achieve our highest level of mental evolution. This is why consciousness seems unprecedented and why philosophy cannot identify what it is and from where it came.

Because the stages of mental evolution involve ordinal distinctions that are no longer relevant to our fully evolved thought—in both the characterization of categories and the representation of concepts—understanding the nature and origin of our modern mind requires both an altered perspective and an uncommon attention to detail.

Despite these hurdles—and as possible incentive to surmount them—the unambiguous nature of the evolutionary stages not only rigorously defines how mental functions arise and how they are related but ties their expression to the archaeologic record of human phylogeny and, thereby, generates testable predictions. It is also through this phylogenetic perspective that a clear view of the sequence of subtle capacities that form the stages of mental evolution becomes apparent.

Assuming that the minimum level of mental capacity necessary to produce an artifact is the capacity indicated by the appearance of that artifact, the increasingly complex levels of mental function predict the appearance of specific artifacts—and only those artifacts—in a specific order in the archaeologic record. This theory of mental evolution not only predicts the precise—and exclusive—observed individual artifact classes but also the sequence in which they appear. In contrast, current interpretations of the meaning of early human artifacts—such as Neandertal burials being the birth of religion, or cave wall paintings being the birth of art—depend on nebulous and undefined notions of religion and art and cannot explain their sequential emergence.

Stages of Mental Evolution and Predicted Archaeologic Artifacts

Mental evolution begins with the partition of internal sensory maps into separate objects. It proceeds through repeated generalization in five ordinal stages: a) categorization, b) protoconceptualization, and c) conceptualization in 1) a contingent physical concept-space, 2) an independent physical concept-space, and 3) an abstract concept-space. Categorization involves recognition of the similarity of objects; protoconceptualization, recognition of the commonality that is the basis of categorization; and conceptualization, explicit specification of this commonality. Initially, physical objects embody the explicit characteristics that determine membership in a category and form a contingent physical concept-space that is inseparable from the concept itself.

The mind next recognizes the concept-space as an entity separate from any concept it carries, constituting an independent physical concept-space. Finally, the concept-space is defined, creating an abstract concept-space. ***The formation of an abstract concept-space marks the achievement of consciousness; and the mode of expression of abstract concepts is language***.

Once the process of mental evolution begins, each stage is formed by identifying an equivalence in the previous one, providing an adaptive advantage that contributes to further mental development. This adaptive advantage is the increasing capacity to retrieve elements of the perceived world for consideration, planning, and communication when they are not physically present.

Categorization

Categorization involves recognition of the similarity of perceived objects, and a category is defined as a collection of these equivalent objects. For example, the mind recognizes a category of horses that serves as a standard of comparison to determine if a newly encountered object is a horse. Each object that is identified as a horse inherits the characteristics of previously encountered horses. All animals have the mental capacity for categorization, since they at least recognize the category of food. Increasing complexity of categorization involves recognition of more categories, subcategories, and higher-order categories, such as categories of categories. Once a category is recognized, details of the category's elements, and similarities among them, also can be identified. These similar details form new categories that are subcategories of the original category. For example, once the category of horse is recognized, it is possible to recognize subcategories such as horse's head, tail, and limbs.

Predicted archaeologic artifacts. Since a category serves only as a standard of comparison and has no independent existence, this stage should not be associated with any observable form of representation or include any nonutilitarian artifacts.

Protoconceptualization

Protoconceptualization emerges with the recognition that the elements of a category have been grouped together because they share an equivalence—a set of defining characteristics. This stage is characterized by the recognition that a category exists independent of its members. That is, the defining characteristics of a category form a generic or ideal element—the equivalence relation—that is not an actual member of the category, but rather can be seen as the category itself**.** Once protoconceptualization, or the recognition of the existence of such a generic element, has occurred, a category can be retrieved for consideration independent of an observation. However, although the equivalence is recognized, it cannot be specified, so only a member of the category that manifests the defining characteristics can represent it. The protoconcept "horse" thus must be a particular horse.

Predicted archaeologic artifacts. The minimal mental capacity required to recognize the equivalence underlying a category, or that a category exists independent of its members— protoconceptualization—is marked by the appearance of unaltered natural objects that are intentionally isolated or displayed, each representing the category of which it is a member.

Conceptualization in a contingent concept-space

Conceptualization in a contingent concept-space occurs when the equivalence forming a category is defined. This can take place once subcategorization has produced protoconcepts that recognize sufficient fine detail within a category. For example, the protoconcept of the category of horse's tails is the recognized generic horse-like tail. A collection of these recognized generic characteristics of horses forms a generic horse—the concept "horse." Thus, a concept is defined as a collection of protoconcepts, or attributes. At this stage of evolution, a collection can only be assembled in a physical object, since no other type of space exists.

Therefore, the attributes defining the equivalence relation of the category are assembled in a unique, physical concept-space—a modified object such as a sculpture, a cave-wall painting, or an engraving of a horse. The concept and its concept-space—the image and the material in which it exists—are inseparable. In other words, the physical medium has significance only as the locus of assembly for the defining characteristics of a category, and the defining characteristics can only be brought together in such a physical object—neither can exist without the other. In this sense, the physical concept-space is contingent. It also provides an adaptive advantage, since concepts can be displayed in any convenient physical medium and be of any size, and so can be assembled and manipulated much more easily than protoconcepts, which must be members of their categories.

Predicted archaeologic artifacts. The minimal mental capacity required to explicitly specify the defining characteristics of a category—or concept—in a contingent concept-space is associated with the appearance of reproductions or representations of individual, recognizable objects in a physical medium.

Conceptualization in an independent physical concept-space

Conceptualization in an independent physical concept-space is defined as the recognized equivalence of contingent concept-spaces and results in a concept-space separate from any particular concept. So, for example, a carving of a horse and a carving of a bull are seen to have something in common—the stone that can accommodate either animal. A recognized equivalence must include any property shared by all of a category's elements, and since the contingent concept-spaces are all physical objects, the independent concept-space must also be a physical space. The emergence of the independent physical concept-space enables expression of increasingly complex conceptual relationships.

This capacity is manifested by compositional reproductions in which multiple concepts interact in a common space, e.g., a composition containing both a horse and a bull. In fact, the existence of an independent concept-space is necessary and sufficient for the innovation of composition. It is necessary because a composition cannot exist without a common space in which the individual elements of the composition are unified; and it is sufficient because all elements that appear in a common space are understood to be part of a unified composition. The appearance of an independent physical concept-space contributes to a significant adaptive advantage. For example, the existence of a common space in which multiple concepts can interact would enable, for the first time, expression of a shared story or myth. It also would enable more detailed transmission of information important for communal concerns such as tribal cohesion or hunting, and so represent a significant improvement over previous stages of evolution.

Predicted archaeologic artifacts. The minimal mental capacity required to define an independent physical concept-space is marked by the appearance of compositional reproductions in the archaeologic record.

Conceptualization in an abstract concept-space

Conceptualization in an abstract concept-space results from the specification of the equivalence of the independent physical concept-spaces, constituting the next ordinal stage—a generic independent concept-space. Each independent physical concept-space can accommodate only a limited number of concepts, but the generic independent concept-space must have an arbitrarily large capacity. Since no physical space is infinite, however, this must be an abstract space. In physical concept-spaces the concepts are expressed as visible collections of a category's defining features, which are shared by those who view them. The abstract space is invisible, however, so a means must be created to retrieve and share the concept. A name, e.g., *horse*, specifies the location of the concept in the abstract space, making language the shared expression of abstract concepts. Language demonstrates the ability to express the collection of attributes defining the category of horses that exists in an abstract concept-space—the abstract concept "horse."

Predicted archaeologic artifacts. The minimal mental capacity required to express the collection of attributes defining a category that exists in an abstract concept-space—an abstract concept—is the use of a word describing that abstract concept. This stage is marked by the appearance of language and, as a result, should be associated with the disappearance of all physical expressions of concepts.

The existence of this abstract concept-space vastly facilitates conceptual operations, since concepts can be juxtaposed and hypotheses tested mentally, rather than by manipulation of physical representations. This increased mental efficiency also enables very high-order categorization identifying fundamental equivalences in the perceived world and defining objects whose existence is completely abstract.

To reiterate, the formation of an abstract concept-space constitutes consciousness, and conscious beings live in a model of the world that is created in this space. This model reproduces conceptual counterparts of the objects and relationships of the external world in the abstract space, and its existence explains the subjective sense of a separate observer that is a prominent characteristic of consciousness. Conscious beings do not simply act, but also are able to observe themselves acting because an action is performed both in the physical world and in the model of that world that resides in the abstract concept-space.

The ordinal nature of the stages of mental evolution provides an explanation for the universal development of language—and other mental capacities—even in possibly isolated human populations. The modern human brain includes the sensorimotor structure necessary to set mental development in motion. The process then unfolds independently, each stage arising as an equivalence identified in the one that precedes it. Although extended over thousands of years in phylogeny, each stage follows a clear path from its formation as a simple equivalence within its predecessor to an intrinsic equivalence that will be identified and then form its successor. As noted previously, the main difficulty in retrospectively perceiving the equivalences that form the levels of evolution is that each is so easily subsumed and made functionally obsolete by the greater mental capacity at the next highest stage. Contact and direct transmittal can alter the evolutionary rate, but not its ultimate occurrence and outcome.

Correlations with Paleolithic-Age Artifacts

The predictions of the theory of mental evolution explain the nonutilitarian Paleolithic-Age artifacts and their sequence, and the exact correlation with the archaeological record simultaneously provides verification of the theory. The artifact classes discussed below encompass the complete archaeological record but do not include all of the details that are discussed in the collected articles.

The only human artifacts found until the end of the Lower--Paleolithic Age and the ascendance of Neandertal Man are stone tools. Although human tools are more modified, more varied, and more permanent than those produced by other animals, the differences are of degree, not kind. Thus, the tool-producing hominids defining the genus Homo (i.e., *Homo habilis* and *Homo erectus*) were at the same level of mental evolution as other animals. This lack of nonutilitarian human artifacts in the archaeologic record correlates with the theoretical prediction of their absence at the evolutionary stage of categorization.

The Middle-Paleolithic Age

The Middle-Paleolithic Age begins with the ascendancy of *Homo sapiens neanderthalensis* approximately 100,000 years ago, and three associated artifactual innovations have been reported: human burial; manganese oxide and ocher used for body painting or dyeing of animal skins; and possible "ritual sites" devoted to cave bears and human skulls. A unifying characteristic of these artifacts is the isolation or display of unaltered natural objects—for burial and body painting, the dead and living human body, respectively; for ritual sites, cave bear skeletons or human skulls. Thus, each of these artifact types exactly demonstrates the predicted products of the evolutionary stage of protoconceptualization.

Although many fanciful meanings have been ascribed to early human burial, it most simply indicates recognition of some property of an individual that exists independent of the body. Since the category of an individual consists of a single object—the body of the individual—recognition of a defining characteristic independent of the body indicates the recognition of a category's existence independent of its element, the definition of protoconceptualization. The absence of burial prior to this era must mean that the body had no meaning beyond its existence as an object, which, in turn, implies that the mental capacity of protoconceptualization had not yet been achieved.

Since a protoconcept must be a member of the category it represents, only the physical body can act as the protoconcept for the human self. In this unique case, both the subject—the proto-I—and the object—"me"—reside in the body of the individual. Distinguishing the two necessitates isolating or displaying the object that is "me," as with any other protoconcept. The presence of pigments in Middle-Paleolithic-Age deposits is thought to indicate that Neandertal man practiced body painting and dyeing of clothes. Dichromatic body painting and the coloring of crude fur clothing are the most elementary methods of differentiating the proto-I from its object, thereby recognizing the existence of the (proto-) subject.

The beginning of the Upper-Paleolithic Age

The beginning of the Upper-Paleolithic Age is heralded by the dominance of *Homo sapiens sapiens*. This is the time when physically modern humans began developing modern mental capacities. Two classes of nonutilitarian artifacts characterize this era—statuettes, paintings, and engravings; and personal ornamentation. Statuettes, paintings, and engravings are discrete, easily recognizable objects reproduced in a physical medium. These characteristics are precisely the predicted consequences of conceptualization in a contingent concept-space and are *prima facie* evidence of the mental capacity of this stage of conceptualization.

Specific characteristics of images produced on cave walls and engraved in stone blocks provide additional support for the conceptual nature of early Upper-Paleolithic-Age reproductions. Discrete cave paintings and block engravings nearly universally demonstrate superposition of images, often to the point of complete obfuscation. In addition, many block engravings were broken and tossed aside, apparently used for paving or building, like any other stone. It seems likely that these creations would have been more carefully preserved if humans capable of abstract thought had produced them with an artistic purpose. A more probable explanation is that the paintings and engravings functioned as concepts inhabiting discrete concept-spaces. These artifacts can be compared with notes that are written at a particular time for a particular purpose. They can then be balled up and thrown away or overwritten, with only the last message having any meaning.

The appearance of personal ornamentation at this stage provides further artifactual evidence of the definition of a category and existence of a concept. The concept here is the subject "I," and the natural choice for its physical concept-space is the body. In all other cases, a true concept is easily separable from a protoconcept of the same category, since the latter is a member of a category, and the former is a reproduction in a different medium. In this case, however, as with the protoconcept "I" and the category "me" at the stage of protoconceptualization, subject and object coexist in the body; and a way must be found to distinguish them.

As body painting provided this differentiation at the prior evolutionary stage, personal ornamentation differentiates the concept "I" from the object "me" at this higher level of mental functioning. Realistically, the only way to distinguish the protoconcept and concept of an individual is the sophistication or complexity of the body's decoration. The multicoloured tattoos and vast array of personal ornaments that characterize the archaeologic record of the Upper-Paleolithic Age contrast strongly with the dichromatic body painting and dyeing of skins associated with the Middle Paleolithic. This advance provides evidence of the mental evolution from recognition of the category to its definition.

The final phase of the Upper-Paleolithic Age

The final phase of the Upper-Paleolithic Age is characterized by the appearance of carved and painted compositional reproductions. This achievement is the predicted consequence of the emergence of an independent physical concept-space and, as previously indicated, it is necessary and sufficient to explain this appearance.

The Mesolithic Age

The Mesolithic Age is a rather opaque era that is characterized by two remarkable and apparently contradictory features: 1) the disappearance of Upper-Paleolithic-Age naturalistic reproductions; and 2) rapidly advancing mental capacities as evidenced by the early stages of urbanization, domestication of plants and animals, and the appearance of organized warfare. The disappearance of Paleolithic-Age "art" has been difficult to reconcile with the cultural innovations of the Mesolithic Age, since art is often considered to be the epitome of cultural expression. However, this theory of mental evolution offers an explanation. Paleolithic-Age "art" disappeared because it did not function as art at all. Rather, it served as the increasingly complex expression of concepts in an evolving physical concept-space that became instantly obsolete when the ability to express abstract concepts through language appeared, as it did during the Mesolithic Age.

Innovative Implications of the Theory

The articles emphasize several innovative implications of this theory, among them, a clear and unambiguous nature and temporal origin of language and consciousness, and the limits of knowledge that can be established by applying these novel results. A distinguishing feature of this analysis—when compared with other descriptions of consciousness and language origins—is that its theoretical construct is independent of any philosophical or linguistic assumptions. It confirms the commonly assumed intimate relationship between consciousness and language, but without reference to philosophy or linguistics. A primary goal of establishing a theory of mental evolution was to explain—as a consequence of a rigorous, ordinal, and independent analysis—what language and consciousness are and when they appeared. The result suggests a late origin of both in human phylogeny supported by the validated predictions of the theory found in the archaeologic record.

A statistical analysis of language also supports its late origin. The argument suggests that the sound-making capacity of the modern human larynx creates a vast redundancy in potential word creation relative to all languages that have existed. Since nature abhors such profligacy, the most reasonable conclusion is that the sound-making capacity of modern humans evolved long before language and for a far less efficient type of communication. When language evolved, only a minuscule fraction of the possible words were needed.

With the preceding articles having established an unambiguous definition of language in the context of an internal model of the world created by each individual, the final article explores an analysis of communication between individuals, societies, and civilizations and identifies semantic limitations on expression that extend from natural language to the most abstract languages of science and mathematics. It demonstrates that all words and symbols have an essential ambiguity that limits the precision of any form of communication and thus limits what can be expressed. For example, the sensory data received by an observer of an epileptic seizure is presumably the same for a Babylonian or a modern neurologist, but the meanings of words used to describe such a natural event are more a result of perception than reception. So the meaning of the Babylonian word for epilepsy, *bennu*, is formed by an observation filtered through the entire social and cultural context that influences its perception. Every aspect of Babylonian life, from notions of the nature of health and disease, to religious and social structures, including hierarchy and kinship, affects it. In other words, the meaning of *bennu* is determined by filtering an observation of an extrinsic recurrent natural event, epilepsy, through the Babylonian model of the world.

This process is, of course, the same for any society, giving rise to two important consequences. First, our observation of a recurrent natural event does not give us enough information to completely determine the meaning of the word describing the same event in another society. And second, since all observations are distorted, no word or symbol used to describe a natural event describes it completely and precisely. A word or symbol denoting any recurrent natural event specifies more information than the simple sensory data—in short, it includes the multifarious contextual associations and interpretations characteristic of the society in which the observation occurs. Thus, any word used by a society to describe a natural event overspecifies the observation.

Societies are composed of individuals, and each individual has his or her own model of the world. Therefore, no two people have the same collection of experiential or contextual data for the meaning of any given word. For example, although the English word *epilepsy* labels a particular disease, each individual's complete definition of epilepsy depends on a unique set of experiences and associations. If this is so, the word *epilepsy* must have a consensual definition. That is, its meaning is formed by the intersection of all individuals' unique associations that comprise their personal definitions of the disease.

Since a society shares a great deal of context, two members of a society will share a more detailed idea of epilepsy then would either person with a member of a different society. And, of course, the society of neurologists will share an even more detailed and specialized definition. But since the meaning of the word *epilepsy* consists of the common features shared by a group of individuals, and each individual has experiences and associations with epilepsy that are not part of the group definition, the exact meaning does not exist for any single member of the group. In this sense, the meaning of a word used by a society underspecifies any individual's definition.

In summary, a word or symbol in any language and society has three interrelated characteristics. First, its meaning cannot be known completely. Second, it overspecifies the observation it describes, containing contextual elements unique to that society, and third, it underspecifies the definition of any member of that society, since it consists of only the aspects common to all members.

Therefore, the meaning of a word or symbol, as it appears in a document or any other form of interpersonal communication, has a strange existence suspended between the individual and the observed world, partially reflecting extrinsic and intrinsic realities, but not accurately reflecting either. It cannot completely reflect external reality because the model of the world through which it is filtered distorts this reality, and it cannot precisely reflect the internal reality of any individual because it is restricted to only those elements held communally. It is this existence apart from the actual realities of the physical and personal worlds that will be shown to impose limits on scientific and historical knowledge.

Modern Consequences of Mental Evolution

This presentation of mental evolution in terms of neurology and neuroscience has some interesting implications for modern research programs in those disciplines. In particular, it suggests new interpretations of the appropriate context for cognitive imaging in general, and its use in law and society in particular. It also has consequences for the perennially popular studies of the "neurology of art." The articles briefly explore these implications.

The designation "cognitive imaging" itself is oxymoronic, since it's only the activity in the neurological substrate, and not a mental process, that can be imaged with fMRI. There is no causal relationship between the imaged cerebral activity and the mental process, only a correlation, and even a complete understanding of the activity can provide no information about the nature of the mental function involved.

So, for example, the brain activity recorded during an fMRI experiment with mental arithmetic clearly has nothing to do with the nature of arithmetic, but only identifies the cerebral machinery used for performing arithmetic mentally. The same information about arithmetic could be determined by studying an abacus. The manner in which arithmetic is performed by the cerebral substrate is certainly a topic of interest, but this cannot be confused with the understanding of any aspect of the nature of arithmetic itself. In contrast, the functional imaging of sensorimotor processes is causal, and recorded activity does identify the sensorimotor function. So, for example, an fMRI study of recovery from stroke identifies exactly how the cerebral substance is re-wired to compensate for damaged regions. Cognitive-imaging practitioners, of course, are aware of this critical distinction, but sometimes don't honor it in interpreting their studies. Consequently, great care is required in the proposed uses of cognitive imaging in legal proceedings, specifically, or in social contexts in general. The idea of using functional imaging as a lie detector clearly demonstrates this difficulty.

Investigations of creativity by functional imaging, as in the "neurology of art," are similarly suspect. The images obtained indicate only the cerebral machinery used for a particular creative mental activity, or deficits created by damaged machinery, and provide no information about the creative process. In fact, the phrase "neurology of art" is *prima facie* oxymoronic, as there can be no deductive description of an inductive process, or a reductive cerebral explanation of an emergent mental function.

Transduction, Objects, and Time

As stated in the beginning of "The Process of Mental Evolution," the initial stages of internal reconstruction—sensory transduction at an organism's boundary surface and the identification of separate objects and the origin of time—although without observable predictive consequences, offer arguably the most significant scientific contributions of this theory. Specifically, an abstract analysis of sensory transduction leads to a novel astrobiological theorem, and of the latter reveals the nature and complementarity of objects and time. These important, yet abstract and somewhat divergent, topics are discussed in the appendices.

Transduction

The astrobiological theorem that results from an analysis of the process of transduction consists of two parts, the first of which proves that an abstract characterization of the transduction of sensory data is equivalent to the sentential calculus of deductive logic. The second part proves that any inductive construct derived from sensory data—such as an internal model of the world—must retain this logical bias. As with humans, diverse sentient species may create different mathematical systems and logics, but there is a common "natural" logic embedded in the internal reconstruction of the external world as a result of transduction. Therefore, any organism that has a boundary surface separating inside from outside and across which information is transduced must include a similar deductive logic as part of the internal model that determines its reality. It follows that this deductive logic must be fundamental to all alternate intelligences and that, as commonly conjectured, mathematics would be the basis of successful communication with extraterrestrial life. It also explains the well-known conundrum posed by Eugene Wigner concerning the "unreasonable effectiveness" of mathematics in physics by demonstrating that the two share a common logic inherited from the process of transduction.

The theorem also has significant implications for the nature of mathematics. Although mathematicians have many ideas about the nature of their discipline, each fits into one of two exclusive categories—formal or platonic, and constructive. Formalists, or platonists, believe that mathematics is universal and exists in a realm external to humanity, where mathematicians discover it. Constructivists, on the other hand, believe mathematics is a creation of the human mind, and therefore any proof must be carefully constructed step-by-step. From the constructive perspective, proof by contradiction—where a mathematical concept is proved to exist because assuming it is false leads to a contradiction—is not valid: nor are proofs that necessitate simultaneous infinite procedures, such as those requiring the axiom of choice. All of the variants of the constructive philosophy share a belief in the epistemological origin of mathematics as opposed to the universal existence favored by platonists.

The relationship between structure and logic identified in the astrobiological theorem suggests a synthesis of these mutually exclusive platonic and constructive ideas. For example, the theorem retains the universal character of mathematical forms found in formal or platonic theories; however it attributes the universality not to the independent external existence of platonic forms, but rather to the universal necessity of converting the external world to an internal model. The theory also confirms an epistemological origin of mathematics, supporting constructive notions; but not as the limited human activity the constructivists imply, since it is shared by any sentient physical organism.

In summary, an attractive aspect of the astrobiological theorem is the synthesis it offers for disparate ideas about the nature of mathematics. Perspectives that appear mutually exclusive are shown to be simply differences in emphasis within a more general explanation.

Objects and Time

Once transduction occurs, internal reconstruction begins with the first identification of equivalence. The transduced bioelectric impulses create a global pattern of brain activation that form a series of discrete sensory maps of the external world, or percepts. The separate nature of these percepts is critical, and a consideration of visual processing is a simple way to appreciate this discreteness. For example, the illusion of continuous motion in a movie is possible only because the interstices between frames are not perceived. If visual perception were continuous, everything, including the interstices, would be registered, providing a very fragmented film. Ironically, it is the discrete nature of perception that allows the perceived continuity of the film.

These discrete, distributed, multi-sensory constructs can be viewed as a "stack" of unrelatable, undifferentiated global patterns of activation. The internal analog of the continuity of the external world requires a generalization that identifies equivalences in the elements of the separate sensory constructs. A familiar experience provides an analogy of how equivalence is used to separate an undifferentiated sensory map into discrete objects. When viewing a photograph of a natural forest scene that is too narrowly focused, there is a brief period when we cannot resolve the subject and elements of the photo, and it conveys no information. However, we quickly separate the image into its individual constituent objects that we identify, for example, as twigs, leaves, and water. Since this familiar process involves recognition of similarity between the elements of the photo and previously categorized objects, it differs fundamentally from their initial identification in mental evolution. It does, however, provide an experiential analog of how the mind uses equivalence to makes sense of an initially undifferentiated image. Although the elements of the separate activation patterns that will be identified as an object are intuitively clear retrospectively, a prospective algorithmic specification is remarkably difficult. That the minds of all living animals can accomplish this is extraordinary, but most likely results, not from an algorithm, but rather from a process of trial and error and successive approximation.

The generalization that identifies an equivalence of specific elements in separate global percepts creates an object and the object's time. Each object is an equivalence class formed by an equivalence relation among elements of the separate global patterns of activation. Inducing that the elements of these separate "images" are the same object merges them together and thereby "squeezes out" their separateness. So the formation of any object by an operation of inclusion is coupled with an operation of exclusion that defines the elements' separateness. This separateness is what I call object-time. An object and its time are complementary notions, since they are defined by the same process.

A possibly more intuitive explanation is that identifying elements in separate global percepts gives the element persistence which "simultaneously" defines object and object-time. Object-time is simply an object's duration––an unmeasurable property similar to ancient Greek ideas espoused by Anaximander, Pythagoras, and Plato. Object-time, however, differs from the Greek concept of duration in that the latter is a global characteristic of the primordial universe whereas concept-time is defined uniquely for each object. In this theory of mental evolution object-time, or duration, is the first stage in a unified inductive hierarchy of the three types of time that previously have been irreconcilable—i.e., 1) duration, 2) the measurable relational structure of the before and after of scientific time, and 3) the *nunc fluens* of past, present, and future of experiential time.

Errata

These articles were written and published over an extended period of time during which my ideas and use of terminology evolved. Therefore, two terms—*analytic* and *mental states*—should be updated where they occur.

Analytic **versus** *ordinal*—Many of the articles use the descriptive term *analytic* when referring to the proposed theory of mental evolution. Although what I mean by this is clearly explained—i.e., each stage is defined exclusively in terms of those previously defined—this non-traditional use of the term is unnecessary. Since each evolutionary level is defined by an equivalence of elements in the next lower stage, the evolutionary hierarchy is naturally ordered, and a more accurate and descriptive term for this type of definition is *ordinal.* Therefore, *ordinal* should be substituted for *analytic* wherever it appears.

Mental states **versus** *mental functions*—Some articles refer to the stages of evolution prior to their instantiation in phylogenetic evolution as *mental states*. Although this generally is not a problem, philosophical discussions of mind dismiss references to mental states, and a more accurate designation in this case is *mental functions.* Therefore, *mental functions* should be substituted for *mental states* in all instances.

CHAPTER II

A THEORY OF MENTAL EVOLUTION AND ITS PREDICTIONS

A. An Analytic and Predictive Theory of Mental Evolution[1]

Abstract: The nature and origin of human mental capacities is one of the great remaining mysteries of science. There has been no lack of effort expended in this regard, but all of these attempts suffer from a common difficulty. Without unambiguous, analytic definitions of mental states, i.e., each mental state is defined solely in terms of those previously defined, a successful analysis of mental evolution is simply not possible. This research proposes such an analytic sequence beginning with reasonable axioms and culminating in consciousness. Although multifarious ideas concerning human consciousness are current in a philosophical context, the present study suggests a simple unambiguous definition that arises naturally as the culmination of an analytic sequence. The expression of these capacities predicts a specific and definite sequence of archaeological artifacts. The exact correlation of actual and predicted Paleolithic-Age artifacts strongly supports this theoretical formulation of mental evolution.

Introduction

This paper introduces an *a priori* theory of mental evolution that posits an analytic hierarchy of mental states—each level is defined solely in terms of those previously defined—and provides unambiguous definitions of mental capacities. In particular, it rigorously defines the nature of consciousness and indicates its origin as the culmination of an analytically defined sequence. The theory predicts the appearance of a specific type of artifact at each evolutionary stage, and its validity can be evaluated by

[1] This paper was presented in part at the Conference on the Origin of Language in Oxford, England, July 1, 2004.

comparing these predictions with the archaeology of the Paleolithic Age. The precise correlation of predicted and actual nonutilitarian artifacts corroborates this scientific formulation of the evolution of the modern mind while providing an explanation of the nature and sequence of Paleolithic-Age "art."

Basic Assumptions

A science of neurology is possible only if the brain is seen as a purely sensorimotor machine (Hughlings Jackson, 1882). Because higher brain functions are increasingly complex, integrated, and interconnected, the afferent function of the brain is the construction of an increasingly complex sensory map of the external world (Hughlings Jackson, 1887). Assuming that the function of the mind is to interpret this construction, these internally constructed sensory maps provide the substrate for mental evolution. Since increasing mental capacity is most generally characterized by an increasing inductive facility—an ability to identify equivalence—the process of mental evolution is assumed to be generalization. The elements of internal sensory maps are generalized and regeneralized in the mind, producing an increasingly complex, analytically structured hierarchy of mental states.

Prediction of a sequence of archaeologic artifacts from a hierarchy of evolutionary mental states necessitates three assumptions: mental capacities 1) can be correlated with a phylogenetic sequence; 2) are reflected in archaeologic data; and 3) are expressed as soon as they arise. Together these assumptions imply that the minimum mental capacity necessary to produce an artifact is the capacity indicated by the appearance of that artifact.

Definition of Terms

This theory of mental evolution defines a concept as a collection of attributes that determines membership in a category, is independent of its representation, and so, can exist in many forms. The theory also introduces the idea of a concept-space—the place where concepts exist. The concepts of modern humans exist in an abstract mental space and their form and content seem inseparable, but the abstract mental space itself is a product of evolution, and before it existed, concepts were embodied in a modified physical object—a physical concept-space. For example, a carved stone displaying the physical characteristics of an animal is the concept-space of an Upper Paleolithic Age concept.

The theory also strictly differentiates the processes of recognition and definition—recognition involves comparison, while definition involves specification. For example, recognition of an object as a horse requires a mental comparison between it and previously encountered horses. Recognition does not require awareness of the characteristics that define a horse, or even that such characteristics exist. In contrast, definition of a horse requires specification of the defining characteristics of "horseness."

Stages of Mental Evolution

The process of mental evolution begins with the partition of internal sensory maps into separate objects. It proceeds through repeated generalization in five analytic stages: categorization, protoconceptualization, and conceptualization in a contingent physical concept-space, an independent physical concept-space, and an abstract concept-space. Categorization involves recognition of the similarity of objects; protoconceptualization, recognition of the commonality that is the basis of categorization; and conceptualization, explicit specification of this commonality. The explicit characteristics that determine membership in a category are first embodied in physical objects—a contingent physical concept-space that is inseparable from the concept itself. The concept-space is next recognized as a separate entity from the concept it carries—an independent physical concept-space. Finally, the concept-space is defined, creating an abstract concept-space. The formation of an abstract concept-space marks the achievement of consciousness; and the mode of expression of abstract concepts is language.

Analyticity and Details of Mental Evolution

Once the process of mental evolution begins, each stage develops analytically from the previous one, providing an adaptive advantage that contributes to further mental development. This adaptive advantage is the increasing capacity to retrieve elements of the perceived world for consideration, planning, and communication when they are not physically present.

Categorization involves recognition of the similarity of perceived objects, and a category is defined analytically as a collection of these objects. For example, the mind recognizes a category of horses that serves as a standard of comparison to determine if a newly encountered object is a horse. The characteristics of previously encountered horses invest each object that is identified as a horse. All animals have the mental capacity for categorization, since they at least recognize the category of food. Increasing complexity of categorization involves recognition of more categories, subcategories, and higher-order categories, such as categories of categories.

Once a category is recognized, details of the category's elements, and similarities among them, also can be identified. These similar details form new categories that are subcategories of the original category. For example, once the category of horse is recognized, it is possible to recognize subcategories such as horse's head, tail, and limbs.

Protoconceptualization emerges analytically with the recognition that the elements of a category have been grouped together because they share an equivalence—a set of defining characteristics. Alternatively, protoconceptualization can be seen as the recognition that a category exists independent of its members. That is, the defining characteristics of a category form a generic or ideal element—the equivalence relation—that is not an actual member of the category, but rather can be seen as the category itself, separate from its members. The recognition of the existence of such a generic element is protoconceptualization. A category can now be retrieved for consideration independent of an observation, but since the equivalence is recognized but cannot be specified, only a member of the category that manifests the defining characteristics can represent it. The protoconcept "horse" thus must be a particular horse, and the display of a horse skeleton in the archaeologic record indicates the minimal mental capacity of protoconceptualization—the ability to recognize the equivalence underlying the category of horses.

Conceptualization in a contingent concept-space occurs when the equivalence forming a category is defined. This can take place once subcategorization has produced protoconcepts recognizing sufficient fine detail within a category. For example, the protoconcept of the category of horse's tails is the recognized generic horse-like tail. A collection of these recognized generic characteristics of horses forms a generic horse—the concept "horse." Thus, a concept is analytically defined as a collection of protoconcepts, or attributes. At this stage of evolution, a collection can only be assembled in a physical object, since no other type of space is available. Therefore, the attributes defining the equivalence of the category are assembled in a unique, physical concept-space—a modified object such as a sculpture, a cave-wall painting, or an engraving of a horse. The concept and its concept-space are inseparable—the image and the material in which it exists are one. In this sense, the physical concept-space is contingent. Since concepts can be displayed in any convenient physical medium and be of any size, they can be assembled and manipulated much more easily than protoconcepts, which must be members of their categories—providing an adaptive advantage. The minimal mental capacity necessary to produce a recognizable reproduction of a horse in the archaeologic record is the ability to explicitly specify the defining characteristics of the category of horse—the concept "horse."

Conceptualization in an independent physical concept-space is seen analytically as the recognized equivalence of contingent concept-spaces and results in a concept-space separate from any particular concept. So, for example, a carving of a horse and a carving of a bull are seen to have something in common—the stone that can accommodate either animal. A recognized equivalence must include any property shared by all of a category's elements, and since the contingent concept-spaces are all physical objects, the independent concept-space must also be a physical space. The emergence of the independent physical concept-space enables expression of increasingly complex conceptual relationships, which contributes to a significant adaptive advantage. This capacity is manifested by compositional reproductions in which multiple concepts interact in a common space, e.g., a composition containing both a horse and a bull. In fact, the existence of an independent concept-space is necessary and sufficient for the innovation of composition. It is necessary because a composition cannot exist without a common space in which the individual elements of the composition are unified; and it is sufficient because all elements that appear within a common space are understood to be part of a unified composition. Thus, the minimal mental capacity indicated by the appearance of compositional reproductions in the archaeologic record is recognition of an independent physical concept-space.

Conceptualization in an abstract concept-space results from the specification of the equivalence of the independent physical concept-spaces, constituting the next analytic stage—a generic independent concept-space. Each independent physical concept-space can accommodate only a limited number of concepts, but the generic independent concept-space must have an arbitrarily large capacity. Since no physical space is infinite, the generic independent concept-space must be an abstract space. In the physical concept-spaces the concepts are expressed as visible collections of a category's defining features, shared by those who view them. The abstract space is invisible, however, so a means must be created to retrieve and share the concept. A name, e.g., *horse*, specifies the location of the concept in the abstract space, making language the shared expression of abstract concepts. The minimal mental capacity indicated by use of the word *horse* is the ability to express the collection of attributes defining the category of horses that exists in an abstract concept-space—the abstract concept "horse."

The existence of this abstract concept-space vastly facilitates conceptual operations, since concepts can be juxtaposed and hypotheses tested mentally, rather than by manipulation of physical representations. This increased mental efficiency also enables very high-order categorization identifying fundamental equivalences in the perceived world and defining objects whose existence is completely abstract.

The formation of an abstract concept-space constitutes consciousness. Conscious beings live in a model of the world that is created in this space. This model reproduces conceptual counterparts of the objects and relationships of the external world in the abstract space, and its existence explains the subjective sense of a separate observer that is a prominent characteristic of consciousness. Conscious beings do not simply act, but also observe themselves acting because an action is performed both in the physical world and in the model of that world that resides in the abstract concept-space.

The analytic nature of the stages of mental evolution provides an explanation for the universal development of language—and other mental capacities—even in possibly isolated human populations. The modern human brain includes the sensorimotor structure necessary to set mental development in motion. The process then unfolds independently, each stage arising analytically out of the one that precedes it. Contact and direct transmittal can alter the evolutionary rate, but not its ultimate occurrence and outcome.

Predictions of Archaeological Artifacts

This theory of mental evolution predicts that specific nonutilitarian archaeologic artifacts—and only those artifacts—should be found in the chronological order corresponding to its stages.

Categorization is the recognition of similarities among objects. As a functional standard of comparison, a category has no independent existence and so is not associated with any form of representation. Therefore, this stage should include no nonutilitarian artifacts.

Protoconceptualization is the recognition that there is an equivalence underlying a category and that a category exists independent of any of its members. Only a member of the category can be a protoconcept, since the equivalence is recognized, but not defined. Thus, this stage should be associated with the appearance of unaltered natural objects that are intentionally isolated or displayed—each representing the category of which it is a member.

Conceptualization in a contingent physical concept-space specifies a category's defining characteristics as an explicit collection of attributes. The collection is assembled in a discrete physical object that is a physical concept-space. This stage, therefore, should be associated with the appearance of reproductions or representations of individual, recognizable objects in a physical medium.

Conceptualization in an independent physical concept-space occurs when it is recognized that a concept-space can exist independent of the concept it carries. Since this recognition is necessary and sufficient to enable multiple concepts to coexist in a unified concept-space, this evolutionary stage should be associated with compositional reproductions.

The abstract concept-space arises by defining the equivalence of physical concept-spaces. The appearance of an abstract concept-space makes the physical concept-spaces obsolete. As a result, this stage should provide evidence of rapidly advancing mental capabilities, and the disappearance of all physical expressions of concepts.

Correlations with Paleolithic-Age Artifacts

The only human artifacts found until the end of the Lower-Paleolithic Age and the ascendance of Neandertal Man are stone tools. Although human tools are more modified, more varied, and more permanent than those produced by other animals, the differences are of degree, not kind. (Beck, 1980) Thus, the tool-producing hominids defining the genus Homo (i.e., *Homo habilis* and *Homo erectus*) were at the same level of mental evolution as other animals. This lack of unique human artifacts in the archaeologic record correlates with the theoretical prediction of their absence at the evolutionary stage of categorization.

The Middle-Paleolithic Age begins with the supremacy of *Homo sapiens neanderthalensis* approximately 100,000 years ago, and three associated artifactual innovations have been reported: human burial (Gamble, 1984; Solecki, 1975); manganese oxide and ocher used for body painting or dyeing of animal skins (Singer and Wymer, 1982; Dart, 1969) and possible "ritual sites" devoted to cave bears (Bächler, 1940) and human skulls (Bergounioux, 1958). A unifying characteristic of these artifacts is the isolation or display of unaltered natural objects—for burial and body painting, the dead and living human body, respectively; for ritual sites, cave bear skeletons or human skulls. Thus, each of these artifact types exactly demonstrates the predicted manifestations of the evolutionary stage of protoconceptualization.

Although many fanciful meanings have been ascribed to early human burial, it most simply indicates recognition of some property of an individual that exists independent from the body. Since the category of an individual consists of a single object—the body of the individual—recognition of a defining characteristic independent of the body indicates the recognition of a category's existence independent of its elements, or protoconceptualization. By identifying the minimal mental capacity capable of producing an artifact as the capacity indicated by the presence of the artifact, burial is best interpreted as an example of protoconceptualization (figure 1). The absence of burial prior to this era must mean that the body had no meaning beyond its existence as an object, which, in turn, implies that the mental capacity of protoconceptualization had not yet been achieved.

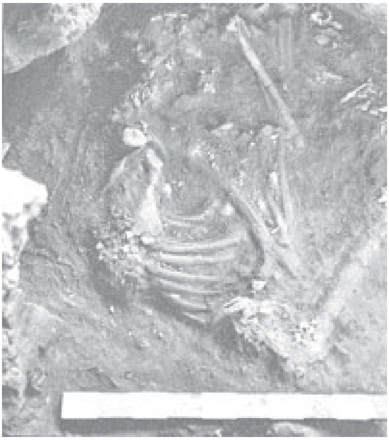

Figure 1. Neandertal burial at Shanidar cave, Iraq c. 60,000 BP. Intentional burial indicates recognition of some property of an individual independent of the body. Since the category of an individual consists of one object—the body—burial is recognition of the existence of a category independent of its member, i.e., protoconceptualization.

Since a protoconcept must be a member of the category it represents, only the physical body can act as the protoconcept for the human self. In this unique case, both the subject—the proto-I—and the object—"me"—reside in the body of the individual. Distinguishing the two necessitates isolating or displaying the object that is "me," as with any other protoconcept. The presence of pigments in Middle-Paleolithic-Age deposits is thought to indicate that Neandertal man practiced body painting. Dichromatic body painting and the colouring of crude fur clothing are the most elementary methods of differentiating the proto-I from its object, thereby recognizing the subject's existence.

The beginning of the Upper-Paleolithic Age is heralded by the dominance of *Homo sapiens sapiens*. This is the time when physically modern humans began developing modern mental capacities. Two classes of nonutilitarian artifacts characterize this era—statuettes, paintings, and engravings (Rieck, 1934); and personal ornamentation (Marshack, 1970a). Statuettes, paintings, and engravings are discrete, easily recognizable objects reproduced in a physical medium (Figure 2). These characteristics are precisely the predicted consequences of conceptualization in a contingent concept-space and are *prima facie* evidence of the mental capacity of conceptualization.

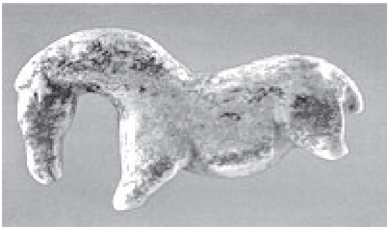

Figure 2. Vogelherd horse. Vogelherd, Germany, c. 35,000 BP. The sculpture of a horse must contain adequate attributes to define a horse because it is seen as one. The minimal mental capacity indicated is contingent conceptualization, in which the concept-space—the carved ivory—and the concept "horse" are inseparable.

Specific characteristics of images produced on cave walls and engraved in stone blocks provide additional support for the conceptual nature of early Upper-Paleolithic-Age reproductions. Discrete cave paintings and block engravings nearly universally demonstrate superposition of images, often to the point of complete obfuscation (Capitan and Bouyssonie, 1924). In addition, many block engravings were broken and tossed aside, apparently used for paving or building, like any other stone (Pales, 1976). It seems likely that these creations would have been more carefully preserved if humans capable of abstract thought had produced them with an artistic purpose. A more probable explanation is that the paintings and engravings function as concepts inhabiting discrete concept-spaces. These artifacts can be compared with notes that are written at a particular time for a particular purpose. They can then be balled up and thrown away or overwritten, with only the last message having any meaning.

The appearance of personal ornamentation at this stage provides further artifactual evidence of the existence of a concept—the definition of a category. The concept here is the subject "I," and the natural choice for its physical concept-space is the body. In all other cases, a true concept is easily separable from a protoconcept of the same category, since the latter is a member of a category, and the former is a reproduction in a different medium. In this case, however, as with the protoconcept "I" and the category "me" at the stage of protoconceptualization, subject and object coexist in the body; and a way must be found to distinguish them. As body painting provided this differentiation at the prior evolutionary stage, personal ornamentation differentiates the concept "I" from the object "me" at this higher level of mental functioning. The only way to distinguish the protoconcept and concept of an individual is the sophistication or complexity of the body's decoration. The multicoloured tattoos and vast array of personal ornaments that characterize the archaeologic record of the Upper-Paleolithic Age contrast strongly with the dichromatic body painting and dyeing of skins associated with the Middle Paleolithic Age. This advance provides evidence of the mental evolution from recognition of the category of an individual to its definition.

The appearance of carved and painted compositional reproductions characterizes the final phase of the Upper- Paleolithic Age (Steven, 1975; Leroi-Gourhan, 1968). This achievement is the predicted consequence of the emergence of an independent physical concept-space (Figure 3).

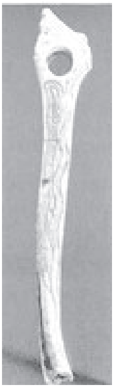

Figure 3. The Bâton of Montgaudier. Montgaudier, France, c. 12,000 BP. This compositional carving contains multiple animals that are seen in the Spring (Marshack, 1970a). The minimal mental capacity indicated by a compositional reproduction is the recognition of a concept-space independent of any particular concept.

The Mesolithic Age is a rather opaque era that is characterized by two remarkable and apparently contradictory features: 1) the disappearance of Upper-Paleolithic-Age naturalistic reproductions (Ahlbäck, 2003; González Morales, 1997); 2) evidence of rapidly increasing mental capacities as evidenced by the early stages of urbanization (Fellner, 1995), domestication of plants (Thorpe, 1996) and animals (Reed, 1960), and the appearance of organized warfare (Midant-Reynes, 2000). The disappearance of Paleolithic "art" has been difficult to reconcile with the cultural innovations of the Mesolithic Age, since art is often considered to be the epitome of cultural expression. This theory of mental evolution offers an explanation. Paleolithic "art" disappeared because it did not function as art at all. Rather, it served as the increasingly complex expression of concepts in an evolving physical concept-space (Table).

EPOCH	HOMINID	STAGE OF MENTAL EVOLUTION	PREDICTED /ACTUAL UNIFYING TRAIT	NONUTILITARIAN ARTIFACTS
PALEOLITHIC AGE				
LOWER **c. 2,000,000-c. 100,000 BP**	*Homo habilis* *Homo erectus*	Categorization	None	None
MIDDLE **c. 100,000-c. 40,000 BP**	*Homo sapiens neanderthalensis*	Protoconceptualization	Naturally occurring objects isolated or displayed	Burial Ritual sites Body painting, skin dyeing
EARLY UPPER **c. 40,000-c. 17,000 BP**	*Homo sapiens sapiens*	Conceptualization in a contingent physical concept-space	Discrete, recognizable reproductions of natural objects	Statuettes Cave paintings and engraving Personal ornamentation
LATE UPPER **c. 15,000-c. 12,000 BP**	*Homo sapiens sapiens*	Conceptualization in an independent physical concept-space	Composition	Carved and painted compositions
MESOLITHIC AGE **c. 12,000-c. 8,000 BP**	*Homo sapiens sapiens*	Conceptualization in an abstract concept-space	Disappearance of naturalistic reproductions	No naturalistic reproductions

Table 1. The archaeology of mental evolution

Conclusions

The proposed theory creates a formal structure for mental evolution that unambiguously and analytically defines mental capacities, including consciousness. No such unambiguous definitions have been previously suggested, and no analytically defined sequence of mental capacities leading to consciousness has been proposed. It also explains the meaning and sequence of Paleolithic-Age artifacts. Although many explanations for individual artifacts or artifact classes have been offered, no coherent hypothesis for their chronological sequence currently exists (Davidson, 1989; Halverson, 1987; Marshack, 1972). Finally, the theory provides an explanation for the abrupt disappearance of the spectacular "art" of the Paleolithic Age with the rapid advance of other aspects of material culture.

The temporal origin of consciousness and language proposed by this theory is independent of any philosophical or linguistic assumptions or prejudices. Although other theories posit a late origin of consciousness and language, none is based on an analytically defined process of mental evolution (Jaynes, 1976; Jerison, 1973). This theory suggests that the evolution of mentally modern capacities began over 100,000 years after the evolution of physically modern man and 30,000 years after the ascendancy of modern humans in the Upper-Paleolithic Age, and that language developed approximately 12,000 years ago. It thus implies that, while consciousness and language are the *sine qua non* of humanity, they were not the proximate causes of the evolution of *Homo sapiens sapiens*.

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B. Paleolithic-Age "Art" and Mental Evolution[2]

Abstract: This paper will propose a theory of mental evolution whose predictions can be verified by the archaeology of human phylogeny. First, a system of mental evolution is proposed consisting of an analytic hierarchy of mental states, including consciousness. Second, by assuming an instantiation of the theory in phylogenetic evolution, mental states become mental capacities, whose expression predicts specific artifact types. Third, the archaeologic record will be used to verify or falsify the predictions. It will be shown that there is a bijective correspondence of predicted and actual artifacts, thereby supporting the theory and also explaining the problematic nature and sequence of Paleolithic-Age artifacts.

Introduction

Skeletal, artifactual, and ecofactual remains of early humans provide the sole evidence for reconstructing the emergence of modern man. This archaeologic data can only be understood, however, by reference to an underlying theory which acts as an organizing principle and a framework for interpretation. For example, skeletal data are explained by physical anthropology whose foundation is the evolutionary theory of Darwinism. But artifactual and ecofactual remains provide data for an obvious concomitant to the physical evolution of the genus *Homo*, i.e., the evolution of mental capacities that are human's most distinguishing feature. The origin of the modern mind is probably the greatest of all intellectual puzzles, yet the exclusive source of data for this evolution has been essentially untapped. The reason is not that the importance of early human artifacts for mental evolution is unrecognized or that there has been a lack of effort expended in its analysis[3], rather, without unambiguous definitions of mental capacities and their relationships a coherent analysis is simply not possible. An integrated interpretation of early human artifacts that corresponds to the explanation of skeletal remains is possible only with a theory of mental evolution corresponding to the theory of biologic evolution. The lack of this framework prevents effective utilization of the available artifactual and ecofactual evidence. This paper presents an outline for a theory of mental evolution that provides such a framework.

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[2] This article appeared in Brain, Mind and Physics, edited by P. Pylkkanen et al., and published by IOS press in 1997.
[3] See [1]-[9] for a selection of articles correlating artifacts and mental capacities.

The theory of mental evolution consists of an analytic hierarchy defining mental states and their relationships, including consciousness. The hierarchy is analytic in the sense that each stage is defined only in terms of previously defined stages, with sensation assumed to be atomic. When instantiated phylogenetically, mental states can be considered mental capacities. Expression of these capacities implies a verifiable sequence of archaeologic artifacts if three assumptions are made. First, a hierarchy of mental states can be correlated with a phylogenetic sequence. Second, mental capacities are reflected in archaeologic data. Third, mental capacities are expressed as soon as they arise. The combination of these assumptions means that the minimum mental capacity necessary to produce an artifact is the capacity indicated by the appearance of that artifact. By making these assumptions, the nature and sequence of archaeologic artifacts can provide independent corroboration of the theory. Additionally, the theory provides a framework through which the artifactual sequence of early man can be explained. It will be shown that there is a bijective correlation of actual and predicted artifacts, providing verification of the theory's predictions and an explanation of problematic archaeologic observations.

The analysis yields a novel interpretation of the sequence and meaning of nonutilitarian Paleolithic-Age artifacts, though some of the interpretations are heterodox. For example, the archaeologic hallmark of the genus *Homo* is the manufacturing of tools, and it has been traditionally assumed that this archaeologic marker also indicates a qualitative advance in mental function. But human tool production represents only a quantitative improvement in mental capacity, not a qualitative one. The use of tools by some non-human animals does not require artificial distinctions to separate it from human tool use since the stage of mental development of the earliest human was the same as that of any other animal. Language, conceptualization, and consciousness are also often attributed to the earliest members of the human genus that emerged approximately 2-3 million years ago.[4] Correlation with an independent theory suggests that these capacities were not even present when physically modern man (*Homo sapiens sapiens*) appeared at the beginning of the Upper-Paleolithic Age, 40,000 years ago.

A Theory of Mental Evolution

The external world of any animal is known by that animal solely as an internal reconstruction, and I suggest that the function of the mind is to interpret the reconstruction. Therefore, mental evolution begins with

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[4] See [10]-[12].

identification of the least complex element of reconstructed images, i.e., separate objects. The stages of mental evolution will be termed categorization, protoconceptualization, conceptualization, and consciousness. The process of mental evolution is identification of equivalence, and once internal images are partitioned into objects, it proceeds so that each step represents an equivalence identified in the preceding stage. First categories of similar objects are recognized (categorization), then the equivalence underlying a category is recognized (protoconceptualization), then the equivalence forming a category is defined (conceptualization). Individual definitions, or names, first exist only as embodiments in physical objects where the material of a representation becomes the inseparable concept-space of that name (contingent physical concept-space).[5] Next the concept-space is recognized as a separable entity from the concept it carries (independent physical concept-space), and finally the concept-space is defined (abstract concept-space). The formation of an abstract concept-space I define as consciousness.[6]

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[5] Simply put, a concept-space is the place where concepts exist. This idea may seem unnecessary since the concepts of modern man exist in an abstract mental space, and it is difficult to imagine any other form for concepts to take. When something is known in only one form, and when it is not clearly defined, it is difficult to separate form from content. But a concept is entirely distinct from the place where it resides. A concept can be viewed as an equivalence relation, a collection of special categories (i.e., maximal ones) or attributes, but how or where this collection is assembled is not part of the definition. Thus, a concept can exist in many forms because the concept is separate from its representation, just as a subject represented in a photograph, painting, drawing, dream, and sculpture is distinct from the subject itself. Before the abstract space existed, the collection of special categories is asssembled in a modified physical object that carries the concept, and is the concept-space of the concept. An example of this process is the miniature sculpture of the Upper-Paleolithic Age where the concept-space is the carved stone displaying the physical characteristics of animals.

[6] As an example of a mental evolutionary sequence, consider a horse. First, a particular horse is recognized as a separate object, i.e., separate from the ground, sky, trees, etc. Next, a category of horses is recognized which serves purely as a standard of comparison to determine if a newly encountered object is a horse. Once a category is recognized, it is possible to recognize that there is an underlying similarity of the horses that causes them to be classified together. I call this recognition protoconceptualization, and the mental advance is the recognition that a category exists independent of any of its members. This advance is demonstrated by the use of a single horse, or horse part, to represent the category of horse. A protoconcept of horse must be a particular horse because only a member of this category manifests the similarity underlying all horses, which at this stage cannot be specified. Protoconceptualization can be recognized since the context of its use

Lower-Paleolithic Age—Age of Categorization

The Lower-Paleolithic Age begins with the appearance of the first tool-producing hominid, *Homo habilis*, approximately 2 million years before the present (BP), and ends with the emergence of *Homo sapiens neanderthalensis* approximately 100,000 BP. The division is characterized by extremely slow progress as measured by variation in stone-tool artifacts—in one documented instance change is imperceptible for a period of over 500,000 years.[7]

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indicates there is meaning attached to an unmodified object beyond its existence as a simple object. This stage of mental evolution appeared in *Homo sapiens neanderthalensis* at the opening of the Middle-Paleolithic Age when unaltered natural objects are first isolated and displayed (e.g., burial and ritual sites).

Conceptualization occurs when the underlying similarity of the category of horse is defined. That is, a concept is the explicit equivalence relation, or collection of attributes (maximal categories), which determines if an object is a horse. Since the equivalence relation is explicit, a concept need not be a member of the category it conceptualizes. At first the collection of attributes is explicitly brought together in a modified object, e.g., a carving of a horse. An adequate specification of the physical attributes of a horse is a prerequisite for such a statuette, for this is the way it is recognized as a horse. This process occurred at the opening of the Upper-Paleolithic Age. The modified physical object that carries the concept is a concept-space. At this stage, a concept-space is contingent in the sense that it only accommodates a single concept. The next stage of evolution recognizes that a carving of a horse and a carving of a bull have something in common. The common feature is the capacity of the underlying material of the carving to accommodate either a bull or a horse. The recognition of the existence of a concept-space independent of any particular concept is necessary and sufficient for the innovation of composition. That is, a composite image can exist if, and only if, the elements of the composition are understood to occupy a common space, and the common space exists independent of any particular concept. Archaeologically, this corresponds to the compositional cave paintings and carvings, and allows a unified image containing a horse and a bull.

Once the concept-space is recognized as an independent entity, it can be defined. The definition is again a collection of attributes, one of which specifies a potentially infinite carrying capacity of the space. This can occur only in an abstract space, and it is the formation of a mental abstract space that is consciousness. The abstract notion of horse that is conveyed by the modern word, 'horse', is a result of this process. According to this analysis, consciousness appeared at the end of the Upper-Paleolithic Age, 10,000 years ago, and accounted for the disappearance of the great cave paintings and the appearance of Mesolithic-Age innovations.

[7] This particular sequence of chopper-core tools was discovered by Mary Leakey in beds I and II at Olduvai gorge.[13]

H. habilis produced the earliest stone-tool industry, known as the Oldowan. The Oldowan tool-making technique is characterized by the chopper-core, which is an alternate name of the industry. Chopper-core tools are archaeologically demonstrable during an interval of 1 million years beginning approximately 1.8 million years ago.[8]

The sole artifactual innovation of the Lower-Paleolithic Age occurred when *Homo erectus*[9] modified the chopper-core tradition to produce hand axes.[10] Migration of *H. erectus* is indicated by hand-ax artifacts which appear in Mediterranean sites about 800,000-700,000 BP, in India and Asia by about 600,000 BP, and by about 400,000 BP, throughout Africa, Europe, and the Indian subcontinent. At the beginning of the Würm glaciation, c.100,000 BP, *Homo sapiens neanderthalensis* appeared, and the Mousterian and Levallois flake-tool industries replaced the Acheulian industry as the dominant stone-working technique.

The single most remarkable feature of the Lower-Paleolithic Age, relative to the succeeding epochs, is the extremely slow rate of artifactual change. Only utilitarian artifacts are found with no evidence of the use of any object for a purpose other than acquisition and/or processing of food.

The manufacture and use of tools is not limited to humans.[11] The distinctions that separate animal from early human tool use are quantitative, not qualitative. That is, human tools are more modified, more varied, and more permanent, but not fundamentally different.[12]

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[8] See [14] for a short summary of the chopper-core industry.

[9] The oldest remains of this new species of hominid were first found near Lake Turkana in Kenya, in strata 1.8 million years old [15]. *H. erectus* is a long-lived and successful species who first controlled naturally-occurring fire and migrated throughout the Old World.

[10] The hand-ax industry is also known as Acheulian after the site of first discovery, St. Acheul near Amiens in northern France. The first known hand-axes, however, are African in origin and are about 1.3 million years old.

[11] Animals from invertebrates to great apes use and manufacture tools of various levels of sophistication. See [16] for an exhaustive survey.

[12] The greater sophistication of human tools is certainly indicative of greater mental capacity, but it is not necessary to invoke a different stage of mental development to explain human tool production. The mental advance indicated by human tools is enhanced categorization and sub-categorization of the perceived world. This results in higher-order categories that reveal more subtle relationships, but there is no difference in principle between the abstract process of categorization in a human creating a hand ax and a sheep dog recognizing a sheep. Viewed differently, there is no category whose equivalence relation is recognized by production of a stone tool, and hence no new stage of mental evolution is indicated.

The abstract similarity of mental processes in other animals does not detract from the revolutionary impact of tools on human development and expansion.[13] Stone tools and the control of natural fire allowed migration of *Homo erectus* throughout the Old World. The absence of any accompanying change in stage of mental development, however, labels the Lower-Paleolithic Age as the Age of Categorization.

Middle-Paleolithic Age—Age of Protoconceptualization

The appearance of Neandertal man *(Homo sapiens neanderthalensis*) c.100,000 BP inaugurated the Middle- Paleolithic Age which lasted until c.40,000 BP.[14] Neandertals created the first nonutilitarian artifacts, which, by hypothesis, is interpreted as evidence for an alteration in mental capacity. At this point predictions of the present theory of mental evolution can be directly supported by the archaeological record. Neandertal nonutilitarian

[13] Quantitative changes which exceed a threshold can produce qualitatively different results. For example, the quantitative addition of falling snow to a mountain slope will eventually produce a qualitative change when the coefficient of static friction is overcome and an avalanche results.

[14] Two distinct stone-tool industries are recognized as products of Neandertal man. They are essentially geographic variants with the Levallois industry found in the Mediterranean region and the Mousterian industry throughout Europe and much of Asia.[17] The classification of all Middle-Paleolithic Age skeletal remains as the subspecies *neanderthalensis* is controversial due to profound morphologic variability.[18] This is not relevant for the present purpose, however, since both the Levalloiso-Mousterian tool industry and the nonutilitarian artifacts are shared by all morphologic variants. Since artifactual evidence is correlated with mental evolution exact taxonomy does not affect the argument.

artifacts[15] can be classified as either human burials[16], natural pigments[17], ritual sites associated with human and cave-bear remains[18], or rare notational markings on bone fragments and stone.[19]

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[15] There is some dispute as to whether there are any nonutilitarian artifacts from the Middle-Paleolithic Age. Although an adequate number of burials have been discovered to suggest these at least are real, other artifacts are more problematic. For example, the ritual sites to be described are very few in number and were not appropriately documented during excavation. Trinkaus and Shipman [19] are skeptical about the existence of human and cave-bear ritual sites, and their conclusions may be correct. However, their skepticism is not totally based on the limited evidence—they do not believe that Neandertals were mentally capable of such artifacts which they interpret as evidence of modern capacities (cf. p.258). According to the present analysis, the mental capacity indicated by these artifacts is far from modern. The capacity that explains the well-documented burials and the equivocal ritual sites is identical and therefore there is no extrinsic reason to reject the available data concerning the latter. For this development, the actual existence of ritual sites is not relevant. An explanation according to this theory is provided, however, in the event that more definitive confirmation is obtained in the future.

[16] Burials are identified in the earliest settlements of Neandertal man. The Mousterian industry at La Chapelle-aux-Saints overlays a grave carved into the solid rock of the cave floor.[20] Other burials of similar type have been found on the Dordogne at La Ferrassie [21], and in the Crimean peninsula at Kiik-Koba.[22,23] A collection of ten Neandertal graves was found near Mt. Carmel at Mugharet es-Skhul.[24] The cave at Shanidar, in present-day Iraq, revealed a burial that had been accompanied by at least eight species of flower.[25] Though Neandertal burials are commonly accepted, some questions about their authenticity have been raised. Recent excavations are more definitive.[26]

[17] Natural pigments are a common finding at Neandertal sites.[27] Intentional mining of these pigments is well-documented. [28,29] Lumps of black manganese oxide and red ochre are found sharpened like pencils and scratched, presumably to make powder for paint.[30] Ochre is used in burials, and although other uses of the pigment are uncertain, body painting is probably among them. Unequivocal evidence of personal ornamentation, such as pendants and necklaces, has not been found.

[18] The first evidence of possible ritual associated with human remains is a product of Neandertal man. At Monte Circeo, in Italy, a Neandertal skull was apparently placed within a raised circle of stones. Stiner provides a detailed evaluation of the Monte Circeo cave site while arguing against its intentional construction.[31] At Teshik-Tash in Uzbekistan a Neandertal infant skull was found which may have been surrounded by six pairs of Siberian mountain-goat horns.[32] These may have been placed upright in a circle surrounding the skull.

Neandertal man may also have made ritual use of cave-bear skulls and skeletons. This animal was very large and dangerous, and the interaction between Neandertal man and the cave-bear was inevitable since the cave-bear was extremely common, The unifying characteristic of all Middle-Paleolithic-Age nonutilitarian innovations is the isolation or display of essentially unaltered natural objects. The theory of mental evolution predicts that an advance from categorization to protoconceptualization involves such a new use of objects (see note 4), and therefore suggests that an explanation of Middle-Paleolithic-Age artifacts lies in recognition of a category's existence independent of its members. Since an element of a category is used to represent the category's underlying equivalence, the equivalence is not specified. There is only the recognition that there are defining characteristics of the category, and that these are manifested by a single member of the category which represents the commonalty.

A particularly important example of this process concerns recognition of the category that consists of a single object - the physical body of an individual. Purposeful treatment of a body after death indicates recognition of some properties of an individual independent of the body as an object. Recognition that an individual possesses defining characteristics independent of their body is the recognition of a category's existence independent of its elements, i.e., protoconceptualization. By preferring the minimal mental capacity capable of producing an artifact as the capacity indicated by the presence of the artifact, burial is best interpreted as an example of protoconceptualization.[20]

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and both species sought the same housing. The cave-bear is the sole non-human animal with attributed ritual sites.

At Drachenloch, high in the Swiss Alps, a number of skulls and assorted limb bones of the cave-bear were found.[33] This cave could not have been occupied during Middle- Paleolithic-Age winters, because of its altitude, and thus suggests a periodically visited ritual site. The arrangement of bear skulls within the cave also suggests some ritual usage. At Peter's cave in Unterfranken, Germany, additional evidence of intentional isolation of a cave-bear skull is found.[34]-[36] Finally, excavation of Regourdou in Southern France revealed the burial of up to twenty cave-bears in a pit underneath a one-ton rock slab. An entire skeleton of a cave-bear may have originally been placed on top of the slab.[21]

[19] Modified and engraved objects are extremely uncommon in Mousterian cultural deposits. They are often found in thin or disturbed occupation layers, and are consequently of questionable significance.[37] At Tata, near Budapest, excavation of a Mousterian settlement from approximately 50,000 BP has uncovered a split mammoth tooth that had apparently been polished and covered with red ochre, and an amulet-like object with an engraved cross made from nummulite [38,39]. Poorly incised and/or drilled bone fragments and teeth are also occasionally found apparently associated with Mousterian deposits [40,41].

[20] Explanation of burial in terms of protoconcepts does not involve the poetic notion of the birth of religion, or the discovery of an afterlife. Rather, burial is evidence of recognition that a category exists (characteristics defining an individual) independent

If the process of protoconceptualization is responsible for the artifact of human burial, there are still two possibilities for its specific meaning. Burial could itself represent differentiation of object from protoconcept, that is, the burial is the modification or display of the body differentiating the object, me, from proto-I. The burial could also represent special treatment of a pre-existing protoconcept as a continuation of the existence of a proto-individual, and as a focus of feelings toward the proto-individual. The latter appears more likely.[21]

If the proto-individual existed prior to death then there must be evidence for an *in vivo* differentiation of object and protoconcept. The category of a proto-individual consists of a single object, the physical body of that individual. Since a protoconcept must be a member of the category it represents, only the physical body can act as the protoconcept (See note 19). In order to distinguish the proto-I from "me" it is necessary to alter the arrangement or display of the object that is "me," just as in any other protoconcept. The presence of pigments in Mousterian deposits is thought to indicate that body painting was practiced by Neandertal man.[22] This inference seems reasonable and is generally accepted. Even if ochre was only used for dyeing skins, the alteration in appearance of an object of clothing has the same implications for mental development as does body painting.[23] Body painting, or the simple coloring of crude fur clothing, is the

of its single element (the body). That is, burial is the first rudimentary attempt at defining an individual. This involves recognition that there is an essence of an individual, that it exists independent of the body, and that the body of the individual can represent this essence. Since the proto-I exists independently of the body, and since only the body can represent the proto-I, burial is a natural method of identifying the uniqueness of a dead individual.

[21] If the protoconcept of the individual could not exist prior to his or her death, the reason for its appearance is obscure. There is little purpose in defining an individual only after they are dead. On the other hand, existence of a proto-individual provides a meaning to the body beyond its reality as an object, i.e., as the representative of the essence of the proto-individual. The continuing existence of the proto-I, which is by definition independent of the physical body, me, is artifactually demonstrated by burial.

[22] Ochre sticks have been discovered that are sharpened, apparently for use as crayons. These were probably used for body painting since no ochre drawings or colorings are found.[30]

[23] Some archaeologists contend, however, that ochre was used solely as a preservative for skins and human carcasses.[42] The abrupt appearance and ubiquity of ochre and manganese oxide in Middle-Paleolithic-Age deposits, however, suggests a more fundamental advance. More importantly, preservation of human bodies would have no purpose until the body had a significance beyond its simple objective existence.

most elementary method of differentiating the object, me, from the proto-I, and thereby recognizing the latter.[24]

Protoconceptualization also is the minimal mental capacity necessary to explain cave-bear ritual sites. In this case the protoconcept of the cave bear, namely, a cave-bear skeleton or skull, could be considered to exert some control over the members of its category, i.e., cave bears. The protoconcept, being an accessible abstract representative of all cave bears, is viewed as an agent through which actual cave bears (the members of its category) can be influenced. Before a category's existence was recognized independent of its members, such a use would be impossible. The ritual sites can then be seen as an attempt by Neandertal man to control his interaction with cave bears by control of the protoconcept, or abstraction of the actual bears. Although this process has aspects of what might be called religion, it is fundamentally much less sophisticated.

The two known human-skull ritual sites may represent the first attempt at definition of a human society. Once the protoconcept of an individual exists, a second-order protoconcept can be recognized. This protoconcept recognizes the commonality of the category of a collection of proto-individuals. Such definitions, or names, in their true conceptual forms are the *sine qua non* of societies and tribes. These names are the definitions of what it means to be a human being according to that group.[25] Attributes held in common by a group thus form the equivalence relation by which membership in the group is determined. The equivalence relation is the name of the category, and the name is the essence of the group of individuals. It is by this essence, or name, or equivalence relation, that a tribe is defined.

Neandertal man did not recognize a sufficient number of attributes to define a tribe, and therefore, a member of the group could be used to represent the collection of attributes characterizing the group. Although of second order, and therefore of greater complexity than other protoconcepts described, this is still an example of protoconceptualization.

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[24] The recognition that ornamentation may be significant for defining an individual is not unique. In relation to Neandertals, Trinkaus and Shipman [19], p.418, state "In some sense, the ornaments an individual wore gave the message, 'this is who or what I am'—meaning that not everyone is the same." This statement, though correct, has little rigorous meaning since its terms are undefined. What is unique about the present explanation is the unambiguous definition of stages in the recognition of an individual existence that can be used as an external framework for interpretation of archaeological data.

[25] Classic examples are the Innuit and Bantu, whose names mean "human beings" [43].

The few isolated examples of notational markings found in Mousterian deposits are of problematic, if any, significance. Although no direct correlation with mental evolution is possible, these marked objects, if truly of Middle-Paleolithic origin, may presage the development of conceptualization in the early Upper-Paleolithic Age.

In summary, the four innovations of the Middle-Paleolithic Age (i.e., human burial, crude ornamentation, cave-bear ritual sites, and human-skull ritual sites) are all naturally explained by protoconceptualization, and the appearance of protoconceptualization would predict such artifacts. These innovations demonstrate that categories of objects have achieved an independent existence from any member of the category. Evidence for this change is found in the obvious new meaning assigned to unaltered natural objects beyond their purely objective existence. It is not relevant if all, or only some, of the innovations described can be validated (see note 14). Rather, the mental capacity necessary to produce all of these artifacts is the same and therefore they are potential products of the Neandertal mind. The presence of these artifacts implies mental development at least to the level of protoconceptualization. By assuming that stages of mental evolution are expressed as soon as they appear, the Middle-Paleolithic Age can be termed the Age of Protoconceptualization.

Upper-Paleolithic Age—Age of Conceptualization

The Upper-Paleolithic Age can be conveniently divided into the Aurignacian, Solutrean, and Magdalenian eras.[26] Nonutilitarian artifacts of the Upper-Paleolithic Age can be classified into five categories. In approximate order of their appearance the categories are; personal ornamentation, statuettes, block engraving and block painting, discrete cave-wall images, and compositional representations in cave paintings and in portable engravings such as late examples of bâtons de commandement and spear-throwers.

Rudimentary personal ornamentation was probably present in the Middle-Paleolithic Age as evidenced by the pigment remnants found in most Mousterian cultural deposits. It was in the early Upper-Paleolithic Age, however, that unequivocal ornamentation appears.[27]

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[26] Although these terms refer to well-defined industries, they are sometimes used in this paper in a less rigorous manner, i.e., as synonyms for early, middle, and late.

[27] This includes beads of pierced animal teeth, shells, and fossils, as well as some amber [44,45]. Ochre blocks were heated to produce a range of colors, and perforation of these blocks implies the use of tattoos [46]. Personal ornamentation is the most consistently encountered, and most numerous, of early Upper-Paleolithic-Age

The Aurignacian culture also produced block engravings and statuettes, including Central European and Russian "Venus" statuettes.[28] The engravings are rudimentary and demonstrate superposition of images and negligent treatment of the final product.[29] Evidence of trade is also first found in the Aurignacian culture with amber, seashells, and high quality flints exchanged between widely separated sites.[30]

The Solutrean era, or middle Upper-Paleolithic Age, was a short-lived civilization whose most important contributions are the eyed-sewing needle, the bow and arrow, and the ornamental laurel-point blades.[31] Personal ornamentation continues with characteristic Solutrean emphasis, as does the Aurignacian palimpsest engraving and painting, as well as careless treatment of these decorations.

The Magdalenian, or final, era of the Upper-Paleolithic Age produced the largest number and variety of nonutilitarian artifacts, and may be divided typologically into three phases. The early part of the Magdalenian era is continuous with Solutrean and Aurignacian cultures in terms of both engraving and painting, although with substantially increased production. In the middle portion of the Magdalenian era unitary cave-wall decoration appears, equivalent to the engravings and paintings of the early phase.[32] Anthropomorphs are also first found in the middle Magdalenian phase. These are not common in cave art, with only about 150 total examples.[33]

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remains. Ornaments are first identified in the Châtelperronian culture, a transitional industry, but are most widespread beginning with the Aurignacian industry [7].

[28] For animal statuettes, see for example [47]. For "Venus" statues see [48]. A brief general survey is in de Sonneville-Bordes [49].

[29] The largest concentration of engraved blocks is at La Marche [50]. Similar engravings were found at Limeuil [51].

[30] See, e.g., Mellars [52].

[31] A brief summary can be found in Pfeiffer [53].

[32] The animals are the same representations previously encountered in block art and statuettes. Abstract signs are found in miniature art and in block art, but are most common in cave-wall decorations. Geometric signs include dots; barbs, harpoons, or hooks; triangular, quadrilateral, or pentagonal signs cleaved by a vertical median line; and other broad or narrow designs. These designs are displayed separately, juxtaposed to animal images, or superimposed on animal images. Superimposed signs are most often *v*- shaped with or without a central shaft, and have been traditionally interpreted as representing wounds. The percentage of the "wounded" animals is only 4% of total animals displayed, but shows marked regional variability, for example, the total reaches 25% at the cave of Niaux [54].

[33] Anthropomorphs are equally distributed between block art and cave-wall paintings [55]. There are few realistic human images in the Paleolithic Age, which contrasts sharply with extremely realistic renderings of Paleolithic-Age fauna. Most anthropomorphs are distorted in some way. A few are distorted animals, and a few

The typologic peak of the Magdalenian era reveals two important developments. The deliberate surmounting of obstacles played a significant part in late Magdalenian cave painting.[34] In addition, paintings show a compositional character with very similar themes throughout the distribution of the decorated caves.[35]

The final innovation of the late Magdalenian era was compositional engraving. These are portable bone carvings that demonstrate multiple, non-superimposed images whose similarity in theme strongly suggests a unified meaning.[36]

In summary, the major innovations of the Upper-Paleolithic Age, in typologic, and approximate temporal, sequence are personal ornamentation, animal statuettes and block engraving, superimposed cave-wall engraving and painting, engraved and painted composite beings, compositional paintings of the deep caves and compositional engravings. Though individual explanations of these artifacts will be presented, it is important to recognize that it is only the progression from unitary representations to

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distorted men, but most are part human-part animal composites. The sorcerer of Les Trois Frères is probably the most famous of these examples, and consists of human limbs, owl's face, horse's tail, and reindeer's antlers [56]. Other similar human forms include a humanoid with the head and tail of a bison from Le Gabillou and one with deer antlers and tail from Lourdes [57]. Several images are also found with tails extending from the shoulders in place of a head. These are located at Hornos de la Peña, Pech-Merle, and Pergouset [58]. Human distortions are also found with marked prognathism and other facial distortions.

[34] See Sieveking [59], Pfeiffer [60]. Artists often chose surfaces that were extremely difficult and inconvenient where they would be forced to work in uncomfortable and awkward positions. Most known examples of cave painting are in dark areas that had to be artificially illuminated, and nearly all the latest examples add a prominent element of inaccessibility to the dark location. For example, the most impressive Niaux reproductions begin more than 600 yards within the cave, and could only be reached after traversing a long and difficult arch-shaped tunnel. The cave paintings are scattered throughout the unlit portion of the cave, ending more than 1200 yards from daylight.[61]

[35] The compositional nature of the cave paintings was first noted by André Leroi-Gourhan [62]. Although there has been considerable argument concerning both his statistical analysis and his interpretation of the compositions, he makes a convincing argument about the similarity of form and content in Magdalenian deep-cave art [63,64]. The compositional nature of deep-cave painting has the support of two other factors. It is indirectly supported by the compositional nature of the coeval parietal engravings, indicating that true composition was present in this era. A simple compositional stage is also the logical preliminary step to complex mythologic compositions such as that found at Lascaux [65].

[36] The first such interpretation can be found in Marshack [66.]

compositional representations that is directly predicted by the theory of mental evolution.

The Magdalenian era also witnessed a rapid and substantial increase in population with new and more distant sites being occupied, yet the end of the era was sudden.[37] The disappearance of cave painting, and other sophisticated and complex Upper-Paleolithic-Age artifacts, is thought by some to be the result of a Mesolithic dark age where nonutilitarian artifacts are of poor quality, mainly limited to abstract designs.[38] In contrast, rapid and revolutionary transition to agriculture and animal domestication characterize the utilitarian aspects of the Mesolithic Age. An explanation of this apparent paradox is suggested by the present theory of mental evolution - no decline in mental development, or expression, occurred at the end of the Magdalenian era, but rather a developmental breakthrough that resulted in the function of the engravings and cave paintings becoming obsolete.

The appearance of personal ornamentation is artifactual evidence of the definition of a category, i.e., according to this formulation, a concept. The concept, in this case, is the specification of an individual's uniqueness. Recalling that the collection of attributes specifying a concept must be assembled somewhere, or it is not a collection, at this stage of mental development, the only space capable of carrying a concept is a physical object. In the case of an individual, the body is a natural choice for the physical concept-space. This is an unique identification, since only in this case is the object, me, constantly present as the center of perception. Since object, me, and concept, I, coexist in the same physical space (the body), there must be some manner of differentiating object from concept. I claim that personal ornamentation serves this function.[39]

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[37] An abrupt change in climate may have precipitated the cultural demise, but this cannot be the entire explanation as similar climatic changes had occurred throughout the Upper-Paleolithic Age without such dramatic social consequences [67].

[38] See de Sonneville-Bordes [50], and Milisaukas [68].

[39] Since the only member of the category "me," as a protoconcept, is identical to the physical concept-space of the concept "I," it is impossible to definitively distinguish the protoconcept from the true concept in this unique case. In all other cases, the true concept is easily separable from the protoconcept of the same category, since the latter is a member of the category, and the former is a reproduction in a different medium. Thus, in the case of the individual, protoconcept and concept can only be distinguished by the sophistication or complexity of the body's decoration. From this perspective, the bichromatic body painting or dyeing of skins contrasts strongly with evidence of multi-colored tattooing and the vast array of personal ornaments which characterizes the Upper-Paleolithic Age. Phenomenologically, this contrast is consistent with the difference between recognizing the category of an individual, and defining it.

The second class of Upper-Paleolithic-Age nonutilitarian artifacts is miniature sculpture in which the artifacts themselves are *prima facie* evidence of conceptualization.[40] According to the present thesis, a concept is a collection of attributes. A reproduction necessarily contains sufficient attributes to define a category if it is recognizable.[41] Not only is existence of a category's equivalence relation recognized, as in protoconceptualization, but its physical attributes are explicitly reproduced in the statuette. Therefore, by this definition, the very act of producing a statuette is evidence of conceptualization, and emergence of conceptualization predicts a process similar to the production of statuettes (or other examples to be described). By assuming that mental capacity is displayed as soon as it occurs, conceptualization can be identified in the early Upper-Paleolithic Age, and not earlier.

Block art lends even further support to this hypothesis. Statuettes are singular representations and appear randomly in archaeologic layers regardless of their intended use, since they are portable by nature. On the other hand, blocks of stone accommodate many images and are not easily moved. Consequently, the character of the images, and the condition and locations of the discovered blocks are of greater use in analyzing the meaning of the reproductions. Block art universally demonstrates superposition of images and careless treatment of the final product. Superimposition and negligent handling of the block engravings supports an explanation in terms of conceptualization, but is inconsistent with an explanation in terms of artistic expression. In this interpretation, the images are conceptual, and as such they are proto-linguistic.[42]

In summary, miniature sculpture and block art provide clear evidence of conceptualization (by this definition) since the reproductions are themselves the physical attribute collection forming the concept. Conversely, in a physical concept-space a concept must take such a form. This interpretation is strengthened by unusual and previously unexplained aspects of the block

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[40] The fundamental difference between Upper-Paleolithic-Age artifacts and art is that in art an internally derived concept is expressed externally in a physical medium, while in a physical concept-space the attribute collection that is the concept does not exist except in its physical manifestation.

[41] Though the concept is more subtle in the Venus statuettes, e.g., birth, pregnancy, fertility, the process is identical.

[42] A useful analogy is communication with a deaf person by writing notes. The only significance of a note is in its use at a particular time for a particular purpose. After the note is written, it is balled up and thrown away, or it may be overwritten, recognizing that only the last message has any meaning. Comparable treatment of block art suggests a similar, but highly rudimentary, protolinguistic function.

art, namely, the superposition of images and their neglectful treatment, supporting a proto-linguistic rather than artistic function.

Discrete cave-wall decorations demonstrate the palimpsest effect seen in block art, with the subjects of the decorations being animals, geometric forms, anthropomorphs, and animal-man composite monsters. The animals can be interpreted as the same simple concepts encountered in other discrete reproductions. Abstract signs may be either attributes or concepts without physical attributes. In either case a naturalistic representation is not possible.[43]

The universality of distortion or monstrosity in human images can be interpreted as a transition between simple concept decorations represented by the superimposed cave-wall paintings, and compositional wall paintings. In a contingent concept-space of miniature sculpture or discrete cave paintings, two or more separate images cannot be combined to display a more complex concept. The combination of individual images in a unitary whole requires recognition of a concept-space as a separate entity from any particular concept it carries. A composition is only possible when the space containing the multiple images is unified, i.e., when it is recognized as existing independent of any particular image. This separation is not possible in a contingent concept-space, and therefore, the only method of combining concepts is in a composite single image whose parts are separate concepts, but whose existence is still in a singular space.[44]

To create a composition, a physical concept-space must be recognized that is independent of the specific concepts displayed. The recognition of this independent concept-space allows a combination of separate images in a single unitary whole.[45] Compositional deep-cave "art" is best viewed as a

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[43] Although it is impossible to translate these signs, such attributes and concepts could include life, death, day, Spring, etc. Superimposed "wound" signs may be used to emphasize a particular attribute of the animal on which they occur. More frequent occurrence of 'wound' signs in advanced cave art suggests that signs may be used to increase the "vocabulary" of simple concept images.

[44] The fact that nearly all monstrous decorations are humanoid suggests that the concept to be defined includes attributes of humanity. These composite images may be an attempt to emphasize important attributes of an individual while restricted to a contingent concept-space. Such emphasis cannot be very complex due to the limitations of a single image. It may have been this limitation imposed on increasing mental capacity that forced recognition of an independent physical concept-space consisting of the entire cave wall.

[45] Three possible conceptual forms may be represented by each single image within the composition. First, a concept may be a simple name in which case the painting of a bison is the name *bison*. Second, a concept may be an agent of causation similar to the protoconcept of the cave bear in the Middle-Paleolithic Age. In this case a painting of a bison is a bison "god." Third, a concept may represent a major

collection of weighted attributes forming a single definition of a complex concept. Each image in such a composition represents a major attribute of the category it conceptualizes (see note 44). The complex concept, whose definition is the collection of attributes displayed, may be the sociological definition of a man or woman.[46] In other words, the collection of attributes displayed defines the characteristics held in common by members of the group, and therefore defines the society.[47] Compositional cave paintings may be the defining characteristics of the first human society. Existence of the independent physical concept-space, for the first time, made such a tribal definition possible.

Interpretation of compositional cave paintings as the definition of a tribe has the support of two other indirect factors. It has been commonly assumed

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nonphysical attribute of the bison, in which case the painting of a bison may mean "strength." The three possible meanings of the individual image within a composition yield four possible explanations of the total composition. A composition composed of multiple elements of the first type would be a proto-sentence; of the second type, a pantheon; of the third type, a definition. There is also the possibility that a composition may include elements with different conceptual forms. For example, one image may be a simple name, another a 'god', and a third may represent a major attribute, or attribute collection. This type of mixed composition recognizes a more subtle unity of the concept-space and is a myth.

[46] Within any specific animal composition, component images can be seen as having relative weighting supplied by, for example, position relative to the center. Thus, if there is validity to the central position of horse and bull, as Leroi-Gourhan states [69], it suggests a central importance and high relative weight. In this particular case, the conjecture is corroborated by the similar importance of these two animals as reflected in the numbers of miniature art objects, and in the central importance of the horse and bull in the first historical mythologies [70.]

[47] A society may be considered to be determined by a common definition of self—a second-order concept. From a simplified perspective, what it means to be an American, Russian, Apache, Venetian, etc. provides the common viewpoint necessary to subjugate individual will to that of a group. The communal definition of self is a collection of attributes chosen and prioritized by society. Dissemination of this societal definition is the most important single requirement of a viable society, for without it the society will cease to exist. If society is defined as a transmissible, commonly held definition of self, then the first society cannot predate conceptualization. The number of attributes needed to specify a communal self is too great to be displayed in a contingent physical concept-space, and thus the independent physical concept-space affords the first opportunity to define a society. In this interpretation, the quintessential nature of this definition is corroborated by the unique use of the compositional cave paintings for the definition of tribal self. Thus, the cave wall complex may be a direct, unimpeded view of the Magdalenian's definition of themselves, although the exact nature of that definition is currently unknowable.

that the population expansion of the Magdalenian had its roots in the formation of tribes since such a cohesive bond is necessary to allow large groups of humans to exist together in a productive society.[48] The interpretation of compositional cave art as the definition of a tribe therefore provides the immediate prerequisite for the observed increase in population. Second, definition of a tribe continues a consistent pattern of expression through all stages of mental evolution. That is, each new stage of mental development is first expressed in relation to the individual, and identification of the compositions as the definition of a tribe (a second-order individual, if you will) continues this progression.[49]

Myths are stories involving supernatural and supranatural individuals, places, or events and are usually based on a natural or historical fact. One of the most common types of myth explains the origin of a tribe in the supranatural tribulations of a supernatural ancestor. This type of myth contains at least the ancestor of the tribe and a god or two, as well as the geographic facts related to the action. This shows how a simple myth would appear in the physical concept-space. An image representing the tribe itself, an image or images of a god or gods, and images of natural objects would constitute such a composition. The image representing the tribe is a definition, the images of the gods are elements of a pantheon, and the images of natural objects are simple names. The mythic image just described is a composition where individual images have different conceptual interpretations. This type of general interpretation is consistent with the only convincing example of mythic cave-painting which is found in the deep pit at Lascaux.[50]

A complete explanation of compositional cave art must also account for the positions of the entire compositions relative to each other and the cave wall. Inaccessibility of cave painting sites is consistent with such a hierarchical interpretation. An independent space allows relative value to be

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48 See Mellars [71.]

49 The first protoconcept displayed was the proto-individual as evidenced by both the rudimentary personal ornamentation, and burial of the dead. The earliest, most widespread, and multifarious Aurignacian innovation was personal ornamentation, forming the definition of an individual. Anthropomorphs are attempts to emphasize human attributes while restricted to a contingent concept-space. The increase in conceptual complexity afforded by an independent physical concept-space allows a second-order definition of an individual. This is the definition of a group composed of individuals and is the definition of a tribe. The pattern is continued in mythologic reproductions. All concepts have an independent existence in the sense that they are separate from any element of the category they name. In the case of the tribe, the relationships of this new concept to other important concepts (i.e., “gods”) results in third-order concepts—the first mythologies.

50 See Campbell [65.]

assessed according to position within the space. Thus, hierarchical arrangement of entire compositions may have been homologous to an arrangement of the independent concept-space itself. A reasonable homology is an increasing abstraction of concepts being reflected as an increasing inaccessibility of the portion of the concept-space carrying the concept.[51] Definition of a tribe is an abstract concept, and its position is normally inconveniently placed in a deep-cave site. The most complex and abstract composition is mythologic, and, at Lascaux, this is found in an extremely awkward and difficult location.

Late examples of the bâton de commandement and carved spear-throwers, are examples of portable compositional art that is even more clearly unified than deep-cave compositions. These also may be interpreted as either sentences, pantheons, definitions, or myths, but again the third explanation is preferable.[52] The compositional engravings are almost all the products of the last stages of the Upper-Paleolithic Age.[53] This suggests that the range of defined complex concepts was expanding to include those less restricted than a tribal definition. A possible mythological carving is also known, sometimes interpreted as a "joke."[54]

Trade between widely separated locations forms the final recognizable phenomenon of Upper-Paleolithic-Age invention. Value attached to an object of trade is evidence of at least recognition of the category of that object. This implies a minimum mental capacity of protoconceptualization. Ability to identify desirable attributes in an object category is equivalent to its definition, or naming, and requires conceptualization. This fixes the first possible occurrence of trade in the Upper-Paleolithic Age. Thus, the appearance of archaeologic evidence of trade in the early Upper-Paleolithic Age is consistent with the present interpretation of mental evolution.

In summary, artifactual classes appearing in the Upper-Paleolithic Age are naturally explained by conceptualization, and the present theory of

[51] The homology of abstraction and inaccessibility has a teleological basis. Since the attribute collection in the deep-cave composition does not represent the tribe, but rather, *is* the tribe it may have been considered essential to isolate and protect it. This same tendency is seen in conscious man *vis à vis* the symbols of kingship, statehood, etc.

[52] An example is the bâton of Mountgaudier whose complex of figures engraved on the bone is interpreted by Marshack [66] to be a representation of objects related to Spring. The present interpretation suggests that what is displayed are the attributes of Spring, so that the bâton is in fact the name of the complex concept, Spring.

[53] See Marshack [66].

[54] The carving is of an ibex standing on a rock, looking over its shoulder at two birds perched on its emerging feces. The spear-thrower was discovered by the Péquarts at Mas d'Azil, and illustrated in Péquart and Péquart [72].

mental evolution predicts that the appearance of conceptualization must be accompanied by some such artifacts. Personal ornamentation and discrete reproductions are *prima facie* evidence of this process where the concept, and the space where it is assembled, are inseparable. The advance from discrete reproductions to a compositional stage can be explained as a further generalization recognizing that a concept-space exists independent of any particular concept. This explanation provides continuity with the rest of the artifactual sequence, and it also is supported by unrelated ecofactual data such as the Magdalenian population explosion. The recognition of the contingent and independent physical concept-spaces in the Upper-Paleolithic Age label this era the Age of Conceptualization.

Discussion

The concomitance of human biologic and mental evolution has produced a vast popular and scientific literature which attempts to temporally correlate the appearance of various mental capacities such as language and consciousness with anatomically defined stages of evolution. However, without a theory of mental development it is not possible to unambiguously define mental capacities much less to identify their associated phylogenetic or taxonomic appearance. The proposed theory of mental evolution both defines mental capacities and indicates their relationship to each other. Within this theory, mental capacities arise naturally out of progressively more complex analysis of an internal image of the external world. Under certain reasonable assumptions, the theory predicts the appearance of artifacts corresponding to expression of its hierarchical stages. When applied to the archaeologic record of nonutilitarian artifacts in the Paleolithic Age the theory provides both a consistent explanation of each artifactual class, and an explanation of the artifactual sequence. Equally important, only these artifactual types and their sequence are observed. Thus a bijective correlation of theory and observation is obtained.

Middle-Paleolithic-Age innovations are characterized by the isolation or display of unaltered natural objects. The appearance of simple bichromatic decoration, burial, and ritual sites represents the mental stage of protoconceptualization, where a category’s existence is recognized independent of any of its members. This recognition is demonstrated when a member of a category is used to represent the equivalence underlying the category.

The definition of a category’s equivalence is first seen in the Upper-Paleolithic Age when the attributes defining a category are explicitly displayed in a modified physical object. This explains the mental advance from Middle- to Upper-Paleolithic Age and specifies an identical mental process, i.e., contingent conceptualization, as the origin of miniature statues, block engraving, personal ornamentation, and discrete cave paintings. Compositional works, including examples of deep-cave art and portable engravings, demonstrate the recognition of an independent physical concept-space that can allow interaction of separate elements. In fact, such independence is a prerequisite for composition. The evolutionary advantage of conceptualization is the ability to manipulate categories of objects without manipulating the objects themselves.

Finally, the concept-space is defined resulting in the abstract concept-space of modern, conscious man. The complexity, efficiency, and speed of concept manipulation in an abstract space is greatly facilitated since hypotheses can be tested and concepts related to each other without juxtaposition of physical objects—neither the physical objects of categories, nor the physical concept-spaces that embody the definitions of categories. The expression of these abstract concepts is language. The development of language made the independent physical concept-space obsolete. This explains the sudden disappearance of deep-cave art and compositional engraving in Mesolithic Age cultures which were otherwise rapidly advancing.

The Upper-Paleolithic Age can be viewed as the time during which physically modern man was developing mentally modern capacities, a development that took 30,000 years. The late appearance of consciousness suggested by this interpretation is not unique. Others have suggested a recent evolution, but not on the basis of an analytic theory.[55]

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C. Paleolithic-Age Artifacts and Mental Evolution[56]

This paper will provide explanatory detail and evidentiary support for a theory of mental evolution consistent with the pioneering theoretical work of the Victorian neurologist John Hughlings Jackson (1835-1911).[57] By viewing the stages of evolution as phylogenetic, new meaning can be ascribed to the nonutilitarian remains, or “art,” of early humanity. I intend to demonstrate that these artifacts are not art as we know it, but are manifestations of increasing mental capacity. The temporal sequence of artifacts, and their individual interpretations, will be shown to be a predictable consequence of the theory to be presented. In this manner, the history of neuroscience can be extended to the history written in the archaeological record.

Hughlings Jackson’s theory of nervous system evolution is a functional hierarchy that is the basis of the modern science of neurology.[58] Through what Hughlings Jackson called the doctrine of concomitance, an analogous structure of the mind is suggested, though he himself ultimately rejected the full consequences of his observation.[59] The best evidence for Hughlings Jackson’s theory of nervous system evolution is the prediction and explanation of neurological disease in an individual, though it originated in a phylogenetic analysis.[60] In contrast, mental evolution is difficult to perceive ontogenetically where organisms of differing stages of evolution are interacting, but is more easily recognized phylogenetically where stages of evolution occur sequentially over extended periods of time.[61] It is for this reason that predictions of the theory are most clearly recognized in the sequence of artifacts of early man.

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[56] This paper was first presented at the International Society for the History of Neuroscience. Oslo, Norway. June 21, 1995.

[57] The derivation of a theory of mental evolution from Hughlings Jackson’s theory of nervous system evolution can be found in Steinberg and York (1994).

[58] See Hughlings Jackson (1958), York and Steinberg (1993, 1994).

[59] See Steinberg and York (1994)

[60] Though Hughlings Jackson does not himself mention the phylogenetic application of his theory, he does refer explicitly to parts of the work of Herbert Spencer that deal with the phylogeny of nervous system evolution. See Spencer (1910), pp.3-67.

[61] Some stages of mental evolution are quantitative, not qualitative, advances and may be rapidly acquired by a developing child. The coexistence of fully conscious adults complicates the separation of discernible stages of mental development in children. This is not a problem in phylogeny where advances are temporally sequential. In this circumstance the artifactual record provides evidence for the maximum stage of mental development at any time, uncomplicated by any more advanced capacity.

Archaeological correlations of the theory of mental evolution depend on two assumptions: first, stages of mental development are reflected in the artifactual record, and second, stages of evolution are expressed as soon as they appear. The combination of these two principles means that the level of mental development indicated by the appearance of a new artifact is the minimum level sufficient to produce that artifact.

A Theory of Mental Evolution

Beginning with Hughlings Jackson's theory of nervous system evolution, a concomitant theory for mental evolution can be generated. This theory consists of a partition of internal images into separate objects (analogous to Hughlings Jackson's partition of the body), and three stages of evolution reached by the repeated action of an ordinal function (analogous to the three stages of nervous system evolution reached by repetitive representation).[62] The stages of mental evolution will be termed categorization, conceptualization, and consciousness. The process of mental evolution is identification of equivalence, and once internal images are partitioned into objects, it proceeds so that each step represents an equivalence identified in the preceding stage. First categories of similar objects are recognized (categorization), then the equivalence underlying a category is recognized (protoconceptualization), then the equivalence forming a category is defined (conceptualization). Individual definitions, or names, first exist only as embodiments in physical objects where the material of a representation becomes the inseparable concept-space of that name (contingent physical concept-space).[63] Next the concept-space is

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[62] For Hughlings Jackson's theory of nervous system evolution see Hughlings Jackson (1958) pp. , York and Steinberg (1993, 1994). For the structure of a concomitant theory of mental evolution see Steinberg and York (1994).

[63]Simply put, a concept-space is the place where concepts exist. This idea may seem unnecessary since the concepts of modern man exist in an abstract mental space, and it is difficult to imagine any other form for concepts to take. When something is known in only one form, and when it is not clearly defined, it is difficult to separate form from content. But a concept is entirely distinct from the place where it resides. A concept can be viewed as an equivalence relation, a collection of special categories or attributes, but how or where this collection is assembled is not part of the definition. Thus, a concept can exist in many forms because the concept is separate from its representation, just as a subject represented in a photograph, painting, drawing, dream, and sculpture is distinct from the subject itself. Before the abstract space existed, the collection of special categories is asssembled in a modified physical object that carries the concept, and is the concept-space of the concept. An example of this process is the miniature sculpture of the Upper-Paleolithic Age

recognized as a separable entity from the concept it carries (independent physical concept-space), and finally the concept-space is defined (abstract concept-space). The formation of an abstract concept-space I define as consciousness.[64] The lowest and middle levels of mental evolution have

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where the concept-space is the carved stone displaying the physical characteristics of animals.

[64] As an example of a mental evolutionary sequence, consider a horse. First, a particular horse is recognized as a separate object, i.e., separate from the ground, sky, trees, etc. Next, a category of horses is recognized which serves purely as a standard of comparison to determine if a newly encountered object is a horse. Once a category is recognized, it is possible to recognize that there is an underlying similarity of the horses that causes them to be classified together. I call this recognition protoconceptualization, and the mental advance is the recognition that a category exists independent of any of its members. This advance is demonstrated by the use of a single horse, or horse part, to represent the category of horse. A protoconcept of horse must be a particular horse because only a member of this category manifests the similarity underlying all horses, which at this stage cannot be specified. Protoconceptualization can be recognized since the context of its use indicates there is meaning attached to an unmodified object beyond its existence as a simple object. This stage of mental evolution appeared in *Homo sapiens neanderthalensis* at the opening of the Middle-Paleolithic Age when unaltered natural objects are first isolated and displayed (e.g., burial and ritual sites).

Conceptualization occurs when the underlying similarity of the category of horse is defined. That is, a concept is the explicit equivalence relation, or collection of attributes, which determines if an object is a horse. Since the equivalence relation is explicit, a concept need not be a member of the category it conceptualizes. At first the collection of attributes is explicitly brought together in a modified object, e.g., a carving of a horse. An adequate specification of the physical attributes of a horse is a prerequisite for such a statuette, for this is the way it is recognized as a horse. This process occurred at the opening of the Upper-Paleolithic Age. The modified physical object that carries the concept is a concept-space. At this stage, a concept-space is contingent in the sense that it only accommodates a single concept. The next stage of evolution recognizes that a carving of a horse and a carving of a bull have something in common. The common feature is the capacity of the underlying material of the carving to accommodate either a bull or a horse. The recognition of the existence of a concept-space independent of any particular concept is necessary and sufficient for the innovation of composition. That is, a composite image can exist if, and only if, the elements of the composition are understood to occupy a common space, and the common space exists independent of any particular concept. Archaeologically, this corresponds to the compositional cave paintings and carvings, and allows a unified image containing a horse and a bull.

Once the concept-space is recognized as an independent entity, it can be defined. The definition is again a collection of attributes, one of which specifies a potentially infinite carrying capacity of the space. This can occur only in an abstract space, and internal structure - the former includes protoconceptualization as a form of categorization, while the latter includes the contingent and independent physical concept-spaces as forms of conceptualization.

Lower-Paleolithic Age—The Age of Categorization

The Lower-Paleolithic Age begins with the appearance of the first tool-producing hominid, *Homo habilis,* approximately 2 million years before the present (BP), and ends with the emergence of *Homo sapiens neanderthalensis* approximately 100,000 BP.[65] The division is characterized by extremely slow progress as measured by variation in stone-tool artifacts—in one documented instance change is imperceptible for a period of over 500,000 years.[66]

H. habilis produced the earliest stone-tool industry, known as the Oldowan. The Oldowan tool-making technique is characterized by the chopper-core, which is an alternate name of the industry. Chopper-core tools are archaeologically demonstrable during an interval of 1 million years beginning approximately 1.8 million years ago.[67]

The sole artifactual innovation of the Lower-Paleolithic Age occurred when *Homo erectus*[68] modified the chopper-core tradition to produce hand axes.[69] Migration of *H. erectus* is indicated by hand-ax artifacts which appear in Mediterranean sites about 800,000-700,000 BP, in India and Asia by about 600,000 BP, and by about 400,000 BP, throughout Africa, Europe, and the Indian subcontinent. At the beginning of the Würm glaciation, c.100,000 BP, *Homo sapiens neanderthalensis* appeared, and the Mousterian

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it is the formation of a mental abstract space that is consciousness. The abstract notion of horse that is conveyed by the modern word, 'horse', is a result of this process. According to this analysis, consciousness appeared at the end of the Upper-Paleolithic Age, 10,000 years ago, and accounted for the disappearance of the great cave paintings and the appearance of Mesolithic-Age innovations.

[65]The Paleolithic Age coincides with the geologic epoch of the Pleistocene and is divided into three segments. The Lower- Paleolithic Age is the longest division, encompassing nearly 2 million years or 95% of the total Age.

[66] This particular sequence of chopper-core tools was discovered by Mary Leakey in beds I and II at Olduvai gorge. See Leakey (1971).

[67] See Wymer (1982).

[68] The oldest remains of this new species of hominid were first found near Lake Turkana in Kenya, in strata 1.8 million years old. See Milisauskas (1978). *H. erectus* is a long-lived and successful species who first controlled naturally-occurring fire and migrated throughout the Old World.

[69] The hand-ax industry is also known as Acheulian after the site of first discovery, St. Acheul near Amiens in northern France. The first known hand-axes, however, are African in origin and are about 1.3 million years old.

and Levallois flake-tool industries replaced the Acheulian industry as the dominant stone-working technique.

The single most remarkable feature of the Lower-Paleolithic Age, relative to the succeeding epochs, is the extremely slow rate of artifactual change. Only utilitarian artifacts are found with no evidence of the use of any object for a purpose other than acquisition and/or processing of food.

The manufacture and use of tools is not limited to humans.[70] The distinctions that separate animal from early human tool-use are quantitative, not qualitative. That is, human tools are more modified, more varied, and more permanent, but not fundamentally different.[71]

The abstract similarity of mental processes in other animals does not detract from the revolutionary impact of tools on human development and expansion.[72] Stone tools and the control of natural fire allowed migration of *Homo erectus* throughout the Old World. The absence of any accompanying change in stage of mental development, however, labels the Lower-Paleolithic Age as the Age of Categorization.

Middle-Paleolithic Age—
The Age of Protoconceptualization

The appearance of Neandertal man (*Homo sapiens neanderthalensis*) c.100,000 BP inaugurated the Middle- Paleolithic Age which lasted until c.40,000 BP.[73] Neandertals created the first nonutilitarian artifacts, which,

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[70] Animals from invertebrates to great apes use and manufacture tools of various levels of sophistication. See Beck (1980) for an exhaustive survey.

[71] The greater sophistication of human tools is certainly indicative of greater mental capacity, but it is not necessary to invoke a different stage of mental development to explain human tool production. The mental advance indicated by human tools is enhanced categorization and sub-categorization of the perceived world. This results in higher-order categories that reveal more subtle relationships, but there is no difference in principle between the abstract process of categorization in a human creating a hand ax and a sheep dog recognizing a sheep. Viewed differently, there is no category whose equivalence relation is recognized by production of a stone tool, and hence no new stage of mental evolution is indicated.

[72] Quantitative changes which exceed a threshold can produce qualitatively different results. For example, the quantitative addition of falling snow to a mountain slope will eventually produce a qualitative change when the coefficient of static friction is overcome and an avalanche results.

[73] Two distinct stone-tool industries are recognized as products of Neandertal man. They are essentially geographic variants with the Levallois industry found in the Mediterranean region and the Mousterian industry throughout Europe and much of Asia. See Champion et al (1984). The classification of all Middle-Paleolithic-Age

by hypothesis, is interpreted as evidence for an alteration in mental capacity. At this point predictions of the present theory of mental evolution can be directly supported by the archaeological record. Neandertal nonutilitarian artifacts[74] can be classified as either human burials[75], natural pigments[76],

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skeletal remains as the subspecies *neanderthalensis* is controversial due to profound morphologic variability (See Swan, 1974, p.145). This is not relevant for the present purpose, however, since both the Levalloiso-Mousterian tool industry and the nonutilitarian artifacts are shared by all morphologic variants. Since artifactual evidence is correlated with mental evolution exact taxonomy does not affect the argument.

[74] There is some dispute as to whether there are any nonutilitarian artifacts from the Middle-Paleolithic Age. Although an adequate number of burials have been discovered to suggest these at least are real, other artifacts are more problematic. For example, the ritual sites to be described are very few in number and were not appropriately documented during excavation. Trinkaus and Shipman (1993) are skeptical about the existence of human and cave-bear ritual sites, and their conclusions may be correct. However, their skepticism is not totally based on the limited evidence—they do not believe that Neandertals were mentally capable of such artifacts which they interpret as evidence of modern capacities (cf. p.258). According to the present analysis, the mental capacity indicated by these artifacts is far from modern. The capacity that explains the well-documented burials and the equivocal ritual sites is identical and therefore there is no extrinsic reason to reject the available data concerning the latter. For this development, the actual existence of ritual sites is not relevant. An explanation according to this theory is provided, however, in the event that more definitive confirmation is obtained in the future.

[75] Burials are identified in the earliest settlements of Neandertal man. The Mousterian industry at La Chapelle-aux-Saints overlays a grave carved into the solid rock of the cave floor. (Bouyssonie *et al* , 1909) Other burials of similar type have been found on the Dordogne at La Ferrassie (Bergounioux, 1958), and in the Crimean peninsula at Kiik-Koba. (Mongait, 1961; Clark, 1969) A collection of ten Neandertal graves was found near Mt. Carmel at Mugharet es-Skhul. (Swan, 1974, p.151) The cave at Shanidar, in present-day Iraq, revealed a burial that had been accompanied by at least eight species of flower. (Solecki, 1975) Though Neandertal burials are commonly accepted, some questions about their authenticity have been raised. Recent excavations are more definitive. (Lévêque and Vandermeersch, 1980).

[76] Natural pigments are a common finding at Neandertal sites (Wymer, 1982, p.174). Intentional mining of these pigments is well-documented (Dart and Beaumont, 1969; Schmid, 1969). Lumps of black manganese oxide and red ochre are found sharpened like pencils and scratched, presumably to make powder for paint. (Singer and Wymer, 1982, p.117) Ochre is used in burials, and although other uses of the pigment are uncertain, body painting is probably among them. Unequivocal evidence of personal ornamentation, such as pendants and necklaces, has not been found.

ritual sites associated with human and cave-bear remains[77], or rare notational markings on bone fragments and stone.[78]

The unifying characteristic of all Middle-Paleolithic-Age nonutilitarian innovations is the isolation or display of essentially unaltered natural objects. The theory of mental evolution predicts that an advance from categorization to protoconceptualization involves such a new use of objects (See note 8), and therefore suggests that an explanation of Middle-Paleolithic-Age artifacts lies in recognition of a category's existence independent of its members. Since an element of a category is used to represent the category's underlying equivalence, the equivalence is not specified. There is only the recognition that there are defining characteristics of

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[77] The first evidence of possible ritual associated with human remains is a product of Neandertal man. At Monte Circeo, in Italy, a Neandertal skull was apparently placed within a raised circle of stones. Stiner (1991) provides a detailed evaluation of the Monte Circeo cave site while arguing against its intentional construction. At Teshik-Tash in Uzbekistan a Neandertal infant skull was found which may have been surrounded by six pairs of Siberian mountain-goat horns. (Movius, 1953) These may have been placed upright in a circle surrounding the skull.

Neandertal man may also have made ritual use of cave-bear skulls and skeletons. This animal was very large and dangerous, and the interaction between Neandertal man and the cave-bear was inevitable since the cave-bear was extremely common, and both species sought the same housing. The cave-bear is the sole non-human animal with attributed ritual sites.

At Drachenloch, high in the Swiss Alps, a number of skulls and assorted limb bones of the cave-bear were found (Schmidt, 1934). This cave could not have been occupied during Middle-Paleolithic-Age winters, because of its altitude, and thus suggests a periodically visited ritual site. The arrangement of bear skulls within the cave also suggests some ritual usage. At Peter's cave in Unterfranken, Germany, additional evidence of intentional isolation of a cave-bear skull is found (Swan 1974, p.154; Wymer, 1982, p.172; Milisaukas, 1978, p.32). Finally, excavation of Regourdou in Southern France revealed the burial of up to twenty cave-bears in a pit underneath a one-ton rock slab. An entire skeleton of a cave-bear may have originally been placed on top of the slab (Bergounioux, 1958).

[78] Modified and engraved objects are extremely uncommon in Mousterian cultural deposits. They are often found in thin or disturbed occupation layers, and are consequently of questionable significance (Mellars, 1973, p.259). At Tata, near Budapest, excavation of a Mousterian settlement from approximately 50,000 BP has uncovered a split mammoth tooth that had apparently been polished and covered with red ochre, and an amulet-like object with an engraved cross made from nummulite (Vértes, 1964; Bordes 1968). Poorly incised and/or drilled bone fragments and teeth are also occasionally found apparently associated with Mousterian deposits (Leonardi, 1983; Marshack, 1976).

the category, and that these are manifested by the single element representing the category.

A particularly important example of this process concerns recognition of the category that consists of a single object—the physical body of an individual. Purposeful treatment of a body after death indicates recognition of some properties of an individual independent of the body as an object. Recognition that an individual possesses defining characteristics independent of their body is the recognition of a category's existence independent of its elements, i.e., protoconceptualization. By preferring the minimal mental capacity capable of producing an artifact as the capacity indicated by the presence of the artifact, burial is best interpreted as an example of protoconceptualization.[79]

If the process of protoconceptualization is responsible for the artifact of human burial, there are still two possibilities for its specific meaning. Burial could itself represent differentiation of object from protoconcept, that is, the burial is the modification or display of the body differentiating the object, me, from proto-I. The burial could also represent special treatment of a pre-existing protoconcept as a continuation of the existence of a proto-individual, and as a focus of feelings toward the proto-individual. The latter appears more likely.[80]

If the proto-individual existed prior to death then there must be evidence for an *in vivo* differentiation of object and protoconcept. The category of a proto-individual consists of a single object, the physical body of that individual. Since a protoconcept must be a member of the category it represents, only the physical body can act as the protoconcept (See note 23). In order to distinguish the proto-I from "me" it is necessary to alter the

[79] Explanation of burial in terms of protoconcepts does not involve the poetic notion of the birth of religion, or the discovery of an afterlife. Rather, burial is evidence of recognition that a category exists (characteristics defining an individual) independent of its single element (the body). That is, burial is the first rudimentary attempt at defining an individual. This involves recognition that there is an essence of an individual, that it exists independent of the body, and that the body of the individual can represent this essence. Since the proto-I exists independently of the body, and since only the body can represent the proto-I, burial is a natural method of identifying the uniqueness of a dead individual.

[80] If the protoconcept of the individual could not exist prior to his or her death, the reason for its appearance is obscure. There is little purpose in defining an individual only after they are dead. On the other hand, existence of a proto-individual provides a meaning to the body beyond its reality as an object, i.e., as the representative of the essence of the proto-individual. The continuing existence of the proto-I, which is by definition independent of the physical body, me, is artifactually demonstrated by burial.

arrangement or display of the object that is "me," just as in any other protoconcept. The presence of pigments in Mousterian deposits is thought to indicate that body painting was practiced by Neandertal man.[81] This inference seems reasonable and is generally accepted. Even if ochre was only used for dyeing skins, the alteration in appearance of an object of clothing has the same implications for mental development as does body painting.[82] Body painting, or the simple coloring of crude fur clothing, is the most elementary method of differentiating the object, me, from the proto-I, and thereby recognizing the latter.[83]

Protoconceptualization also is the minimal mental capacity necessary to explain cave-bear ritual sites. In this case the protoconcept of the cave bear, namely, a cave-bear skeleton or skull, could be considered to exert some control over the members of its category, i.e., cave bears. The protoconcept, being an accessible abstract representative of all cave bears, is viewed as an agent through which actual cave bears (the members of its category) can be influenced. Before a category's existence was recognized independent of its members, such a use would be impossible. The ritual sites can then be seen as an attempt by Neandertal man to control his interaction with cave bears by control of the protoconcept, or abstraction of the actual bears. Although this process has aspects of what might be called religion, it is fundamentally much less sophisticated.

The two known human-skull ritual sites may represent the first attempt at definition of a human society. Once the protoconcept of an individual exists, a second-order protoconcept can be recognized. This protoconcept recognizes the commonality of the category of a collection of proto-

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[81] Ochre sticks have been discovered that are sharpened, apparently for use as crayons. These were probably used for body painting since no ochre drawings or colorings are found. See Singer and Wymer (1982).

[82] Some archaeologists contend, however, that ochre was used solely as a preservative for skins and human carcasses (Audouin and Plisson, 1982). The abrupt appearance and ubiquity of ochre and manganese oxide in Middle-Paleolithic-Age deposits, however, suggests a more fundamental advance. More importantly, preservation of human bodies would have no purpose until the body had a significance beyond its simple objective existence.

[83] The recognition that ornamentation may be significant for defining an individual is not unique. In relation to Neandertals, Trinkaus and Shipman (1993), p.418 state, "In some sense, the ornaments an individual wore gave the message, 'this is who or what I am'—meaning that not everyone is the same." This statement, though correct, has little rigorous meaning since its terms are undefined. What is unique about the present explanation is the unambiguous definition of stages in the recognition of an individual existence that can be used as an external framework for interpretation of archaeological data.

individuals. Such definitions, or names, in their true conceptual forms are the *sine qua non* of societies and tribes. These names are the definitions of what it means to be a human being according to that group.[84] Attributes held in common by a group thus form the equivalence relation by which membership in the group is determined. The equivalence relation is the name of the category, and the name is the essence of the group of individuals. It is by this essence, or name, or equivalence relation, that a tribe is defined.

Neandertal man did not recognize a sufficient number of attributes to define a tribe, and therefore, a member of the group could be used to represent the collection of attributes characterizing the group. Although of second order, and therefore of greater complexity than other protoconcepts described, this is still an example of protoconceptualization.

The few isolated examples of notational markings found in Mousterian deposits are of problematic, if any, significance. Although no direct correlation with mental evolution is possible, these marked objects, if truly of Middle Paleolithic origin, may presage the development of conceptualization in the early Upper-Paleolithic Age.

In summary, the four innovations of the Middle-Paleolithic Age (i.e., human burial, crude ornamentation, cave-bear ritual sites, and human-skull ritual sites) are all naturally explained by protoconceptualization, and the appearance of protoconceptualization would predict such artifacts. These innovations demonstrate that categories of objects have achieved an independent existence from any member of the category. Evidence for this change is found in the obvious new meaning assigned to unaltered natural objects beyond their purely objective existence. It is not relevant if all, or only some, of the innovations described can be validated (see note 18). Rather, the mental capacity necessary to produce all of these artifacts is the same and therefore they are potential products of the Neandertal mind. The presence of these artifacts implies mental development at least to the level of protoconceptualization. By assuming that stages of mental evolution are expressed as soon as they appear, the Middle-Paleolithic Age can be termed the Age of Protoconceptualization.

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[84] Classic examples are the Innuit and Bantu, whose names mean "human beings" (Simpson, 1989; vol. VII p.999, vol.I p.939).

Upper-Paleolithic Age—The Age of Conceptualization

The Upper-Paleolithic Age can be conveniently divided into the Aurignacian, Solutrean, and Magdalenian eras.[85] Nonutilitarian artifacts of the Upper-Paleolithic Age can be classified in five categories. In approximate order of their appearance the categories are; personal ornamentation, statuettes, block engraving and block painting, discrete cave-wall images, and compositional representations in cave paintings and in portable engravings such as late examples of bâtons de commandement and spear-throwers.

Rudimentary personal ornamentation was probably present in the Middle-Paleolithic Age as evidenced by the pigment remnants found in most Mousterian cultural deposits. It was in the early Upper-Paleolithic Age, however, that unequivocal ornamentation appears.[86]

The Aurignacian culture also produced block engravings and statuettes, including Central European and Russian "Venus" statuettes.[87] The engravings are rudimentary and demonstrate superposition of images and negligent treatment of the final product.[88] Evidence of trade is also first found in the Aurignacian culture with amber, seashells, and high quality flints exchanged between widely separated sites.[89]

The Solutrean era, or middle Upper-Paleolithic Age, was a short-lived civilization whose most important contributions are the eyed-sewing needle, the bow and arrow, and the ornamental laurel-point blades.[90] Personal ornamentation continues with characteristic Solutrean emphasis, as does the Aurignacian palimpsest engraving and painting, as well as careless treatment of these decorations.

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[85] Although these terms refer to well-defined industries, they are sometimes used in this paper in a less rigorous manner, i.e., as synonyms for early, middle, and late.

[86] This includes beads of pierced animal teeth, shells, and fossils, as well as some amber. See, for example, Leroi-Gourhan (1961) and Hahn (1972). Ochre blocks were heated to produce a range of colors, and perforation of these blocks implies the use of tattoos (Péquart and Péquart, 1960, p.243). Personal ornamentation is the most consistently encountered, and most numerous, of early Upper Paleolithic Age remains. Ornaments are first identified in the Chatelperronian culture, a transitional industry, but are most widespread beginning with the Aurignacian industry. (See Marshack (1972).

[87] For animal statuettes, see for example Riek (1934). For “Venus” statues see Delporte (1979). A brief general survey is in de Sonneville-Bordes (1979).

[88] The largest concentration of engraved blocks is at La Marche (Pales, 1976). Similar engravings were found at Limeuil (Capitan and Bouyssonie, 1924).

[89] See Mellars (1973) p.266.

[90] See Pfeiffer (1972) p.238.

The Magdalenian, or final, era of the Upper-Paleolithic Age produced the largest number and variety of nonutilitarian artifacts, and may be divided typologically into three phases. The early part of the Magdalenian era is continuous with Solutrean and Aurignacian cultures in terms of both engraving and painting, although with substantially increased production. In the middle portion of the Magdalenian era unitary cave-wall decoration appears, equivalent to the engravings and paintings of the early phase.[91] Anthropomorphs are also first found in the middle Magdalenian phase. These are not common in cave art, with only about 150 total examples.[92]

The typologic peak of the Magdalenian era reveals two important developments. The deliberate surmounting of obstacles played a significant part in late Magdalenian cave painting.[93] In addition, paintings show a

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[91] The animals are the same representations previously encountered in block art and statuettes. Abstract signs are found in miniature art and in block art, but are most common in cave-wall decorations. Geometric signs include dots; barbs, harpoons, or hooks; triangular, quadrilateral, or pentagonal signs cleaved by a vertical median line; and other broad or narrow designs. These designs are displayed separately, juxtaposed to animal images, or superimposed on animal images. Superimposed signs are most often *v*- shaped with or without a central shaft, and have been traditionally interpreted as representing wounds. The percentage of the "wounded" animals is only 4% of total animals displayed, but shows marked regional variability, for example, the total reaches 25% at the cave of Niaux (Leroi-Gourhan, 1982, p.57).
[92] Anthropomorphs are equally distributed between block art and cave-wall paintings (Leroi-Gourhan, 1982, p.51). There are few realistic human images in the Paleolithic Age, which contrasts sharply with extremely realistic renderings of Paleolithic- Age fauna. Most anthropomorphs are distorted in some way. A few are distorted animals, and a few distorted men, but most are part human-part animal composites. The sorcerer of Les Trois Frères is probably the most famous of these examples, and consists of human limbs, an owl's face, horse's tail, and reindeer's antlers (Breuil, 1979, p.166). Other similar human forms include a humanoid with the head and tail of a bison from Le Gabillou and one with deer antlers and tail from Lourdes (Leroi-Gourhan, 1982, p.52. Several images are also found with tails extending from the shoulders in place of a head. These are located at Hornos de la Peña, Pech-Merle, and Pergouset (Leroi-Gourhan, 1982, p.54). Human distortions are also found with marked prognathism and other facial distortions.
[93] See Sieveking (1979), Pfeiffer (1972), p.264. Artists often chose surfaces that were extremely difficult and inconvenient where they would be forced to work in uncomfortable and awkward positions. Most known examples of cave painting are in dark areas that had to be artificially illuminated, and nearly all the latest examples add a prominent element of inaccessibility to the dark location. For example, the most impressive Niaux reproductions begin more than 600 yards within the cave, and could only be reached after traversing a long and difficult arch-shaped tunnel. The cave paintings are scattered throughout the unlit portion of the cave, ending more than 1200 yards from daylight (Breuil, 1979, p.179-197).

compositional character with very similar themes throughout the distribution of the decorated caves.[94]

The final innovation of the late Magdalenian era was compositional engraving. These are portable bone carvings that demonstrate multiple, non-superimposed images whose similarity in theme strongly suggests a unified meaning.[95]

In summary, the major innovations of the Upper-Paleolithic Age, in typologic, and approximate temporal, sequence are personal ornamentation, animal statuettes and block engraving, superimposed cave-wall engraving and painting, engraved and painted composite beings, compositional paintings of the deep caves and compositional engravings. Though individual explanations of these artifacts will be presented, it is important to recognize that it is only the progression from unitary representations to compositional representations that is directly predicted by the theory of mental evolution.

The Magdalenian era also witnessed a rapid and substantial increase in population with new and more distant sites being occupied, yet the end of the era was sudden.[96] The disappearance of cave painting, and other sophisticated and complex Upper-Paleolithic-Age artifacts, is thought by some to be the result of a Mesolithic dark age where nonutilitarian artifacts are of poor quality, mainly limited to abstract designs.[97] In contrast, rapid and revolutionary transition to agriculture and animal domestication characterize the utilitarian aspects of the Mesolithic Age. An explanation of this apparent paradox is suggested by the present theory of mental evolution - no decline in mental development, or expression, occurred at the end of

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[94] The compositional nature of the cave paintings was first noted by André Leroi-Gourhan (Leroi-Gourhan, 1968). Although there has been considerable argument concerning both his statistical analysis and his interpretation of the compositions, he makes a convincing argument about the similarity of form and content in Magdalenian deep-cave art. (Stevens, 1975; Parkington, 1969) The compositional nature of deep-cave painting has the support of two other factors. It is indirectly supported by the compositional nature of the coeval parietal engravings, indicating that true composition was present in this era. A simple compositional stage is also the logical preliminary step to complex mythologic compositions such as that found at Lascaux (Campbell, 1986, p.301).

[95] See Marshack (1970)

[96] An abrupt change in climate may have precipitated the cultural demise, but this cannot be the entire explanation as similar climatic changes had occurred throughout the Upper-Paleolithic Age without such dramatic social consequences (Pfeiffer, 1972, p.246).

[97] See de Sonneville-Bordes (1979), p.353, and Milisaukas (1978), p.40.

the Magdalenian era, but rather a developmental breakthrough that resulted in the function of the engravings and cave paintings becoming obsolete.

The appearance of personal ornamentation is artifactual evidence of the definition of a category, i.e., according to this formulation, a concept. The concept, in this case, is the specification of an individual's uniqueness. Recalling that the collection of attributes specifying a concept must be assembled somewhere, or it is not a collection, at this stage of mental development, the only space capable of carrying a concept is a physical object. In the case of an individual, the body is a natural choice for the physical concept-space. This is an unique identification, since only in this case is the object, me, constantly present as the center of perception. Since object, me, and concept, I, coexist in the same physical space (the body), there must be some manner of differentiating object from concept. I claim that personal ornamentation serves this function.[98]

The second class of Upper-Paleolithic-Age nonutilitarian artifacts is miniature sculpture in which the artifacts themselves are *prima facie* evidence of conceptualization.[99] According to the present thesis, a concept is a collection of attributes. A reproduction necessarily contains sufficient attributes to define a category if it is recognizable.[100] Not only is existence of a category's equivalence relation recognized, as in protoconceptualization, but its physical attributes are explicitly reproduced in the statuette. Therefore, by this definition, the very act of producing a statuette is evidence of conceptualization, and emergence of conceptualization predicts a process similar to the production of statuettes (or other similar examples

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[98] Since the only member of the category "me," as a protoconcept, is identical to the physical concept-space of the concept, I, it is impossible to definitively distinguish the protoconcept from the true concept in this unique case. In all other cases, the true concept is easily separable from the protoconcept of the same category, since the latter is a member of the category, and the former is a reproduction in a different medium. Thus, in the case of the individual, protoconcept and concept can only be distinguished by the sophistication or complexity of the body's decoration. From this perspective, the bichromatic body painting or dyeing of skins contrasts strongly with evidence of multi-colored tattooing and the vast array of personal ornaments which characterizes the Upper-Paleolithic Age. Phenomenologically, this contrast is consistent with the difference between recognizing the category of an individual, and defining it.

[99] The fundamental difference between Upper-Paleolithic-Age artifacts and art is that in art an internally derived concept is expressed externally in a physical medium, while in a physical concept-space the attribute collection that is the concept does not exist except in its physical manifestation.

[100] Though the concept is more subtle in the Venus statuettes, e.g., birth, pregnancy, fertility, the process is identical.

to be described). By assuming that mental capacity is displayed as soon as it occurs, conceptualization can be identified in the early Upper-Paleolithic Age, and not earlier.

Block art lends even further support to this hypothesis. Statuettes are singular representations and appear randomly in archaeologic layers regardless of their intended use, since they are portable by nature. On the other hand, blocks of stone accommodate many images and are not easily moved. Consequently, the character of the images, and the condition and locations of the discovered blocks are of greater use in analyzing the meaning of the reproductions. Block art universally demonstrates superposition of images and careless treatment of the final product. Superimposition and negligent handling of the block engravings supports an explanation in terms of conceptualization, but is inconsistent with an explanation in terms of artistic expression. In this interpretation, the images are conceptual, and as such they are proto-linguistic.[101]

In summary, miniature sculpture and block art provide clear evidence of conceptualization (by this definition) since the reproductions are themselves the physical attribute collection forming the concept. Conversely, in a physical concept-space a concept must take such a form. This interpretation is strengthened by unusual and previously unexplained aspects of the block art, namely, the superposition of images and their neglectful treatment, supporting a proto-linguistic rather than artistic function.

Discrete cave-wall decorations demonstrate the palimpsest effect seen in block art, with the subjects of the decorations being animals, geometric forms, anthropomorphs, and animal-man composite monsters. The animals can be interpreted as the same simple concepts encountered in other discrete reproductions. Abstract signs may be either attributes or concepts without physical attributes. In either case a naturalistic representation is not possible.

The universality of distortion or monstrosity in human images can be interpreted as a transition between simple concept decorations represented by the superimposed cave-wall paintings, and compositional wall paintings. In a contingent concept-space of miniature sculpture or discrete cave paintings, two or more separate images cannot be combined to display a more complex concept. The combination of individual images in a unitary whole requires recognition of a concept-space as a separate entity from any particular concept it carries. A composition is only possible when the space

[101] A useful analogy is communication with a deaf person by writing notes. The only significance of a note is in its use at a particular time for a particular purpose. After the note is written, it is balled up and thrown away, or it may be overwritten, recognizing that only the last message has any meaning. Comparable treatment of block art suggests a similar, but highly rudimentary, protolinguistic function.

containing the multiple images is unified, i.e., when it is recognized as existing independent of any particular image. This separation is not possible in a contingent concept-space, and therefore, the only method of combining concepts is in a composite single image whose parts are separate concepts, but whose existence is still in a singular space.[102]

To create a composition, a physical concept-space must be recognized that is independent of the specific concepts displayed. The recognition of this independent concept-space allows a combination of separate images in a single unitary whole.[103] Compositional deep-cave "art" is best viewed as a collection of weighted attributes forming a single definition of a complex concept. Each image in such a composition represents a major attribute of the category it conceptualizes (see note 48). The complex concept, whose definition is the collection of attributes displayed, may be the sociological definition of a man or woman.[104] In other words, the collection of attributes displayed defines the characteristics held in common by members of the

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[102] The fact that nearly all monstrous decorations are humanoid suggests that the concept to be defined includes attributes of humanity. These composite images may be an attempt to emphasize important attributes of an individual while restricted to a contingent concept-space. Such emphasis cannot be very complex due to the limitations of a single image. It may have been this limitation imposed on increasing mental capacity that forced recognition of an independent physical concept-space consisting of the entire cave wall.

[103] Three possible conceptual forms may be represented by each single image within the composition. First, a concept may be a simple name in which case the painting of a bison is the name, *bison.* Second, a concept may be an agent of causation similar to the protoconcept of the cave bear in the Middle-Paleolithic Age. In this case a painting of a bison is a bison "god." Third, a concept may represent a major nonphysical attribute of the bison, in which case the painting of a bison may mean "strength." The three possible meanings of the individual image within a composition yield four possible explanations of the total composition. A composition composed of multiple elements of the first type would be a proto-sentence; of the second type, a pantheon; of the third type, a definition. There is also the possibility that a composition may include elements with different conceptual forms. For example, one image may be a simple name, another a "god," and a third may represent a major attribute, or attribute collection. This type of mixed composition recognizes a more subtle unity of the concept-space and is a myth.

[104] Within any specific animal composition, component images can be seen as having relative weighting supplied by, for example, position relative to the center. Thus, if there is validity to the central position of horse and bull, as Leroi-Gourhan (1968) states, it suggests a central importance and high relative weight. In this particular case, the conjecture is corroborated by the similar importance of these two animals as reflected in the numbers of miniature art objects, and in the central importance of the horse and bull in the first historical mythologies (Campbell, 1986).

group, and therefore defines the society.[105] Compositional cave paintings may be the defining characteristics of the first human society. Existence of the independent physical concept-space, for the first time, made such a tribal definition possible.

Interpretation of compositional cave paintings as the definition of a tribe has the support of two other indirect factors. It has been commonly assumed that the population expansion of the Magdalenian had its roots in the formation of tribes since such a cohesive bond is necessary to allow large groups of humans to exist together in a productive society.[106] The interpretation of compositional cave art as the definition of a tribe therefore provides the immediate prerequisite for the observed increase in population. Second, definition of a tribe continues a consistent pattern of expression through all stages of mental evolution. That is, each new stage of mental development is first expressed in relation to the individual, and identification of the compositions as the definition of a tribe (a second-order individual, if you will) continues this progression.[107]

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[105] A society is determined by a common definition of self - a second order concept. From a simplified perspective, what it means to be an American, Russian, Apache, Venetian, etc. provides the common viewpoint necessary to subjugate individual will to that of a group. The communal definition of self is a collection of attributes chosen and prioritized by society. Dissemination of this societal definition is the most important single requirement of a viable society, for without it the society will cease to exist. If society is defined as a transmissible, commonly held definition of self, then the first society cannot predate conceptualization. The number of attributes needed to specify a communal self is too great to be displayed in a contingent physical concept-space, and thus the independent physical concept-space affords the first opportunity to define a society. In this interpretation, the quintessential nature of this definition is corroborated by the unique use of the compositional cave paintings for the definition of tribal self. Thus, the cave wall complex may be a direct, unimpeded view of the Magdalenians' definition of themselves, although the exact nature of that definition is currently unknowable.

[106] See Mellars (1973), p.268.

[107] The first protoconcept displayed was the proto-individual as evidenced by both the rudimentary personal ornamentation, and burial of the dead. The earliest, most widespread, and multifarious Aurignacian innovation was personal ornamentation, forming the definition of an individual. Anthropomorphs are attempts to emphasize human attributes while restricted to a contingent concept-space. The increase in conceptual complexity afforded by an independent physical concept-space allows a second-order definition of an individual. This is the definition of a group composed of individuals and is the definition of a tribe. The pattern is continued in mythologic reproductions. All concepts have an independent existence in the sense that they are separate from any element of the category they name. In the case of the tribe, the

Myths are stories involving supernatural and supranatural individuals, places, or events and are usually based on a natural or historical fact. One of the most common types of myth explains the origin of a tribe in the supranatural tribulations of a supernatural ancestor. This type of myth contains at least the ancestor of the tribe and a god or two, as well as the geographic facts related to the action. This shows how a simple myth would appear in the physical concept-space. An image representing the tribe itself, an image or images of a god or gods, and images of natural objects would constitute such a composition. The image representing the tribe is a definition, the images of the gods are elements of a pantheon, and the images of natural objects are simple names. The mythic image just described is a composition where individual images have different conceptual interpretations. This type of general interpretation is consistent with the only convincing example of mythic cave-painting which is found in the deep pit at Lascaux.[108]

A complete explanation of compositional cave art must also account for the positions of the entire compositions relative to each other and the cave wall. Inaccessibility of cave painting sites is consistent with such a hierarchical interpretation. An independent space allows relative value to be assessed according to position within the space. Thus, hierarchical arrangement of entire compositions may have been homologous to an arrangement of the independent concept-space itself. A reasonable homology is an increasing abstraction of concepts being reflected as an increasing inaccessibility of the portion of the concept-space carrying the concept.[109] Definition of a tribe is an abstract concept, and its position is normally inconveniently placed in a deep-cave site. The most complex and abstract composition is mythologic, and, at Lascaux, this is found in an extremely awkward and difficult location.

Late examples of the bâton de commandement and carved spear-throwers, are examples of portable compositional art that is even more clearly unified than deep-cave compositions. These also may be interpreted as either sentences, pantheons, definitions, or myths, but again the third

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relationships of this new concept to other important concepts (i.e., "gods") results in third-order concepts—the first mythologies.

[108] See Campbell (1986), p.301.

[109] The homology of abstraction and inaccessibility has a teleological basis. Since the attribute collection in the deep-cave composition does not represent the tribe, but rather, *is* the tribe it may have been considered essential to isolate and protect it. This same tendency is seen in conscious man *vis à vis* the symbols of kingship, statehood, etc.

explanation is preferable.[110] The compositional engravings are almost all the products of the last stages of the Upper-Paleolithic Age.[111] This suggests that the range of defined complex concepts was expanding to include those less restricted than a tribal definition. A possible mythological carving is also known, sometimes interpreted as a "joke."[112]

Trade between widely separated locations forms the final recognizable phenomenon of Upper Paleolithic Age invention. Value attached to an object of trade is evidence of at least recognition of the category of that object. This implies a minimum mental capacity of protoconceptualization. Ability to identify desirable attributes in an object category is equivalent to its definition, or naming, and requires conceptualization. This fixes the first possible occurrence of trade in the Upper Paleolithic Age. Thus, appearance of archaeologic evidence of trade in the early Upper-Paleolithic Age is consistent with the present interpretation of mental evolution.

In summary, artifactual classes appearing in the Upper-Paleolithic Age are naturally explained by conceptualization, and the present theory of mental evolution would suggest that the appearance of conceptualization must be accompanied by some such artifacts. Personal ornamentation and discrete reproductions are *prima facie* evidence of this process where the concept, and the space where it is assembled, are inseparable. The advance from discrete reproductions to a compositional stage can be explained as a further generalization recognizing that a concept-space exists independent of any particular concept. This explanation provides continuity with the rest of the artifactual sequence, and it also is supported by unrelated ecofactual data such as the Magdalenian population explosion. The recognition of the contingent and independent physical concept-spaces in the Upper-Paleolithic Age label this era the Age of Conceptualization.

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[110] An example is the bâton of Mountgaudier whose complex of figures engraved on the bone is interpreted by Marshack (1970) to be a representation of objects related to Spring. The present interpretation suggests that what is displayed are the attributes of Spring, so that the bâton is in fact the name of the complex concept, Spring.

[111] See Marshack (1970).

[112] The carving is of an ibex standing on a rock, looking over its shoulder at two birds perched on its emerging feces. The spear-thrower was discovered by the Péquarts at Mas d'Azil, and illustrated in Péquart and Péquart (1960), p.299.

Conclusion

The concomitance of human biologic and mental evolution has produced a vast popular and scientific literature which attempts to temporally correlate the appearance of various mental capacities such as language and consciousness with anatomically defined stages of evolution. However, without a theory of mental development it is not possible to unambiguously define mental capacities much less to identify their associated phylogenetic or taxonomic appearance. By beginning with Hughlings Jackson's theory of nervous system evolution, and interpreting the doctrine of concomitance in a general manner, a theory of mental evolution can be generated. The proposed theory of mental evolution both defines mental capacities and indicates their relationship to each other. Within this theory, mental capacities arise naturally out of progressively more complex analysis of an internal image of the external world. When applied to the archaeologic record of nonutilitarian artifacts in the Paleolithic Age the theory provides both a consistent explanation of each artifactual class, and an explanation of the artifactual sequence. More importantly, these artifactual types and their sequence are predicted by the theory of mental evolution.

Middle-Paleolithic-Age innovations are characterized by the isolation or display of unaltered natural objects. The appearance of simple bichromatic decoration, burial, and ritual sites represents the mental stage of protoconceptualization, where a category's existence is recognized independent of any of its members. This recognition is demonstrated when a member of a category is used to represent the equivalence underlying the category.

The definition of a category's equivalence is first seen in the Upper-Paleolithic Age when the attributes defining a category are explicitly displayed in a modified physical object. This explains the mental advance from Middle- to Upper-Paleolithic Age and specifies an identical mental process, i.e., contingent conceptualization, as the origin of miniature statues, block engraving, personal ornamentation, and discrete cave paintings. Compositional works, including examples of deep-cave art and portable engravings, demonstrate the recognition of an independent physical concept-space that can allow interaction of separate elements. In fact, such independence is a prerequisite for composition. The evolutionary advantage of conceptualization is the ability to manipulate categories of objects without manipulating the objects themselves.

Finally, the concept-space is defined resulting in the abstract concept-space of modern, conscious man. The complexity, efficiency, and speed of concept manipulation in an abstract space is greatly facilitated since hypotheses can be tested and concepts related to each other without juxtaposition of physical objects—neither the physical objects of categories, nor the physical concept-spaces that embody the definitions of categories. The expression of these abstract concepts is language. The development of language made the independent physical concept-space obsolete. This explains the sudden disappearance of deep-cave art and compositional engraving in Mesolithic-Age cultures which were otherwise rapidly advancing.

The Upper-Paleolithic Age can be viewed as the time during which physically modern man was developing mentally modern capacities, a development that took 30,000 years. The late appearance of consciousness suggested by this interpretation is not unique. Others have suggested a recent evolution, but not on the basis of an analytic theory.[113]

In conclusion, a theory of mental evolution is proposed concomitant with a theory of nervous system evolution devised by John Hughlings Jackson. Through this theory, it is possible to extend the purview of historical neuroscience to the archaeology of human evolution. The theory of mental evolution provides an unified explanation of the artifactual record of early man, thereby identifying and defining the mental changes that accompanied the emergence of modern humanity.

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[113] Jaynes (1976) suggests an evolution of consciousness within the last ten thousand years. However, he does not present a sequence of mental capacities that result in consciousness, nor does he elaborate a mechanism of mental evolutionary change, and therefore does not provide a theory of mental evolution.

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CHAPTER III

ORIGIN AND NATURE OF LANGUAGE

A. Neurological Science, Mental Evolution, and the Origin of Language[114]

Abstract: This investigation suggests a definition and temporal origin of language that emerge naturally—without linguistic assumptions or preconceptions—from an analytic and predictive theory of mental evolution. The derivation does not address the many clinical and neuroscientific aspects of language, but answers a question that underlies them. The description of mental evolution is scientific—consisting of explicit axioms, an unambiguous and rigorously defined theory, and testable predictions—and represents a significant departure from previous attempts. The axioms are from the foundations of neurological science, the theory is an analytic sequence of increasingly complex capacities wherein every stage is defined exclusively in terms of those previously defined, and its predictions are verified by the archaeology of human phylogeny. The exact correlation of predicted and actual artifacts supports the theory and its explanations of the nature and origin of language and the human mind.

Introduction

Language is one of humanity's defining features, as well as one of neurology's most compelling and perplexing concerns. In addition to neurology, numerous disciplines of neuroscience, cognitive science, computer science, psychology, anthropology, and mathematics—as well as their multiple hybrids—have various aspects of language as their primary focus. In any reasonable format, it would be overly ambitious to attempt a statement—not to mention a resolution—of the multifarious complex linguistic conundrums. However, certain foundational questions underlie

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any investigation of language—e.g., its nature and origin—and these can be addressed in a concise and comprehensible manner.

A distinguishing feature of this analysis—when compared to other descriptions of language origins—is that its explanations arise from an independent theoretical construct based on the foundations of neurology, rather than beginning with linguistic assumptions and predispositions. It contains no reference to any aspect of linguistics, and when a fundamental description of language appears from the analytic sequence of increasing mental capacities, it is natural as well as unexpected.

This study places language within a comprehensive temporal and theoretical framework, but does not offer solutions to any other problems in language studies. The primary goal of this investigation is to suggest—as a consequence of a rigorous, analytic, and independent analysis—what language is and when it appeared.

A second objective of this formulation is to extend the boundaries of science—in particular, neuroscience—and claim territory that has traditionally been ceded to philosophy. Specifically, a scientific theory of mental evolution is proposed that unambiguously defines mental capacities in an analytic manner—i.e., each increasingly complex stage is defined solely in terms of those that precede it. No such comprehensive and unambiguous structure of the mind has been previously suggested. The theory predicts the appearance of a specific type of nonutilitarian artifact as an expression of each evolutionary level, and its validity is evaluated by comparing these predictions with the archaeology of the Paleolithic Age. The precise correlation of predicted and actual artifacts supports this derivation of the evolution of the modern mind and the origin of language.

Preliminaries

Since language appears at the end of the evolutionary sequence to be described, there are fairly extensive preliminaries that are necessary to construct the analytic framework from which it emerges. It is, in fact, these preliminaries that differentiate this proposal from those that have preceded it, since it is the axiom-based analytic chain of definitions and corroborations that establish the logic and scientific structure of the argument. This groundwork occupies the majority of the following discussion.

Axioms and Assumptions

The theory of mental evolution is derived from three axioms—the first two based directly on the foundations of neurological science—and requires one axiom for its validation. A science of neurology is possible only if the brain is seen as a purely sensorimotor machine (Hughlings Jackson, 1882.) This is the fundamnetal axiom of scientific neurology as formulated by John Hughlings Jackson (1835-1911) in 1884, and the first axiom of this derivation (Hughlings Jackson, 1884; Steinberg, 2013). According to Hughlings Jackson's evolutionary theory, higher brain functions are increasingly complex, integrated, and interconnected, so the afferent function of the brain can be seen as the construction of an increasingly complex sensory map of the external world (Hughlings Jackson, 1887). The second axiom is that the function of the mind is to interpret this construction, and, therefore, these internally constructed sensory maps provide the substrate for mental evolution. Since increasing mental capacity is characterized by an increasing inductive facility—an ability to identify equivalence—the process of mental evolution is assumed to be generalization—the third axiom. The elements of internal sensory maps are generalized and regeneralized in the mind, producing an increasingly complex, analytically structured hierarchy of mental capacities.

Prediction of a sequence of archaeologic artifacts from a hierarchy of evolutionary mental functions necessitates three additional assumptions: 1) mental capacities can be correlated with a phylogenetic sequence; 2) they are reflected in archaeologic data; 3) they are expressed as soon as they arise. Together these assumptions imply that the minimum mental capacity necessary to produce an artifact is the capacity indicated by the appearance of that artifact. This final axiom is necessary to evaluate the theory's predictions.

Definition of Terms

This theory of mental evolution defines a concept as a collection of attributes that determines membership in a category, i.e., a category's explicit equivalence relation. A concept is independent of its representation, and so, can exist in many forms. The theory also introduces the idea of a concept-space—the place where concepts exist. The concepts of modern humans reside in an abstract mental space and their form and content seem inseparable, but the abstract mental space itself is a product of evolution, and before it existed, concepts were embodied in a modified physical object—a physical concept-space. For example, a carved stone displaying the physical characteristics of an animal is the concept-space of an Upper-Paleolithic-Age concept.

The theory also strictly differentiates the processes of recognition and definition—recognition involves comparison, while definition involves specification. For example, recognition of an object as a horse requires a mental comparison between it and previously encountered horses. Recognition does not require awareness of the characteristics that define a horse, or even that such characteristics exist. In contrast, definition of a horse requires specification of the defining characteristics of "horseness."

Stages of Mental Evolution

The distinctions that form this theory's analytically defined stages are subtle. In ontogeny, the levels are rapidly surmounted in the first year or two of life with guidance from fully (mentally) evolved elders, and the differentiations emphasized here either never appear, or rapidly disappear. In phylogeny, however, these stages occur over thousands of years, and this extended development can be easily seen when viewed from an appropriate perspective. Regaining this perspective requires careful attention to what may initially appear as trivial details. The abstract simplicity of the analytically defined evolutionary stages is a major strength of the development, though the sequence is not—at first exposure—necessarily obvious or easy to grasp. Any intellectual effort expended is, hopefully, rewarded by an understanding of a scientific explanation of language and the mind.

The process of mental evolution begins with the partition of internal sensory maps into recognized separate objects. It proceeds through repeated generalizations in five distinct stages: categorization, protoconceptualization, and conceptualization in a contingent physical concept-space, an independent physical concept-space, and an abstract concept-space. Categorization involves recognition of the similarity of objects; protoconceptualization, recognition of the commonality that is the basis of categorization; and conceptualization, explicit specification of this commonality. The explicit characteristics that determine membership in a category are first embodied in physical objects—a contingent physical concept-space that is inseparable from the concept itself. The concept-space is next recognized as a separate entity from the concept it carries—an independent physical concept-space. Finally, the concept-space is defined, creating an abstract concept-space. The formation of an abstract concept-space marks the achievement of consciousness, and the mode of expression of abstract concepts is language.

Analytic Details of Mental Evolution

Once the process of mental evolution begins, each stage develops analytically from the previous one, providing an adaptive advantage that contributes to further mental development. This adaptive advantage is the increasing capacity to retrieve elements of the perceived world for consideration, planning, and communication when they are not physically present. The process culminates in the creation of an abstract mental space where an internal conceptual model of the external world resides.

Categorization involves recognition of the similarity of perceived objects, and a category is defined analytically as a collection of these objects. For example, the mind recognizes a category of horses that serves as a standard of comparison to determine if a newly encountered object is a horse. Each object that is identified as a horse is invested with the characteristics of previously encountered horses. All animals have the mental capacity for categorization, since they at least recognize a category of food. Increasing complexity of categorization involves recognition of more categories, subcategories, and higher-order categories, such as categories of categories. Once a category is recognized, details of the category's elements, and similarities among them, also can be identified. These similar details form new categories that are subcategories of the original category. For example, once the category of horse is recognized, it is possible to recognize subcategories such as horse's head, tail, and limbs. Subcategorization is particularly important for the succeeding stages of evolution.

Protoconceptualization emerges analytically with the recognition that the elements of a category have been grouped together because they share an equivalence—a set of defining characteristics. Alternatively, protoconceptualization can be seen as the recognition that a category exists independent of its members. That is, the defining characteristics of a category form a generic element—the equivalence relation—that is not an actual member of the category, but rather is the category itself, separate from its members. The recognition of the existence of such a generic element—or equivalence relation—is protoconceptualization. A category can now be retrieved for consideration independent of an observation, but since the equivalence is recognized but cannot be specified, only a member of the category that manifests the defining characteristics can represent it. The protoconcept "horse" thus must be a particular horse, and the minimal mental capacity indicated by the intentional display of, e.g., a horse skeleton in the archaeologic record is protoconceptualization. Protoconceptualization demonstrates the ability to recognize the equivalence underlying the category of horses, i.e., the existence of a category of "horse" independent of any particular horse.

Conceptualization in a contingent concept-space occurs when the equivalence forming a category is defined. This can occur once subcategorization has produced protoconcepts recognizing sufficient fine detail within a category. For example, the protoconcept of the category of horse's tails is the generic horse-like tail. A collection of these recognized generic characteristics of horses defines a generic horse—the concept "horse." Thus, a concept is analytically defined as a collection of protoconcepts, or attributes. At this stage of evolution, a collection can only be assembled as a physical object, since no other type of space is available. Therefore, the attributes defining the equivalence of the category are assembled in a unique, physical concept-space—a modified object such as a sculpture, a cave-wall painting, or an engraving of a horse. The concept and its concept-space are inseparable—the image and the material in which it exists are one. In this sense, the physical concept-space is contingent. Since the concept can be displayed in any convenient physical medium and be of any size, it can be manipulated much more easily than a protoconcept, which must be a member of its category—providing an adaptive advantage. The minimal mental capacity necessary to produce a recognizable reproduction of a horse in the archaeologic record is the ability to explicitly specify the defining characteristics of the category of horse—the concept "horse."

Conceptualization in an independent physical concept-space is seen analytically as the recognized equivalence of contingent concept-spaces and results in a concept-space separate from any particular concept. So, for example, a carving of a horse and a carving of a bull are seen to have something in common—the stone that can accommodate either animal. A recognized equivalence must include any property shared by all of a category's elements, and since the contingent concept-spaces are all physical objects, the independent concept-space must also be a physical space. However, the increased complexity of conceptual relationships possible in an independent physical concept-space results in a significant adaptive advantage. The emergence of this capacity is heralded by the appearance of compositional reproductions in which multiple concepts interact in a common space, e.g., a composition containing both a horse and a bull. In fact, the existence of an independent concept-space is necessary and sufficient for the innovation of composition. It is necessary because a composition cannot exist without a common space in which the individual elements of the composition are unified, and it is sufficient because all elements that appear within a common space are understood to be part of a unified composition. Thus, the minimal mental capacity indicated by the appearance of compositional reproductions in the archaeologic record is recognition of an independent physical concept-space.

Conceptualization in an abstract concept-space occurs when the physical concept-space is defined. It is seen analytically as a specification of the equivalence of the independent physical concept-spaces—a generic independent concept-space. Each independent physical concept-space can accommodate only a limited number of concepts, but the generic independent concept-space must have an arbitrarily large capacity. Since no physical space is infinite, the generic independent concept-space specifies an abstract space. In the physical concept-spaces the concepts are expressed as visible collections of a category's defining features, shared by those who view them. But the abstract space is invisible and so there must be a way to retrieve the concept and a shared expression to communicate it. The name of a concept in the abstract concept-space, e.g., *horse*, encodes its address—or coordinates—and the shared expression of abstract concepts is language. A name consists of only a few sounds, yet can easily convey a large amount of information that previously—if possible at all—required arduous labor. The minimal mental capacity indicated by use of the word *horse* is the ability to express the collection of attributes defining the category of horses that exists in an abstract concept-space—the abstract concept "horse." In this scenario, words are atomic and are presupposed by grammar that allows greater complexity of conceptual constructs.

The existence of this abstract concept-space vastly facilitates conceptual operations, since concepts can be juxtaposed and hypotheses tested mentally, rather than by manipulation of physical representations. This increased mental efficiency also enables very high-order categorization, definition of objects whose existence is completely abstract, and identification of fundamental equivalences in the perceived world.

The formation of an abstract concept-space constitutes consciousness. Conscious beings live in a model of the world that is created in this space. This model reproduces the objects and relationships in the external world with their conceptual counterparts in the abstract space, and its existence explains the subjective sense of a separate observer that is one prominent characteristic of consciousness. Conscious beings do not simply act, but also contemplate actions and observe themselves acting, because there is both a physical world and a model of that world that resides in the abstract concept-space. This duality provides an extraordinary potential for mental advance. Any decision or hypothesis involves projecting the outcomes of various possibilities, and an abstract model of the world greatly facilitates such projections.

The analytic nature of the stages of mental evolution provides an explanation for the universal development of language—and other mental capacities—even in possibly isolated human populations. The modern human brain includes the sensorimotor structure necessary to set mental development in motion. The process can then unfold independently, each stage arising analytically out of the one that precedes it. Contact and direct transmittal can alter the evolutionary rate—as in ontogeny—but not its ultimate occurrence and outcome. This process is identical to other forms of parallel evolution where similar physical characteristics arise independently due to common environmental characteristics.

Theoretical Predictions of Archaeological Artifacts

This theory of mental evolution predicts that specific nonutilitarian archaeologic artifacts—and only those artifacts—should be found in the chronological order corresponding to its stages.

Categorization is the recognition of similarities among objects. As a functional standard of comparison, a category has no independent existence and so is not associated with any form of representation. Therefore, this stage should include no nonutilitarian artifacts.

Protoconceptualization is the recognition that there is an equivalence underlying a category and that a category exists independent of any of its members. Only a member of the category can be a protoconcept, since the equivalence is recognized, but not defined. Thus, this stage should be associated with the appearance of unaltered natural objects that are intentionally isolated or displayed—each representing the category of which it is a member.

Conceptualization in a contingent physical concept-space specifies a category's defining characteristics as an explicit collection of attributes. The collection is assembled in a discrete physical object that is a physical concept-space. This stage, therefore, should be associated with the appearance of individual reproductions or representations of recognizable objects in a physical medium.

Conceptualization in an independent physical concept-space occurs when it is recognized that a concept-space can exist independent of the concept it carries. Since this recognition is necessary and sufficient to enable multiple concepts to coexist in a unified concept-space, this evolutionary stage should be associated with compositional reproductions.

The abstract concept-space arises by defining the equivalence of physical concept-spaces. The remarkable efficiency of concept manipulation in an abstract concept-space makes the physical concept-spaces obsolete. As a result, this stage should provide evidence of rapidly advancing mental capabilities, and the disappearance of all physical expressions of concepts.

Correlations with the Sequence of Paleolithic-Age Artifacts

The only human artifacts found until the end of the Lower-Paleolithic Age and the ascendance of Neandertal Man are stone tools. Although human tools are more modified, more varied, and more permanent than those produced by other animals, the differences are of degree, not kind (Beck, 1980.) Thus, the tool-producing hominids defining the genus Homo (i.e., *Homo habilis* and *Homo erectus*) were at the same level of mental evolution as other animals. This lack of nonutilitarian human artifacts in the archaeologic record correlates with the theoretical prediction of their absence at the evolutionary stage of categorization.

The Middle-Paleolithic Age begins with the supremacy of *Homo sapiens neanderthalensis* approximately 100,000 years ago, and three associated artifactual innovations have been reported: human burial (Gamble, 1984; Solecki, 1975); manganese oxide and ocher used for body painting and/or dyeing of animal skins (Singer, 1982; Dart 1969); and "ritual sites" devoted to cave bears and human skulls (Hadingham, 1979; Bergounioux, 1958). Though bichromatic residues are uncontroversial, there are questions concerning the existence of ritual sites—and even some skepticism as to burial (Gargett, 1989). An interesting perspective of this development is that all three artifact types are equally possible since they demonstrate the same unifying characteristic—the isolation or display of unaltered natural objects, i.e., for burial and body painting, the dead and living human body, respectively; for ritual sites, cave bear skeletons or human skulls. Thus, each of these artifact types—despite some controversy—exactly demonstrates the predicted manifestations of the evolutionary stage of protoconceptualization.

Although many fanciful meanings have been ascribed to early human burial, it most simply indicates recognition of some property of an individual that exists independent of the body. Since the category of an individual consists of a single object—the body of the individual—this recognizes a category's existence independent of its elements, or protoconceptualization. By identifying the minimal mental capacity capable of producing an artifact as the capacity indicated by the presence of the artifact, burial is best interpreted as an example of protoconceptualization (Figure 1). The absence of burial prior to this era must mean that the body had no meaning beyond its existence as an object, which, in turn, implies that the mental capacity of protoconceptualization had not yet been achieved.

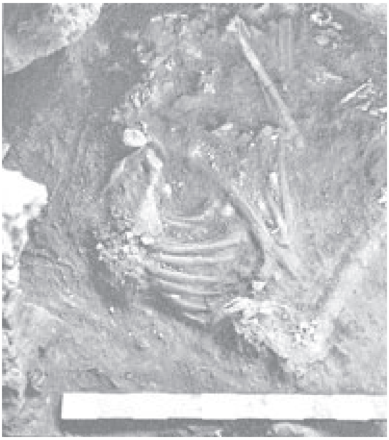

Figure 1. Neandertal burial at Shanidar cave, Iraq c. 60,000 BP. Intentional burial indicates recognition of some property of an individual independent of the body. Since the category of an individual consists of one object—the body—burial is recognition of the existence of a category independent of its member, i.e., protoconceptualization.

Since a protoconcept must be a member of the category it represents, only the physical body can act as the protoconcept for the human self. In this unique case, both the subject—the proto-I—and the object—“me”—reside in the body of the individual. Distinguishing the two necessitates isolating or displaying the object that is “me,” as with any other protoconcept. The presence of dichromatic pigments in Middle-Paleolithic-Age deposits is thought to indicate that Neandertal man practiced body painting and the coloring of crude fur clothing. These are the most elementary methods of differentiating the proto-I from its object, thereby recognizing the subject’s existence.

The beginning of the Upper-Paleolithic Age is heralded by the dominance of *Homo sapiens sapiens*. This is the time when physically modern humans began developing modern mental capacities. Two classes of nonutilitarian artifacts characterize this era—statuettes, paintings, and engravings (Rieck, 1934); and personal ornamentation (Marshack, 1970b). Statuettes, paintings, and engravings are discrete, easily recognizable objects reproduced in a physical medium (Figure 2). These characteristics are precisely the predicted consequences of conceptualization in a contingent concept-space and are *prima facie* evidence of the mental capacity of conceptualization.

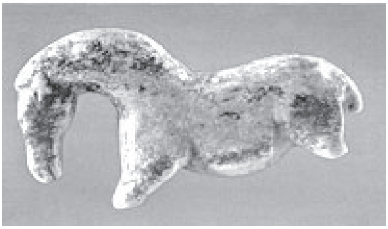

Figure 2. Vogelherd horse. Vogelherd, Germany, c. 35,000 BP. The sculpture of a horse must contain adequate attributes to define a horse because it is seen as one. The minimal mental capacity indicated is contingent conceptualization, in which the concept-space—the carved ivory—and the concept “horse” are inseparable.

The appearance of personal ornamentation at this stage provides further artifactual evidence of the existence of a concept—the definition of a category. The concept here is the subject “I,” and the natural choice for its physical concept-space is the body. In all other cases, a true concept is easily separable from a protoconcept of the same category, since the latter is a member of a category, and the former is a reproduction in a different medium. In this case, however, as with the protoconcept “I” and the category “me” at the stage of protoconceptualization, subject and object coexist in the body, and a way must be found to distinguish them. As body painting provided this differentiation at the prior evolutionary stage, personal ornamentation differentiates the concept “I” from the object “me” at this higher level of mental functioning. The only way to distinguish the protoconcept and concept of an individual is the sophistication or complexity of the body’s decoration. The multicolored tattoos and vast array of personal ornaments that characterize the archaeologic record of the Upper-Paleolithic Age contrast strongly with the dichromatic body painting and dyeing of skins associated with the Middle-Paleolithic Age. This advance provides evidence of the mental evolution from recognition of the category of an individual to its definition.

The appearance of carved and painted compositional reproductions characterize the final phase of the Upper- Paleolithic Age (Stevens, 1975; Leroi-Gourhan, 1968). This achievement is the necessary and sufficient predicted consequence of the emergence of an independent physical concept-space (Figure 3).

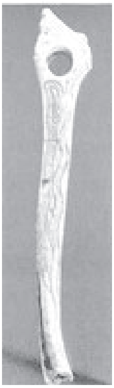

Figure 3. The Bâton of Montgaudier. Montgaudier, France, c. 12,000 BP. This compositional carving contains multiple animals that are seen in the Spring (Marshack, 1970a). The minimal mental capacity indicated by a compositional reproduction is the recognition of a concept-space independent of any particular concept.

At the end of the Paleolithic- and beginning of the Mesolithic-Age, approximately 12,000 years ago, all forms of naturalistic reproductions abruptly disappear (Milisauskas, 1978). Simultaneously, the domestication of plants and animals and the rise of cities provide evidence of rapidly advancing mental capacity. According to this theory, language—as the expression of abstract concepts—also appeared at this time. The disappearance of Paleolithic "art" has been difficult to reconcile with the rapid advance of material culture in the Mesolithic Age, since art is often considered to be the epitome of cultural expression. This theory offers an explanation. Paleolithic "art" disappeared because it did not function as art. Rather, it served as the increasingly complex expression of concepts in an evolving physical concept-space (Table 1).

EPOCH	HOMINID	STAGE OF MENTAL EVOLUTION	PREDICTED /ACTUAL UNIFYING TRAIT	NONUTILITARIAN ARTIFACTS
PALEOLITHIC AGE				
LOWER **c. 2,000,000-c. 100,000 BP**	*Homo habilis* *Homo erectus*	Categorization	None	None
MIDDLE **c. 100,000-c. 40,000 BP**	*Homo sapiens neanderthalensis*	Protoconceptualization	Naturally occurring objects isolated or displayed	Burial Ritual sites Body painting, skin dyeing
EARLY UPPER **c. 40,000-c. 17,000 BP**	*Homo sapiens sapiens*	Conceptualization in a contingent physical concept-space	Discrete, recognizable reproductions of natural objects	Statuettes Cave paintings and engraving Personal ornamentation
LATE UPPER **c. 15,000-c. 12,000 BP**	*Homo sapiens sapiens*	Conceptualization in an independent physical concept-space	Composition	Carved and painted compositions
MESOLITHIC AGE **c. 12,000-c. 8,000 BP**	*Homo sapiens sapiens*	Conceptualization in an abstract concept-space	Disappearance of naturalistic reproductions	No naturalistic reproductions

Table 1. The archaeology of mental evolution

Current Explanations of the Nature and Origin of Language

This section highlights some modern arguments about the nature and temporal origin of language. This overview is, of necessity, very brief and incomplete, and does not do justice to the subtleties and insights of the representative ideas discussed. It attempts only to contrast the present theory with current views by indicating generic difficulties shared by broad classes of existing linguistic ideas.

Previous investigations of the origin of language can be classified into at least three discrete categories—anatomic, intuitional, or statistical. The anatomic type suggests a temporal origin based on the phylogenetic appearance of the physical structure of the modern human larynx. The second type utilizes intuition and insight to create an idea of what language is, then uses this assumption to predict when language appeared. A final type is a statistical analysis where divergence of certain linguistic forms is traced backwards to a convergent origin. A statistical analysis—being intrinsic to language itself—identifies a temporal origin of language without suggesting its nature.

The first linguistic class centers on the structural adequacy—or inadequacy—of the Neandertal larynx to produce the range of sounds in modern language (Schepartz, 1993). This type of investigation assumes an intimate relationship of sound-making capacity and language emergence that either conflates speech and language, or at least suggests that the number of sounds made by Neandertals was sufficient—or insufficient—to conclude that modern language was present—or absent. There may be a relationship between the number of sounds that can be made, and the development of language, but—as outlined in the next section—this relationship is indirect and strongly indicates an appearance of language after the evolution of modern laryngeal anatomy.

The second type of argument for the nature and temporal origin of language begins with an intuition—or preferred explanation—of the nature of language and then uses this assumption to place it within a temporal sequence. Most novel contributions to science begin with an intuition concerning the nature of a problem. As an example, Albert Einstein (1879-1955) intuited that the speed of light must be the same in any inertial reference frame and, from this axiom, derived special relativity. He assumed that inertial and gravitational mass were identical—or gravity is equivalent to geometry—and derived general relativity. The intuitions concerning the nature of language, at this first stage, are formally no different than Einstein's. The determinative difference arises at the next step. Einstein—

and other scientists—use intuitions as axioms, then derive a theory that has novel explanatory and predictive consequences. In the case of language, this essential step is missing, the intuitions—or axioms—stand alone, not as the first step in a scientific derivation, but as the only step. This creates two significant problems—one pragmatic and one logical—irrespective of the quality of the initial insight. A pragmatic problem is that this analysis produces proliferating incommensurable ideas. Since distinct intuitions result in different axioms, and axioms are—by definition—unquestioned, the discrete ideas proposed cannot be compared. It is possible to argue about whose intuitions are better, but there is a tendency for the advocacy of a particular view to remain fixed to its creator. Without testable and predictive consequences—or explanatory detail—there is no way to choose one intuition from another. A second difficulty is an error in classical logic that arises when an assumed nature of language is used to determine its temporal origin. This circular reasoning is an example of the fallacy of classical logic known as *petitio principii* where an assumption entails the conclusion. Though without an independent theory—derived from axioms—this is the extent of what can be accomplished, the result is nonetheless scientifically unsatisfying.

Intuitional types of linguistic analysis can be further divided into discontinuous and continuous models. Simplified examples are presented to demonstrate only that both forms share the generic difficulties just described.

Any linguistic study must acknowledge the pioneering work of Noam Chomsky (1928-). Chomsky's main contributions involve details of linguistic structure—essentially their invention—and for much of his career he resisted hypothesizing on the foundational question of the nature of language (Chomsky, 2007). More recently, however, he has presented ideas concerning language's nature and temporal origin (Chomsky, 2005). As would be expected, these ideas are sophisticated and insightful. However, they also demonstrate the generic problems common to intuitional approaches mentioned above.

Chomsky views the origin of language as discontinuous. He sees development of a language faculty as a result of a single mutation in a single individual that allows a countably infinite form of recursive operations to appear where only finite recursion was previously possible (Chomsky, 2005). He believes that language presupposes this denumerably infinite recursive capacity. Although specifying a temporal origin is not an integral concern of his analysis, based on the assumption of a point mutation, Chomsky places the origin of language between 50,000-100,000 years ago, when the brain presumably achieved its modern status. In summary, the discontinuous theory of Chomsky conforms to—and has the problems of—the intuitional type of language theory described above. It assumes a nature of language—i.e., a language faculty derived from a mutation producing a countably infinite recursive capacity—then uses this assumption to place the temporal origin of language when the modern brain with this new ability appears.

The continuous type of ideas about language origins and nature are more widely accepted, but are more nebulous—specifying a binary distinction in a continuum is problematic. In fact, one of the most prominent contributors in this category states only that language development was innate, evolutionary and gradual (Pinker, 1990). Other perspectives within this type posit language as evolving out of primate vocalizations (Cross, 2009), gestures (Tomasello, 1996), or appearance of increasingly complex cultures (Knight, 2010). All of these models contain more ambiguous and undefined terms than Chomsky's, but they have in common an intuited formulation of the nature of language, and the use of that assumption to suggest at least an approximate temporal origin based on that assumption. They inherit the problems outlined above.

The last type of investigation on language origin is a statistical one based on rates of divergence of various linguistic forms that are projected backwards to a point of convergence. There is general agreement on an inability of cladistic models to identify language origins accurately beyond about 6,000 years due to erosion of family relatedness (Diamond, 2011; Nichols, 1998), but at least one statistical model uses this limitation as a starting point to trace language back much further (Nichols, 1998). The analysis begins by assuming that language and modern humanity coevolved. Using this assumption, geographical densities of language families existing 6,000 years ago are adjusted so that a branching rate, in multiples of 6,000 years, converges to a single ancestral form 130,000-100,000 years ago. This analysis—though more subtle—demonstrates a form of circular reasoning noted in the previous classes.

In summary, contemporary ideas about the nature and origin of language have been placed in three classes. Generic problems in the classes are identified, and specific examples are presented that demonstrate these. In all three cases, the difficulties result from a self-referential argument wherein a basic assumption about language is used to explain an additional linguistic property. In the anatomic and intuitional classes, its nature is assumed to determine its temporal origin, and in the statistical class, its origin is assumed, and then rationales suggested to adjust the statistics to cohere with the assumption. In all three cases, there is a direct, self-referential connection from assumption to conclusion rather than the conclusion being a predictive consequence of an independent axiom-based theory.

Statistics of Language and Sound

This section presents a statistical calculation that supports the late appearance of language in human phylogeny and contradicts the conclusions of the three classes above—i.e., that modern humanity and language are coextensive. Though the numbers used are prone to significant error, the results—even at an order of magnitude level—are impressive. The argument is that the ability of the human larynx to make distinct sounds—and therefore potential phonemes—results in a massively redundant potential for word creation relative to any one language—or all languages that have ever existed. Since nature abhors such waste, this implies that the distinct sounds that can be produced evolved for a much less efficient process than language. In other words, the modern human larynx evolved for non-linguistic communication, and when language appeared with its remarkable efficiency, it required only a miniscule fraction of the existing sound-making capacity.

A generic language will be considered to contain 100,000 words—in any case, the order of magnitude is probably valid as an upper bound (Simpson & Weiner, 2009.) Early languages were most likely less complex. A current estimate of the number of phonemes—which are semantically defined within existing languages as atomic elements of sound—is approximately 100-200 (International Phonetics Association, 1999). However, phonemes are equivalence classes of distinct sounds, or phones, so the number of phones is much greater—about 800 (Dobrovolsky & Katamba, 2001). In the present context, phones are considered to be potential phonemes in an arbitrary language. Studies of many languages suggest that there are, on average, about 2 syllables/word and 2.5 phonemes/syllable (Fenk et al, 2005). Combining these statistics yields a potential production of approximately $3 \text{ X } 10^{14}$ words (this may be reduced somewhat by laryngeal incompatibilities with some consecutive phones/phonemes), or a redundancy for any single language of 3,000,000,000:1. This statistic specifies the redundancy at the time of appearance of the first languages and is the best measure of sound-making inefficiency—or alternatively, language efficiency. Estimates of the number of languages that have existed depend significantly on assumptions of when language began, but an average estimate is about 100,000 languages (Pagel, 2000). Therefore, considering all languages that have ever existed, the redundancy is 30,000:1. There are two conclusions from this calculation: 1) sound production is unrelated to language, and 2) the evolution of modern humans—and the modern larynx—must significantly antedate the appearance of language. This result is consistent with the current identification of language origins and contradicts most previous estimates that predict the emergence of language—at the latest—coincident with the appearance of modern humanity.

Conclusion

This investigation has both a theoretical and applied significance. The former is the comprehensive structure suggested for mental evolution that unambiguously and analytically defines mental capacities, including language. No such unambiguous definitions have been previously suggested, and no analytically defined sequence of mental capacities leading to language and consciousness has been proposed. This provides a rigorous basis for scientific—rather than philosophical—discourse.

The applied significance is the reciprocal consequences that result from the exact correlation of predicted and actual artifacts. The theory's definitions—when tied to archaeology—explain the meaning and sequence of Paleolithic Age artifacts, and simultaneously, archaeology provides a datable chronology for the stages of mental evolution.

The definitions of mental capacities in the sequential levels of mental evolution provide a unique interpretation of the meaning and sequence of early human nonutilitarian artifacts. Although many explanations for individual artifacts or artifact classes have been offered, no coherent hypothesis for their chronological sequence in the Paleolithic Age currently exists (Davidson & Noble, 1989; Halverson, 1987; Marshack, 1972). The theory also explains the abrupt disappearance of the spectacular "art" of the Paleolithic Age with the rapid advance of other aspects of material culture.

The theory's definitions—once tied to an archaelogical chronology—establish a temporal origin of consciousness and language independent of any philosophical or linguistic assumptions or prejudices. Though the conclusions are heterodox, they are validated consequences of a previously nonexistent comprehensive theory that provides—at a minimum—an unambiguous basis for disagreement. Although other theories posit a late origin of langauge and consciousness, none is based on an analytically defined process of mental evolution (Jaynes, 1976). This theory suggests the evolution of modern mental capacities followed the appearance of physically modern humans by over 100,000 years; the ascendancy of modern humanity in the Upper-Paleolithic Age by 30,000 years; and that language developed approximately 12,000 years ago. It thus implies that, while consciousness and language are the *sine qua non* of humanity, they were not coincident with the evolution of *Homo sapiens sapiens*.

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B. Mental Evolution and the Origin of Language[115]

Abstract: A theory of mental evolution is presented consisting of an analytically defined sequence of mental capacities. Each evolutionary level predicts a specific artifact type as its expression and these predictions can be compared to the archaeologic record of the Paleolithic Age. The bijective correlation of predicted and actual artifacts supports the theory, provides a unified explanation of Paleolithic-Age artifacts and their sequence, and suggests a temporal origin of human language independent of linguistic assumptions.

Introduction

This paper introduces an *a priori* theory of mental evolution that extends the borders of science into a traditionally philosophical realm by creating a hierarchy of mental states that is analytic in the sense that each level is defined solely in terms of those previously defined. The theory predicts a specific artifact type at each evolutionary stage, and its validity can be evaluated by comparing these predictions to the record of Paleolithic-Age archaeology. The precise correlation of predicted and actual nonutilitarian artifacts supports the hypothesis, identifies phylogenetic correlates of the mental evolutionary levels, and thereby suggests a temporal origin for mental capacities, in particular, language.

Nature of Mental Evolution

A science of neurology is possible only if the brain is a purely sensorimotor machine (Hughlings Jackson 1958). Higher brain functions are increasingly complex, integrated and interconnected, and therefore the afferent function of the brain is the construction of an increasingly complex sensory map of the external world (Hughlings Jackson 1958). I hypothesize that the function of the mind is to interpret this construction. Therefore, internally constructed sensory maps are assumed to form the substrate of mental evolution.

Increasing mental capacity is most generally characterized by an increasing inductive facility, i.e., an increasing ability to identify equivalence. Therefore, I hypothesize that the process of mental evolution is generalization. That is, elements of internal sensory maps are generalized and regeneralized

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in the mind. Mental states are then unambiguously and analytically defined as the levels of this hierarchy.

Definition of Terms

The theory of mental evolution introduces the idea of a concept-space and differentiates recognition from definition. Simply put, a concept-space is the place where concepts exist. This idea may seem unnecessary, since the concepts of modern humans exist in an abstract mental space and their form and content seem inseparable. However, a concept will be defined as a collection of attributes that define membership in a category and because it is independent of its representation, it can exist in many forms. Before an abstract mental space existed, a collection of attributes was assembled in a modified physical object, which then became a concept-space. For example, the carved stone displaying the physical characteristics of an animal is the concept-space of an Upper-Paleolithic-Age concept.

The stages of mental evolution also strictly differentiate the processes of recognition and definition—recognition involves comparison, while definition involves specification. For example, recognition of an object as a horse requires a mental comparison between it and previously encountered horses. Recognition does not require an awareness of the characteristics that define a horse, or even that such characteristics exist. In contrast, definition of a horse requires specifying exactly what characterizes "horse-ness." A recognizable reproduction of a horse must adequately evoke the defining characteristics of a horse to be recognized as one.

Stages of Mental Evolution

The process of mental evolution begins by partitioning internal sensory maps into separate objects that for the present purposes are assumed to be atomic. The levels of mental evolution arise through repeated generalizations and are labeled categorization, protoconceptualization, conceptualization, and consciousness.

First, the mind recognizes categories of similar objects (categorization), next it recognizes the commonalty that is the basis of categorization (protoconceptualization), and then it explicitly specifies this commonalty (conceptualization). The explicit characteristics that determine membership in a category are first embodied in physical objects where the material of a representation—the concept-space—is inseparable from the concept itself (contingent physical concept-space). Next the mind recognizes the concept-space as a separable entity from the concept it carries (independent physical concept-space), and finally the concept-space is defined (abstract concept-space). I define the formation of an abstract concept-space as consciousness and the mode of expression of abstract concepts as language.

Evolutionary mental states predict a verifiable sequence of archaeologic artifacts if three assumptions are made: 1) a hierarchy of mental states can be correlated with a phylogenetic sequence; 2) mental capacities are reflected in archaeologic data; 3) mental capacities are expressed as soon as they arise. Together these assumptions imply that the minimum mental capacity necessary to produce an artifact is the capacity indicated by the appearance of that artifact.

Analyticity and Adaptive Advantages of Mental Evolutionary Stages

The adaptive advantages of the stages of mental evolution are found in the increasing capacity to retrieve elements of the perceived world for consideration, planning, and communication at times when they are not physically present.

Categorization recognizes the similarity of perceived objects, and as collections of these objects it is defined analytically. All animals have the mental capacity of categorization at some level since they have, at a minimum, the capacity to recognize the category of food. As the process of categorization progresses, more categories and higher-order categories are recognized, i.e., categories recognizing the equivalence of other categories and categories of categories, etc. Increasing complexity of categorization is the same as recognition of fine detail in objects. The adaptive advantage of recognizing increasing fine detail is obvious, but its limitation is that a category is still only a standard of comparison and exists only in conjunction with a particular observation. For example, a tail is recognized as a separate object when one is encountered, but there is no handle by which the category "tail" can be retrieved independent of its actual presence.

Protoconceptualization appears when the equivalence underlying a category is first recognized but before it is possible to specify the entire set of defining characteristics. At this point, a category can be retrieved for consideration independent of an observation, but only a member of the category that manifests the defining characteristics can represent it. Obtaining such representative elements is inconvenient, but nonetheless, some important categories can be retrieved independent of an observation.

When adequate fine detail is recognized in the structure of objects, the equivalence underlying a category can be specified as a collection of special categories. The special categories that form the category-defining collections are termed *attributes*, and as a collection of categories, a concept is defined analytically. At this stage a concept-space only accommodates a single concept and therefore the complexity of concept manipulation is limited, but as physical reproductions, concepts are easily retrieved at a convenient time and location and reside in a ubiquitous material. The complexity of concept manipulation increases with the recognition of a concept-space independent of any particular concept. Only a physical object manifests the underlying equivalence of the physical contingent concept-spaces and, therefore, an independent concept-space must be a physical reproduction. The recognition of the existence of a concept-space independent of any particular concept is necessary and sufficient for the innovation of composition. It is necessary because a composition cannot exist without a common space in which the individual elements of the composition are unified, and it is sufficient because given a common space, all elements that appear within it are understood to be part of a unified composition. Thus, multiple concepts can interact in a common space. Since an independent concept-space is a similarity recognized in pre-existing contingent spaces, it is defined analytically. The definition of the concept-space results in reproduction of the space in an abstract form, just as definition of a category's equivalence allows the concept to exist in a different medium. The abstract concept-space vastly facilitates conceptual manipulations since concepts can be juxtaposed and hypotheses tested mentally, rather than by manipulation of physical representations. A corollary of this efficiency is that very high order categorization becomes possible defining objects whose existence is completely abstract and identifying fundamental equivalences in the perceived world.

A direct implication of the analytic nature of the stages of mental evolution is that once the modern human brain evolved, there is, in essence, an internal clock that results in independent development of the stages of mental evolution without the necessity of direct transmittal of a revolutionary "discovery." Direct contact will alter the rate of advance but not its ultimate occurrence. This may explain the universal development of language, even in possibly isolated human populations.

An Example

The example of a horse may help clarify a mental evolutionary sequence. First, the mind recognizes a particular horse as a separate object—separate from the ground, sky, trees, etc. Next, it recognizes a category of horses that serves as a standard of comparison to determine if a newly encountered object is a horse. By recognizing an object as a horse, the mind invests the object with the characteristics of previously encountered horses.

The process of protoconceptualization is the recognition that there is an underlying equivalence of horses that causes them to be classified together, and that a set of defining features forms the basis of categorization. The equivalence relation that determines whether an object is a horse forms a template that consists of a set of horse-defining characteristics or attributes. This horse is not an actual member of the category and does not exist physically. Thus, protoconceptualization is the recognition that a category exists independent of any of its members. This mental ability is demonstrated by the use of a single horse, or horse part, to represent the category of horses. The protoconcept "horse" must be a particular horse since only a member of this category manifests the similarity—as yet unspecified—underlying all horses. Conversely, the minimal mental capacity indicated by isolation or display of a horse skeleton or skull is the recognition of a generic horse. This generic horse is the equivalence relation that underlies the category of horse.

The concept "horse" is the explicit collection of attributes that determines whether an object is a horse. That is, it is the specification of the equivalence relation underlying the horse category. Thus, the concept "horse" is defined as the collection of horse-defining attributes—horse-like limbs, horse-like head, horse-like tail, etc. The categories of "limbs," "head," and "tail" are second-order categories formed by an equivalence recognized between categories of objects that have limbs, heads, and tails. The horse-like attributes are then subcategories of these more general types. At first, the collection is brought together in a modified object, e.g., a carving of a horse that *prima facie* contains sufficient physical attributes to define a horse because we recognize it as one. Conversely, the minimal mental capacity indicated by a recognizable reproduction of a horse is the ability to create an explicit collection of the defining attributes—or concept—of a horse. The modified physical object that carries the concept is a physical concept-space. At this stage, each physical concept-space can accommodate only a single concept and is inseparable from it—the carving and the carved stone are inseparable. In this sense, the physical concept-space is contingent. In the next stage of mental evolution, the mind recognizes that a carving of a horse and a carving of a bull have something in common—the capacity of the underlying material of the carving to accommodate either a bull or a horse. Since an independent concept-space is necessary and sufficient for composition, the minimal mental capacity indicated by the appearance of compositional reproductions is recognition of an independent concept-space. The independent concept-space allows a horse and a bull to appear together in a unified composite representation.

Once the mind recognizes a concept-space as an independent entity, the concept-space can be defined. Just as the concept "horse" allows the equivalence of the horse category to be reproduced in a physical concept-space, so definition of the concept-space allows it to be reproduced in a non-physical medium. Among the attributes defining this space is one that specifies an arbitrarily large carrying capacity. Since no physical space is infinite in extent, this can occur only in an abstract space. It is the formation of an abstract, mental concept-space that is consciousness. The expression of abstract concepts I define as language, and a result of this process is the ability to express the mental collection of characteristics of a horse that is embodied in the modern word *horse*. Conversely, the minimal mental capacity indicated by use of the word *horse* is the ability to express the collection of attributes defining the category of horses that exists in an abstract mental space, that is, the abstract concept "horse." Because of its importance, it is worth briefly elaborating on one characteristic of the abstract concept-space. The existence of an abstract concept-space means that conscious beings live in a model of the world that is created in this space. Subjectively, the existence of an abstract mental space explains the sense of a separate observer that is one prominent characteristic of consciousness. Conscious beings do not simply act, but also observe themselves acting because an action is performed both in the physical world and in the model of that world that resides in the abstract mental space. Objectively, this duality provides an extraordinary potential for mental advance. It is equivalent to the difference between designing an automobile using stone carvings and computer simulations. Any decision involves projecting the outcome of various possible choices, and this process is greatly facilitated in a model of the world that exists in the abstract mental space.

Predictions

The theory of mental evolution predicts that specific nonutilitarian archaeologic artifacts, and only these artifacts, should be found in the chronological order corresponding to its evolutionary stages. The first stage, categorization, predicts the absence of nonutilitarian artifacts. Since a category is simply a recognized collection of similar objects, and is functionally a standard of comparison, it has no independent existence.

The second stage, protoconceptualization, is the recognition that there is an equivalence underlying a category—the recognition that a category exists independent of any of its members. Since the equivalence that forms a category is recognized, but not defined, only a member of the category can be a protoconcept. Thus, the process of protoconceptualization predicts the appearance of unaltered natural objects, which are intentionally isolated or displayed—each representing the category of which it is a member.

The third stage of mental evolution is contingent conceptualization, in which an explicit collection of attributes specifies a category's defining characteristics. The collection must be assembled somewhere, and that place is a concept-space. At this stage, only physical objects can act as concept-spaces. Therefore, the contingent physical concept-space predicts the appearance of reproductions or representations of individual, recognizable objects in a physical medium.

The next stage of mental evolution is the recognition that a concept-space can exist independent of any particular concept it carries. The recognition of an independent physical concept-space is necessary and sufficient to allow composition where more than one concept coexist in a unified concept-space. This evolutionary stage predicts compositional reproductions.

The final stage in the mental evolutionary sequence is the appearance of an abstract concept-space. The appearance the abstract space makes the physical spaces immediately obsolete. As a result, the theory predicts evidence of rapidly advancing mental capabilities, the disappearance of all physical expressions of concepts, and their replacement by language—the expression of abstract concepts.

Explanations of Paleolithic-Age Artifacts and their Sequence

The only human artifacts found until the end of the Lower-Paleolithic Age and the ascendance of Neandertal Man are stone tools. Though human tools are more modified, more varied, and more permanent than those produced by other animals, the differences are of degree, not kind (Beck, 1980). Thus, the tool-producing hominids defining the genus Homo (i.e., *Homo habilis* and *Homo erectus*) were at the same level of mental evolution as other animals.

The Middle-Paleolithic Age begins with the supremacy of *Homo sapiens neanderthalensis*, approximately 100,000 years before the present, and is generally characterized by the appearance of three artifactual innovations: 1. human burial (Gamble, 1986; Solecki, 1975); 2. "ritual sites" devoted to cave bears and human skulls (Hadingham, 1979; Bergounioux, 1958); and 3. natural pigments used for body painting or dyeing of animal skins

(Singer, Wyman, 1982; Dart, Beaumont, 1969). A unifying character of these artifacts is the isolation or display of unaltered natural objects—for burial, the human body; for ritual sites, cave bear skeletons or human skulls; and for body painting and skin dyeing, naturally occurring pigments.

There have been many fanciful meanings previously ascribed to the appearance of human burial. At its simplest, however, preservation of a body after death recognizes some property of an individual independent of the body as an object. Since the category of an individual consists of a single object, the body of the individual, recognition of some defining characteristic independent of the body is the recognition of a category's existence independent of its elements, i.e., protoconceptualization. By identifying the minimal mental capacity capable of producing an artifact as the capacity indicated by the presence of the artifact, burial is best interpreted as an example of protoconceptualization. Alternatively, the absence of burial prior to this era must mean that the body had no meaning beyond its existence as an object, which in turn means that the mental capacity of protoconceptualization had not yet been achieved. If the protoindividual existed prior to death then there must be evidence for an *in vivo* differentiation of object and protoconcept. Since a protoconcept must be a member of the category it represents, only the physical body can act as the protoconcept. In order to distinguish the proto-I from "me" it is necessary to alter the arrangement or display of the object that is "me"—as in any other protoconcept. The presence of pigments in Middle-Paleolithic-Age deposits is thought to indicate that Neandertal man practiced body painting. Body painting or the simple coloring of crude fur clothing, is the most elementary method of differentiating the object "me" from the proto-I, and thereby recognizing the existence of the latter.

The beginning of the Upper-Paleolithic Age is heralded by the dominance of *Homo sapiens sapiens*. Two classes of nonutilitarian artifacts characterize this era—statuettes, paintings, and engravings (Rieck, 1934), and personal ornamentation (Marshack, 1972).

Statuettes, paintings, and engravings are discrete, easily recognizable objects reproduced in a physical medium—contingent concepts according to this formulation. Additional support for the conceptual nature of early Upper-Paleolithic-Age reproductions is found in the characteristics of cave wall and block art images. Block engraving and discrete cave art nearly universally demonstrate superposition of images, often to the point of complete obfuscation. In the case of block engravings, the finished products were broken and apparently tossed aside, to be used as any other stone for paving or building (Pales, 1976). If these engravings had an artistic purpose, it is difficult to understand their apparently careless treatment. A simpler explanation is that the paintings and engravings are concepts, and hence proto-linguistic. They may be compared with notes that are written at a particular time for a particular purpose. They can then be balled up and thrown away or overwritten, recognizing that only the last message has any meaning. Comparable treatment of block art and discrete cave art suggests a similar, but highly rudimentary, protolinguistic function.

The appearance of personal ornamentation is artifactual evidence of the definition of a category—a concept. The concept, in this case, is the subject "I", and a natural choice for a physical concept-space is the body. Since the object "me" and the concept "I" coexist in the same physical space—the body—there must be some way to differentiate object from concept. I claim that personal ornamentation serves this function.

Since the only member of the category "me," as a protoconcept, is identical to the physical concept-space of the concept "I" it is impossible to definitively distinguish the protoconcept from the true concept. In all other cases, the true concept is easily separable from the protoconcept of the same category, since the latter is a member of the category, and the former is a reproduction in a different medium. Thus, in the case of an individual, protoconcept and concept can only be distinguished by the sophistication or complexity of the body's decoration. From this perspective, the bichromatic body painting or dyeing of skins associated with the Middle- Paleolithic Age contrasts strongly with evidence of multi-colored tattooing and the vast array of personal ornaments that characterize the Upper-Paleolithic Age. Phenomenologically, this contrast is consistent with the difference between the recognition of the category of an individual and its definition.

The appearance of carved and painted compositional reproductions characterizes the final phase of the Upper- Paleolithic Age (Stevens, 1975; Leroi-Gourhan, 1968). At the end of that period, approximately 12,000 years ago, all forms of naturalistic reproductions abruptly disappear (Sommerville-Bordes, 1979). Simultaneously, the domestication of plants and animals and the rise of cities provide evidence of rapidly advancing mental capacity.

Correlations

The theory of mental evolution predicts a chronologic sequence of archaeologic artifacts corresponding to expression of its hierarchical stages—display or isolation of unaltered natural objects predicted by protoconceptualization, individual reproductions of recognizable objects predicted by the contingent physical concept-space, compositional works predicted by the independent physical concept-space, and the disappearance of these artifacts predicted by the abstract concept-space.

As predicted, these, and only these, artifact classes are found in the archaeologic record. Neandertal man first displayed unaltered natural objects in the Middle-Paleolithic Age 100,000 years ago. Recognizable reproductions in a physical medium are found with the ascendance of *Homo sapiens sapiens* at the dawn of the Upper-Paleolithic Age, about 40,000 years ago. Compositional reproductions appear in the last phase of the Upper-Paleolithic Age circa 15,000 BP, and all artistic works disappear with the onset of the Mesolithic Age, approximately 12,000 years before the present. This disappearance of Paleolithic-Age art has been difficult to reconcile with the rapid advance in material culture in the Mesolithic Age, since art is often considered the epitome of cultural expression. This theory provides an explanation. The Paleolithic-age "art" disappears because it was not art to begin with, but rather the increasingly complex expression of concepts in an evolving physical concept-space. By this formulation, language, as the expression of abstract concepts, appeared at the end of the Paleolithic Age, 12,000 years ago. From this perspective, the Upper-Paleolithic Age is the time during which physically modern man was developing mentally modern capacities.

Conclusions

A formal structure for mental evolution is created by defining the substrate of the mind as internally constructed sensory maps of the external world, and the function acting on this substrate as generalizing the elements of these maps. The stages of evolution are categorization—the recognition of similarity in objects; protoconceptualization—recognition that an equivalence underlies a category; conceptualization—definition or specification of the equivalence defining a category. The attributes forming this equivalence relation are defined as a concept and are assembled first in a contingent physical concept-space where concept and concept-space are inseparable. Next, a concept-space is recognized as independent of any concept it carries, and finally the concept-space is defined, specifying an abstract mental space where concepts reside. Expression of these abstract concepts is language.

The proposed temporal origin of language arises naturally from this analytic theory of mental evolution that has several additional heuristic characteristics. First, the theory unambiguously and analytically defines mental capacities including consciousness. No such unambiguous definitions have been previously suggested and no analytic sequence of mental capacities leading to consciousness has been proposed. Second, the theory provides an explanation of the meaning and sequence of Paleolithic-Age artifacts. Though many explanations have been offered for individual artifacts or artifact classes, there is presently no coherent hypothesis for their chronological sequence. Finally, the theory provides an explanation for the problematic transition from Paleolithic to Mesolithic Ages—a reason for the abrupt disappearance of the spectacular "art" of the Paleolithic Age with the rapid advance of other aspects of material culture.

Implications of the theory for the origin of language are heterodox, but appear as consequences of a logical sequence that is independent of any linguistic assumptions or prejudices. There have been other proposals of a late origin of consciousness and language, but none based on an analytically defined sequence of mental evolution (Jaynes, 1976). The theory suggests that language developed approximately 12,000 years ago. It hypothesizes that the evolution of mentally modern capacities appeared over 100,000 years after the evolution of physically modern man, and 30,000 years after the ascendancy of modern humans in the Upper-Paleolithic Age. The theory implies that though consciousness and language are the *sine qua non* of humanity, they were not the proximate causes of the evolution of *Homo sapiens sapiens*.

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C. A Theory of Mental Evolution and the Origin of Language[116]

Abstract: The nature and origin of human mental capacities are two of the great open questions of science. There has been no lack of effort expended in attempts to explain how mental capacities arise in the brain and how they evolved, but all of these attempts suffer from a common difficulty. Without unambiguous, analytic definitions of mental abilities—i.e., definitions in which each mental function is defined solely in terms of those previously defined—a successful analysis of mental evolution is simply not possible. The description of mental evolution in this investigation is scientific—consisting of explicit axioms, an unambiguous and rigorously defined theory, and testable predictions—and represents a significant departure from previous attempts. The axioms are from the foundations of neurological science, the theory is an analytic sequence of increasingly complex capacities in which every stage is defined exclusively in terms of those preceding it, and its predictions are verified by the archaeology of human phylogeny. The exact correlation of predicted and actual artifacts supports the theory and its explanations of the nature and origin of the human mind. Reciprocal consequences of the correlations concomitantly provide a previously absent explanation of the meaning and sequence of Paleolithic-Age nonutilitarian artifacts and a chronology for the appearance of mental capacities. A definition and temporal origin of language arises naturally from this analytic sequence—without linguistic assumptions or preconceptions. The independent nature of this identification avoids an error of classical logic present in previous ideas about language origins.

Introduction

Language is one of humanity's defining features, as well as one of the most compelling and perplexing concerns of diverse scientific disciplines. In addition to the clinical science of neurology, specialities of neuroscience, cognitive science, computer science, psychology, anthropology, and mathematics—as well as their multiple hybrids—have various aspects of language as their primary focus. In any reasonable format, it would be overly ambitious to attempt a statement—not to mention a resolution—of the multifarious complex linguistic conundrums. However, certain foundational questions underlie any investigation of language—e.g., its

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nature and origin—and these are adequately abstract to be addressed in a relatively concise and comprehensible manner.

The first part of this paper will set the stage for the current explanation of language origins by presenting a short review of previous ideas (Section 2) and a novel statistical assessment of language and sound (Section 3). The former is not a critique of specific linguistic research, but rather identifies an abstract logical error that is common to the various existing approaches to the origin of language. The latter presents a simple calculation that implies language must have appeared after the emergence of modern humans—a conclusion that contradicts existing views and is consistent with the current analysis.

A distinguishing feature of this investigation—when compared to other descriptions of language origins—is that its explanations arise from an independent theoretical construct based on the foundations of neurology. It contains no reference to any aspect of linguistics, and its fundamental description of language is a natural and unexpected culmination of an analytic sequence of increasing mental capacities that forms a theory of mental evolution.

There are three interrelated areas of significance of the proposed theory—1. its rigorous and analytic definitions of mental capacities—including consciousness—in an axiom-based, predictive, and falsifiable structure that replaces philosophical discourse and, at a minimum, provides an unambiguous basis for disagreement; 2. the validation of the theory by corroboration of its predictions in the archaeology of human phylogeny and its concomitant explanation—previously absent—of the meaning and sequential appearance of Paleolithic Age nonutilitarian artifacts; 3. its implications for the nature and origin of language.

The first objective and significance of the proposed theory of mental evolution is an extension of the boundaries of science—in particular, neuroscience—that claims territory traditionally ceded to philosophy. Specifically, a scientific theory of mental evolution is proposed that unambiguously defines mental capacities in an analytic manner—i.e., each increasingly complex stage is defined solely in terms of those that precede it. No such comprehensive and integrated structure of the mind has been previously suggested. The lack of ambiguity in the theory's axiom-based definitions and structure provides for a commonalty of scientific discourse absent in existing discussions of the human mind.

The second significance of this analysis is the independent support for the description of mental evolution found in the archaeology of human phylogeny, and the concomitant explanation of the sequence and meaning of Paleolithic-Age nonutilitarian artifacts. The theory predicts the appearance of specific artifact types corresponding to expressions of its analytic stages. The exact correlation of predicted and actual artifacts provides strong support for the theory. Concomitantly, the stages of mental evolution suggest an explanation of the sequence and meaning of the artifacts. Although many explanations have been proffered for the meaning of individual nonutilitarian Paleolithic-Age artifacts (Insoll 2012), there has—to my knowledge—been no proposed theory that explains the sequence of their appearance. Without an integrated prediction of the progression of observed artifacts, any explanation of individual archaeological remains—regardless of how clever or insightful—is useful only anecdotally, reflecting a preconceived notion. Thus, for example, the cave paintings as "the birth of art" (Lorblanchet 2007; Lewis-Williams and Clottes 1998; Dutton 1987), or burial as the "origin of religion" (Culotta 2009; Boyer and Bergstrom 2008; Rossano 2006), are supported only by the anachronistic assumptions from which they arise. This circular reasoning—or *petitio principii*—is an example of a classical logical error, and is scientifically unsatisfying. Additionally, and of greater concern from a heuristic perspective, disputed claims for the nature of Paleolithic-Age artifacts are essentially incommensurable. These infelicities are eliminated in the current proposal by the suggestion of an axiomatic, comprehensive, and validated sequence of evolving mental capacities that establishes a coherent and integrated explanation of Paleolithic-Age nonutilitarian artfacts that is both novel and arguable.

The final significance of this study is the suggestion of a nature and temporal origin of language that emerges from the archaeological correlations of the theory. This result is unexpected and natural, arising from an independent theory based on the axioms of neurology and neuroscience. Though this is a unique and abstract contribution to the science of linguistic—whose consequences underlie any investigation of language—it does not offer solutions to specific problems in other fields of language studies. A primary goal and significance of this investigation is to suggest—as a consequence of a rigorous, analytic, and independent analysis—what language is, and when it appeared.

In summary, the proposed structure for mental evolution is a novel, axiom-based, predictive, and falsifiable scientific theory. It predicts the appearance of a specific type of nonutilitarian artifact as an expression of each evolutionary stage, and its validity is evaluated by comparing these predictions with the archaeology of the Paleolithic Age. The precise correlation of predicted and actual artifacts supports this derivation of the evolution of the modern mind and the origin of language, and provides a previously non-existent explanation for the meaning and sequence of Paleolithic-Age artifacts.

Current Explanations of the Nature and Origin of Language

This section highlights some modern research concerning the nature and temporal origin of language. There are two aspects of this overview that are important to note. First, of necessity, this analysis is brief and incomplete, and does not do justice to the subtleties and insights of even the few representative ideas that are discussed—the examples are presented solely as illustrations of an analytic technique. Second, this review identifies a generic difficulty shared by broad classes of existing linguistic ideas and attempts to contrast it with the logic of the origin of language found in this investigation. This difficulty is a 'meta-problem' and is not the main concern of any of the referenced research. Consequently, the following is not a critique of the quoted ideas but rather an indication of a fundamental, logical conundrum that underlies existing approaches to the origin and nature of language.

Previous investigations into the origin of language can be classified in at least three discrete categories—anatomic, intuitional, or statistical. The anatomic type suggests a temporal origin based on the phylogenetic appearance of the physical structure of the modern human larynx. The second type utilizes intuition and insight to create an idea of what language is, then uses this assumption to predict when language appeared. A final type is a statistical analysis where divergence of certain linguistic forms is traced backwards to a convergent origin. A statistical analysis—based on an evaluation of language morphology—identifies a temporal origin of language without suggesting its nature.

Anatomic Theories

The first linguistic class centers on the structural adequacy—or inadequacy—of the Neandertal larynx to produce the range of sounds in modern language (e.g., Schepartz 1993). This type of investigation assumes an intimate relationship of sound-making capacity and language emergence that either conflates speech and language, or at least suggests that the number of sounds made by Neandertals was sufficient—or insufficient—to conclude that modern language was present—or absent. There may be a relationship between the number of sounds that can be made, and the development of language, but—as outlined in the next section—this relationship is indirect and strongly indicates an appearance of language after the evolution of modern laryngeal anatomy.

Intuitional Theories

The second type of argument for the nature and temporal origin of language begins with an intuition—or preferred explanation—of the nature of language and then uses this assumption to place it within a temporal sequence. Most novel contributions to science begin with an intuition concerning the nature of a problem. As an example, Albert Einstein (1879-1955) intuited that the speed of light must be the same in any inertial reference frame and, from this axiom, derived special relativity. He assumed that inertial and gravitational mass were identical—or gravity is equivalent to geometry—and derived general relativity. The intuitions concerning the nature of language, at this first stage, are formally no different than Einstein's. The determinative difference arises at the next step. Einstein—and other scientists—use intuitions as axioms, then derive a theory that has novel explanatory and predictive consequences. In the case of language, this essential step is missing, the intuitions—or axioms—stand alone, not as the first step in a scientific derivation, but as the only step. This creates two problems—one pragmatic and one logical—irrespective of the quality of the initial insight. A pragmatic problem is that this type of analysis produces proliferating incommensurable ideas. Since distinct intuitions result in different axioms, and axioms are—by definition—unquestioned, the discrete ideas proposed cannot be effectively compared. It is possible to argue about whose intuitions are better, but there is a tendency for the advocacy of a particular view to remain fixed to its creator. Without testable and predictive consequences—or explanatory detail—there is no convincing way to choose one intuition from another. A second difficulty is an error in classical logic that arises when an assumed nature of language is used to determine its temporal origin. This self-reference is an example of the fallacy of classical logic known as *petitio principii* where an assumption entails the conclusion. Though without an independent theory—derived from axioms—this is the extent of what can be accomplished, the result is nonetheless scientifically unsatisfying.

Intuitional types of linguistic analysis can be further divided into discontinuous and continuous models. Simplified examples are presented, using the ideas of arguably the most influential investigators, to demonstrate only that both forms share the generic difficulties just described.

Discontinuous intuitional theories

Any linguistic study must acknowledge the pioneering work of Noam Chomsky (1928-). Chomsky's main contributions involve details of linguistic structure—essentially their invention—and for much of his career he resisted hypothesizing on the foundational question of the nature of language (Chomsky 2007). More recently, however, he has presented ideas concerning language's nature and temporal origin (Chomsky 2005). As would be expected, these ideas are sophisticated and insightful. However, they also demonstrate the generic problems common to intuitional approaches mentioned above.

Chomsky views the origin of language as discontinuous. He sees development of a language faculty as a result of a single mutation in a single individual that allows a countably infinite form of recursive operations to appear where only finite recursion was previously possible (Chomsky 2005). Because there is a potentially countably-infinite diversity of linguistic expressions, he believes that language presupposes this denumerably infinite recursive capacity. Although specifying a temporal origin is not an integral concern of Chomsky's analysis, based on the assumption of a point mutation, he places the origin of language between 50,000-100,000 years ago, when the brain achieved its modern status.

The discontinuous theory of Chomsky conforms to—and has the problems of—the intuitional type of language theory described above. It assumes a nature of language—i.e., a language faculty derived from a mutation producing a countably infinite recursive capacity—then uses this assumption to place the temporal origin of language when the modern brain with this new ability appears.

Continuous intuitional theories

The continuous type of ideas about language nature and origins are more widely accepted, but are more nebulous since binary distinctions in a continuum are problematic. In fact, one of the most prominent contributors in this category implies only that language development was innate, evolutionary, and gradual (Pinker and Bloom 1990). Though Pinker and Bloom state that language originated coextensively with humanity, it is not clear if they mean the human species—including Neandertal—or *Homo sapiens sapiens.* In either case their main argument is that language was a product of natural selection and that its grammatical structure gradually changed over time. They would disagree with the notion that language could appear after humanity's evolution and that it could spread from one group of humans to another. The basis for these views is, however, intrinsic to language and evolution and begins with the—unexamined—assumption that the nature of language is a collection of its observable characteristics. That is, intrinsic characteristics of language are shown to be consistent with ideas of natural selection, but the fact that language—*a posteriori*—is defined by its characteristics, is assumed. Then, since these aspects of language are unique to humans, their origin is identified with the emergence of humanity. Like the other ideas outlined here, the arguments are sophisticated and perspicacious, but subtly self-referential. It is important to emphasize that this meta-analysis is not directly relevant to the purposes of Pinker and Bloom whose goal is to demonstrate that language can be a naturally evolved function. Nonetheless, the presence of this abstract self-reference does indicate that the analysis of language—and its origins—is incomplete.

Other perspectives within this type posit language as evolving out of primate vocalizations (Cross 2009), gestures (Tomasello 1996), or appearance of increasingly complex cultures (Knight 2010). All continuous models contain more ambiguous and undefined terms than Chomsky's, but they have in common an intuited formulation of the nature of language, and the use of that assumption to suggest at least an approximate temporal origin. They inherit the problems outlined above.

Statistical Theories

The last type of investigation on language origin is a statistical one based on rates of divergence of various linguistic forms that are projected backwards to a point of convergence. There is general agreement on an inability of cladistic models to identify language origins accurately beyond about 6,000 years due to erosion of family relatedness (Diamond 2011; Nichols 1998), but at least one statistical model uses this limitation as a starting point to trace language back much further (Nichols 1998). The analysis begins by assuming that language and modern humanity coevolved. Using this assumption, geographical densities of language families existing 6,000 years ago are adjusted so that a branching rate, in multiples of 6,000 years, converges to a single ancestral form 130,000-100,000 years ago. This analysis—though more subtle—demonstrates a form of circular reasoning noted in the previous classes.

In summary, contemporary ideas about the nature and origin of language can be placed in three classes. Generic problems in the classes are identified, and specific examples are presented that demonstrate these. In all three cases, the difficulties result from a self-referential argument wherein a basic assumption about language is used to explain an additional linguistic property. In the anatomic and intuitional classes, its nature is assumed to determine its temporal origin, and in the statistical class, its origin is assumed, and then rationales suggested to adjust the statistics to cohere with the assumption. In all three cases, there is a direct, self-referential connection from assumption to conclusion rather than the conclusion being a predictive consequence of an independent axiom-based theory.

Statistics of Language and Sound

This section presents a calculation that is consistent with the late appearance of language in human phylogeny and contradicts the conclusions of the three classes above—i.e., that modern humanity and language are coextensive. Though the numbers used are prone to significant error, the results—even at an order of magnitude level—are impressive. The argument is that the ability of the human larynx to make distinct sounds—and therefore potential phonemes—results in a massively redundant capacity for word creation relative to any one language—or all languages that have ever existed. Since nature abhors such waste—or more prosaically, since there can be no selective pressure for such redundancy—this implies that the distinct sounds that can be produced evolved for a much less efficient process than language. In other words, the modern human larynx evolved for non-linguistic communication, and when language appeared with its remarkable efficiency, it required only a miniscule fraction of the existing word-creating capacity.

A generic language will be considered to contain 100,000 words—in any case, this order of magnitude is probably valid as an upper bound (Simpson and Weiner 2009). Early languages were most likely less complex. A current estimate of the number of phonemes—which are semantically defined within existing languages as atomic elements of sound—is approximately 100-200 (International Phonetics Association 1999). However, phonemes are equivalence classes of distinct sounds, or phones, so the number of phones is much greater—about 800 (Dobrovolsky and Katamba 2001). In the present context, phones are considered to be potential phonemes in a hypothetical language—i.e., phones become equivalence classes under the identity relation. Studies of many languages suggest that there are, on average, about 2 syllables/word and 2.5 phonemes/syllable (Fenk et al 2005). Combining these statistics yields a potential production of approximately $3X10^{14}$ words, or a redundancy for any single language of 3,000,000,000:1. This number specifies the redundancy at the time of appearance of the first languages and is a reasonable quantitative measure of the relative efficiency of linguistic *vs.* non-linguistic communication. However, as a further indication of the degree of redundancy present in human word generating capacity, an additional—approximate— calculation is possible for the totality of human languages since their first appearance. Estimates of the number of languages that have existed depend significantly on assumptions of when language began, but an average estimate is about 100,000 languages (Pagel 2000). Therefore, considering all languages that have ever existed, the redundancy is 30,000:1.

Some degree of redundancy would be anticipated in word-generating capacity, so the results obtained above should be normalized for this expected redundancy. A reasonable normalization would be to use the redundancy of potential word creation of modern phonemes relative to modern languages. Using approximately 150 phonemes in modern languages, and the same distribution of phonemes and syllables, gives an approximate number of 7.6×10^{10} potential words. There are many estimates of current languages but the most authoritative appears to be about 7,000 (Lewis, et al 2013). With 100,000 words/language, this yields about 7×10^{8} extant words, and a value for an expected redundancy of approximately 100:1. Applying this value to the previous calculation yields a normalized redundancy for the first languages of 30,000,000:1, and for all languages that have existed, 300:1.

There are two conclusions from this result—one definitive and one speculative. First, the modern larynx must have evolved before language, since after language appears there is no selective pressure for the diversity of sounds that result in a massive overproduction of potential words. This conclusion is sufficient to differentiate the present formulation from the standard view that language and modern humanity coevolved, and is all that is claimed for the calculation. The second consequence—regarding the length of time separating the appearance of language and the modern larynx—is more speculative. Since an obvious conclusion of the calculation is that sound production and language are completely independent, in theory, language could arise at any time after modern laryngeal evolution, including very early in human evolution. However, if language appeared early in modern human development, the redundant capacity for sound production should begin to atrophy—just as other vestigial organs such as third molars have in physical evolution over a comparable period of time (Smith et al 2010; Trinkaus 1978). The fact that such a massive redundancy of sound production remains is at least suggestive of a relatively short temporal interval since language appeared.

Though insufficient to offer independent verification of this investigation's exact temporal origin of language, the result is consistent with the current formulation. Of greater import, it contradicts most previous estimates that predict the emergence of language, at the latest, coincident with the appearance of modern humanity.

Preliminaries

Since language appears at the end of the evolutionary sequence to be described, there are fairly extensive preliminaries that are necessary to construct the analytic framework from which it emerges. It is, in fact, these preliminaries that differentiate this proposal from those that have preceded it, since it is the axiom-based analytic chain of definitions and corroborations that establish the logic and scientific structure of the argument. The unique nature of the proposed system for mental evolution—and its consequences for fundamental open questions regarding the mind—requires a detailed evaluation of its predictions, since if the intrinsic logic of the theory, and its extrinsic verifications, are accepted, then its conclusions regarding the origin of the mind and language are unavoidable. Though the logical structure of mental evolution is compelling, it is abstract and heterodox. The greater the explanatory scope of a theory, the more extensive the required validation, and therefore, the archaeology of the Paleolithic Age—and its correlations with the theory's predictions—occupies the majority of the following discussion.

Nature of Language

The ultimate goal of this analysis is an independent and scientifically rigorous explanation of the nature and origin of language. To accomplish this, it is essential to explicitly identify those aspects of language that are relevant in the current context. There are many elements of language, and the more closely it is examined, the greater the complexities that appear. But at a level of abstraction applicable to this investigation of language's origins, most of these details are not relevant.

At its most abstract, the notion of a language is an essential component of the foundations of mathematics. This metamathematical construct contains the necessary symbols and relations to make statements about a particular universe of discourse. The statements are finite strings of concatenated symbols and relations of the language. Formulas, which are strings of symbols that make coherent statements, are determined by recursive definitions beginning with atomic formulas. The validity of a well-formed statement about the universe can be demonstrated either syntactically or semantically. Syntactic proofs are generally long, clumsy, and non-intuitive, while semantic proofs—utilizing model theory—are intuitive and elegant. A similar dichotomy exists between the relative primacy of syntactic and semantic aspects of natural language. As with most debates involving the nature of language, the arguments are sophisticated, complex, and legion. All of these hypotheses about natural language are intrinsic to linguistics itself, i.e., they arise from, and are supported by, assumptions and suppositions about language. The nature of language that arises from the current independent analysis suggests that it evolved as a semantic process. The support for this position does not arise from a linguistic argument, but from the internal logic of the system of mental evolution that is proposed, and from its validation by the correlation of its predictions and the archaeology of nonutilitarian Paleolithic-Age artifacts.

Axioms and Assumptions

The theory of mental evolution is derived from three axioms—the first two borrowed from the foundations of neurological science. An additional (fourth) axiom is required to validate the predictions of the theory.

Neurology is a reproducible and demonstrably useful clinical science that has helped relieve the suffering of untold millions in the century and a half of its existence. Though many contributed significantly to the understanding of the brain, the coalescence into a scientific structure was accomplished by the Victorian physician John Hughlings Jackson (1835-1911) in 1884 (Hughlings Jackson 1884; Steinberg 2013). Hughlings Jackson's key insight was that a science of neurology is possible only if the brain is seen as a purely sensorimotor machine (Hughlings Jackson 1882). This is the fundamental axiom of scientific neurology and the first axiom of this derivation. According to Hughlings Jackson's evolutionary theory, higher brain functions are increasingly complex, integrated, and interconnected, so the afferent function of the brain can be seen as the construction of an increasingly complex sensory map of the external world (Hughlings Jackson 1887). The second axiom is that the function of the mind is to interpret this construction, and, therefore, these internally constructed sensory maps provide the substrate for mental evolution. Since increasing mental capacity is characterized by an increasing inductive facility—an ability to identify equivalence—the third axiom is that the process of mental evolution is generalization. The elements of internal sensory maps are generalized and re-generalized in the mind, producing an increasingly complex, analytically structured hierarchy of mental capacities.

Prediction of a sequence of archaeologic artifacts from a hierarchy of evolutionary mental functions necessitates three additional assumptions: 1) mental capacities can be correlated with a phylogenetic sequence; 2) they are reflected in archaeologic data; 3) they are expressed as soon as they arise. Together these assumptions imply that the minimum mental capacity necessary to produce an artifact is the capacity indicated by the appearance of that artifact. This final axiom is necessary to evaluate the theory's predictions.

Definition of Terms

The term *analytic* in this investigation is not identical with its use in mathematics, linguistics, or philosophy. It has both ordinal and traditional analytic elements. As mentioned above, it refers to a sequence of definitions where each element is defined exclusively in terms previously defined. This type of nested sequence is particularly useful in describing evolution. It has the considerable additional advantage of limiting ambiguity and emphasizing rigor.

This theory of mental evolution defines a concept as a collection of attributes that determines membership in a category, i.e., a category's explicit equivalence relation. A concept is independent of its representation, and so, can exist in many forms. The theory also introduces the idea of a concept-space—the place where concepts exist. The concepts of modern humans reside in an abstract mental space and their form and content seem inseparable, but the abstract mental space itself is a product of evolution, and before it existed, concepts were embodied in a modified physical object—a physical concept-space. For example, a carved stone displaying the physical characteristics of an animal is the concept-space of an Upper-Paleolithic Age concept.

The theory also strictly differentiates the processes of recognition and definition—recognition involves comparison, while definition involves specification. For example, recognition of an object as a horse requires a mental comparison between it and previously encountered horses. Recognition does not require awareness of the characteristics that define a horse, or even that such characteristics exist. In contrast, definition of a horse requires specification of defining characteristics of "horseness."

Stages of Mental Evolution

The distinctions that form this theory's analytically defined stages are subtle. In ontogeny, the levels are rapidly surmounted in the first year or two of life with guidance from fully (mentally) evolved elders, and the differentiations emphasized here either never appear, or rapidly disappear. In phylogeny, however, these stages occur over thousands of years and this extended development can be easily seen when viewed from an appropriate perspective. Acquiring this perspective requires careful attention to what may initially appear as trivial details. The abstract simplicity of the analytically defined evolutionary stages is a major strength of the development, though the sequence is not—at first exposure—necessarily obvious or easy to grasp. Any intellectual effort expended is, hopefully, rewarded by an understanding of a scientific explanation of language and the mind.

The process of mental evolution begins with the partition of internal sensory maps into recognized separate objects. It proceeds through repeated generalizations in five distinct stages wherein each stage is defined exclusively in terms of those previously defined: categorization, protoconceptualization, and conceptualization in a contingent physical concept-space, an independent physical concept-space, and an abstract concept-space. Categorization involves recognition of the similarity of objects; protoconceptualization, recognition of the commonality that is the basis of categorization; and conceptualization, explicit specification of this commonality. The explicit characteristics that determine membership in a category are first embodied in physical objects—a contingent physical concept-space that is inseparable from the concept itself. The concept-space is next recognized as a separate entity from the concept it carries—an independent physical concept-space. Finally, the concept-space is defined, creating an abstract concept-space. The formation of an abstract concept-space marks the achievement of consciousness, and the mode of expression of abstract concepts is language.

Analytic Details of Mental Evolution

Once the process of mental evolution begins, each stage develops analytically from the previous one, providing an adaptive advantage that contributes to further mental development. This adaptive advantage is the increasing capacity to retrieve elements of the perceived world for consideration, planning, and communication when they are not physically present. The process culminates in the creation of an abstract mental space where an internal conceptual model of the external world resides.

Categorization

Categorization involves recognition of the similarity of perceived objects, and a category is defined analytically as a collection of these objects. For example, the mind recognizes a category of horses that serves as a standard of comparison to determine if a newly encountered object is a horse. Each object that is identified as a horse is invested with the characteristics of previously encountered horses. All animals have the mental capacity for categorization, since they at least recognize a category of food. Increasing complexity of categorization involves recognition of more categories, subcategories, and higher-order categories, such as categories of categories. Once a category is recognized, details of the category's elements, and similarities among them, also can be identified. These similar details form new categories that are subcategories of the original category. For example, once the category of horse is recognized, it is possible to recognize subcategories such as horse's head, tail, and limbs. Subcategorization is particularly important for the succeeding stages of evolution.

Protoconceptualization

Protoconceptualization emerges analytically with the recognition that the elements of a category have been grouped together because they share an equivalence—a set of defining characteristics. Alternatively, protoconceptualization can be seen as the recognition that a category exists independent of its members. That is, the defining characteristics of a category form a generic element—the equivalence relation—that is not an actual member of the category, but rather is the category itself, separate from its members. The recognition of the existence of such a generic element—or equivalence relation—is protoconceptualization. A category can now be retrieved for consideration independent of an observation, but since the equivalence is recognized but cannot be specified, only a member of the category that manifests the defining characteristics can represent it. The protoconcept "horse" thus must be a particular horse, and the minimal mental capacity indicated by the intentional display of, e.g., a horse skeleton in the archaeologic record is protoconceptualization. Protoconceptualization demonstrates the ability to recognize the equivalence underlying the category of horses, i.e., the existence of a category of "horse" independent of any particular horse.

Conceptualization in Contingent Physical Concept-Space

Conceptualization in a contingent concept-space occurs when the equivalence forming a category is defined. This can occur once subcategorization has produced protoconcepts recognizing sufficient fine detail within a category. For example, the protoconcept of the category of horse's tails is the generic horse-like tail. A collection of these recognized generic characteristics of horses defines a generic horse—the concept "horse." Thus, a concept is analytically defined as a collection of protoconcepts, or attributes. At this stage of evolution, a collection can only be assembled as a physical object, since no other type of space is available. Therefore, the attributes defining the equivalence of the category are assembled in a unique, physical concept-space—a modified object such as a sculpture, a cave-wall painting, or an engraving of a horse. The concept and its concept-space are inseparable—the image and the material in which it exists are one. In this sense, the physical concept-space is contingent. Since the concept can be displayed in any convenient physical medium and be of any size, it can be manipulated much more easily than a protoconcept, which must be a member of its category—providing an adaptive advantage. The minimal mental capacity necessary to produce a recognizable reproduction of a horse in the archaeologic record is the ability to explicitly specify the defining characteristics of the category of horse—the concept "horse."

Conceptualization in Independent Physical Concept-Space

Conceptualization in an independent physical concept-space is seen analytically as the recognized equivalence of contingent concept-spaces and results in a concept-space separate from any particular concept. So, for example, a carving of a horse and a carving of a bull are seen to have something in common—the stone that can accommodate either animal. A recognized equivalence must include all properties shared by a category's elements, and since the contingent concept-spaces are all physical objects, the independent concept-space must also be a physical space. However, the increased complexity of conceptual relationships possible in an independent physical concept-space results in a significant adaptive advantage. The emergence of this capacity is heralded by the appearance of compositional reproductions in which multiple concepts interact in a common space, e.g., a composition containing both a horse and a bull. In fact, the existence of an independent concept-space is necessary and sufficient for the innovation of composition. It is necessary because a composition cannot exist without a common space in which the individual elements of the composition are unified, and it is sufficient because all elements that appear within a common space are understood to be part of a unified composition. Thus, the minimal mental capacity indicated by the appearance of compositional reproductions in the archaeologic record is recognition of an independent physical concept-space.

Conceptualization in Abstract Concept-Space

Conceptualization in an abstract concept-space occurs when the physical concept-space is defined. It is seen analytically as a specification of the equivalence of the independent physical concept-spaces—a generic independent concept-space. Each independent physical concept-space can accommodate only a limited number of concepts, but the generic independent concept-space must have an arbitrarily large capacity. Since no physical space is infinite, the generic independent concept-space specifies an abstract space. In the physical concept-spaces the concepts are expressed as visible collections of a category's defining features, shared by those who view them. But the abstract space is invisible and so there must be a way to retrieve the concept and a shared expression to communicate it. The name of a concept in the abstract concept-space, e.g., *horse*, encodes its address—or coordinates—and the shared expression of abstract concepts is language. A name consists of only a few sounds, yet can easily convey a large amount of information that previously—if possible at all—required arduous labor. The minimal mental capacity indicated by use of the word *horse* is the ability to express the collection of attributes defining the category of horses that exists in an abstract concept-space—the abstract concept "horse." In this scenario, words are atomic and are presupposed by grammar that allows greater complexity of conceptual constructs.

The existence of an abstract concept-space vastly facilitates conceptual operations, since concepts can be juxtaposed and hypotheses tested mentally, rather than by manipulation of physical representations. This increased mental efficiency also enables very high-order categorization, definition of objects whose existence is completely abstract, and identification of fundamental equivalences in the perceived world.

According to the present development, formation of an abstract concept-space constitutes consciousness. Conscious beings live in a model of the world that is created in this space. The model reproduces the objects and relationships in the external world with their conceptual counterparts in the abstract space, and its existence explains the subjective sense of a separate observer that is one prominent characteristic of consciousness. Conscious beings do not simply act, but also contemplate actions and observe themselves acting, because there is both a physical world and a model of that world that resides in the abstract concept-space. This duality provides an extraordinary potential for mental advance. Any decision or hypothesis involves projecting the outcomes of various possibilities, and an abstract model of the world greatly facilitates such projections.

Previous philosophical treatments of consciousness have noted, e.g., the separation of observer from observed—and other novel characteristics—but have mistaken these manifestations for the function itself. Consciousness is not any, or all, of the operations that occur in an abstract mental space, rather it is the space itself that forms a substrate from which the processes emerge. Once this is realized, consciousness can be seen as the natural evolutionary culmination of an analytically defined sequence of capacities that intimately connect all animal life, rather than a miraculous and discontinuous ability bestowed on humans alone.

The analytic nature of the stages of mental evolution provides an explanation for the universal development of language—and other mental capacities—even in possibly isolated human populations. The modern human brain includes the sensorimotor structure necessary to set mental development in motion. The process can then unfold independently, each stage arising analytically out of the one that precedes it. Contact and direct transmittal can alter the evolutionary rate—as in ontogeny—but not its ultimate occurrence and outcome. This process is similar to other forms of parallel evolution where identical physical characteristics arise independently due to common environmental characteristics.

Theoretical Predictions of Archaeological Artifacts

This theory of mental evolution predicts that specific nonutilitarian archaeologic artifacts—and only those artifacts—should be found in the chronological order corresponding to its stages.

Categorization is the recognition of similarities among objects. As a functional standard of comparison, a category has no independent existence and so is not associated with any form of representation. Therefore, this stage should produce no nonutilitarian artifacts.

Protoconceptualization is the recognition that there is an equivalence underlying a category and that a category exists independent of any of its members. Only a member of the category can be a protoconcept, since the equivalence is recognized, but not defined. Thus, this stage should be associated with the appearance of unaltered natural objects that are intentionally isolated or displayed—each representing the category of which it is a member.

Conceptualization in a contingent physical concept-space specifies a category's defining characteristics as an explicit collection of attributes. The collection is assembled in a discrete physical object that is a physical concept-space. This stage, therefore, should be associated with the appearance of individual reproductions or representations of recognizable objects in a physical medium.

Conceptualization in an independent physical concept-space occurs when it is recognized that a concept-space can exist independent of the concept it carries. Since this recognition is necessary and sufficient to enable multiple concepts to coexist in a unified concept-space, this evolutionary stage should be associated with compositional reproductions.

The abstract concept-space arises by defining the equivalence of physical concept-spaces. The remarkable efficiency of concept manipulation in an abstract concept-space makes physical concept-spaces obsolete. As a result, this stage should provide evidence of rapidly advancing mental capabilities, and the disappearance of all physical expressions of concepts.

Correlations with the Sequence of Paleolithic-Age Artifacts

This section presents the archaeology of Paleolithic-Age nonutilitarian artifacts and correlates them with the predictions of mental evolution. The divisions of the Paleolithic Age conform exactly to the emergence of new mental capacities as predicted and so each division is discussed separately with an introduction to the archaeology followed by its correlations with the predictions of the theory. Although specific explanations of artifact classes are presented, it is the abstract commonality shared by each era's artifacts that is the significant validation of the theory's predictions.

Lower-Paleolithic Age

The Paleolithic Age coincides with the geologic epoch of the Pleistocene and is divided into three segments. The Lower-Paleolithic Age is the longest division, encompassing nearly 2 million years, or 95% of the total Age. The Lower-Paleolithic Age begins with the appearance of the first tool-producing hominid, *Homo habilis,* approximately 2 million years before the present (BP), and ends with the emergence of *Homo sapiens neanderthalensis* approximately 100,000 BP. No nonutilitarian artifacts are found in the Lower-Paleolithic Age labelling it the Age of Categorization.

Lower-Paleolithic-Age archaeology

The Lower-Paleolithic Age is characterized by extremely slow progress as measured by variation in stone-tool artifacts - in one documented instance change is imperceptible for a period of over 500,000 years. This particular sequence of chopper-core tools was discovered by Mary Leakey in beds I and II at Olduvai gorge (Leakey 1971).

H. habilis produced the earliest stone-tool industry, known as the Oldowan. The Oldowan tool-making technique is characterized by the chopper-core, which is an alternate name of the industry. Chopper-core tools are archaeologically demonstrable during an interval of 1 million years beginning approximately 1.8-2 million years ago (Wymer 1982).

The sole artifactual innovation of the Lower-Paleolithic Age occurred when *Homo erectus* modified the chopper-core tradition to produce hand axes. The oldest remains of this new species of hominid were first found near Lake Turkana in Kenya, in strata 1.8 million years old (Milisauskas 1978). *H. erectus* is a long-lived and successful species who first controlled naturally-occurring fire and migrated throughout the Old World. Migration of *H. erectus* is indicated by hand-axe artifacts which appear in Mediterranean sites about 800,000 - 700,000 BP, in India and Asia by about 600,000 BP, and by about 400,000 BP, throughout Africa, Europe, and the Indian subcontinent. This hand-axe industry is often called Acheulian after a representative French site. At the beginning of the Würm glaciation, c.100,000 BP, *Homo sapiens neanderthalensis* appeared, and the Mousterian and Levallois flake-tool industries replaced the Acheulian industry as the dominant stone-working technique.

The single most remarkable feature of the Lower-Paleolithic Age, relative to the succeeding epochs, is the extremely slow rate of artifactual change. Only utilitarian artifacts are found with no evidence of the use of any object for a purpose other than acquisition and/or processing of food.

Lower-Paleolithic-Age correlations

The manufacture and use of tools is not limited to humans. Animals from invertebrates to great apes use and manufacture tools of various levels of sophistication (Beck 1980). The distinctions that separate animal from early human tool use are quantitative, not qualitative. That is, human tools are more modified, more varied, and more permanent, but not fundamentally different.

The abstract similarity of mental processes in other animals does not detract from the revolutionary impact of tools on human development and expansion. Quantitative changes which exceed a threshold can produce qualitatively different results. For example, the quantitative addition of falling snow to a mountain slope will eventually produce a qualitative change when the coefficient of static friction is overcome and an avalanche results. Stone tools and the control of natural fire allowed migration of *Homo erectus* throughout the Old World, but tool-producing hominids defining the genus Homo (i.e., *Homo habilis* and *Homo erectus*) were at the same level of mental evolution as other animals. The lack of nonutilitarian human artifacts in the archaeologic record correlates with the theoretical prediction of their absence at the evolutionary stage of categorization.

Middle-Paleolithic Age

The Middle-Paleolithic Age begins with the supremacy of *Homo sapiens neanderthalensis* approximately 100,000 years ago and ends with the ascendancy of *Homo sapiens sapiens*, c. 30,000 BP. Neandertals produce the first nonutilitarian artifacts in the archaeological record, and thus provide the first constructive test of the predictions of mental evolution. All recognized artifacts share the characteristic of isolation or display of an unaltered naturally occurring object and thus the Middle-Paleolithic Age can be described as the Age of Protoconceptualization.

Middle-Paleolithic-Age archaeology

Two distinct stone-tool industries are recognized as products of Neandertal man. They are essentially geographic variants with the Levallois industry found in the Mediterranean region and the Mousterian industry throughout Europe and much of Asia (Champion, Gamble, Shennan, and Whittle 1984). The classification of all Middle-Paleolithic-Age skeletal remains as the subspecies *neanderthalensis* is controversial due to profound morphologic variability (Swan 1974). This is not relevant for the present purpose, however, since both the Levalloiso-Mousterian tool industry and the nonutilitarian artifacts are shared by all morphologic variants. Since artifactual evidence is correlated with mental evolution exact taxonomy does not affect the argument.

Uncontroversial Neandertal nonutilitarian artifacts

Two generally accepted nonutilitarian artifactual innovations are associated with Neandertal Man—1. manganese oxide and ocher used for body painting and/or dyeing of animal skins (Roebroeks, et al 2012; Barham

2002; Singer 1982; Dart 1969); and 2. human burial (Nadel 2013; Hayden 2012; Gamble 1984; Solecki 1975).

Natural pigments are a common finding at Neandertal sites (Wymer 1982). Intentional mining of these pigments is well-documented (Dart and Beaumont 1969; Schmidt 1969). Lumps of black manganese oxide and red ochre are found sharpened like pencils and scratched, presumably to make powder for paint (Singer and Wymer 1982). Ochre is used in burials, and although other uses of the pigment are uncertain, body painting is probably among them. Unequivocal evidence of personal ornamentation, such as pendants and necklaces, has not been found.

Burials are identified in the earliest settlements of Neandertal man. The Mousterian industry at La Chapelle-aux-Saints overlays a grave carved into the solid rock of the cave floor (Bouyssonie, Bouyssonie, and Barton 1909). Other burials of similar type have been found on the Dordogne at La Ferrassie (Bergounioux 1958), and in the Crimean peninsula at Kiik-Koba (Clark 1969; Mongait 1961). A collection of ten Neandertal graves was found near Mt. Carmel at Mugharet es-Skhul (Swan 1974). The cave at Shanidar, in present-day Iraq, revealed a burial that had apparently been accompanied by at least eight species of flower (Solecki 1975). Though Neandertal burials are commonly accepted some questions about their authenticity have been raised (Goldberg et al 2013; Sandgathe et al 2011; Gargett 1989). The most careful excavations appear to be more definitive (Lévêque and Vandermeersch 1980).

Controversial (and unlikely) Neandertal nonutilitarian artifacts

Three additional—and controversial—classes of nonutilitarian artifacts are sometimes suggested as products of Neandertal. In increasing order of improbability—1. modified and engraved objects; 2. “ritual sites” devoted to human skulls and cave-bear skeletons; and 3. musical instruments. These artifacts are very rare in the Middle- Paleolithic Age and they are not generally accepted.

Modified and engraved objects are extremely uncommon in Mousterian cultural deposits. They are often found in thin or disturbed occupation layers, and are consequently of questionable significance (Mellars 1973). At Tata, near Budapest, excavation of a Mousterian settlement from approximately 50,000 BP has uncovered a split mammoth tooth that had apparently been polished and covered with red ochre, and an amulet-like object with an engraved cross made from nummulite (Vértes 1964; Bordes 1968). Poorly incised and/or drilled bone fragments and teeth are also occasionally found apparently associated with Mousterian deposits (Leonardi 1983; Marshack 1976).

At Drachenloch, high in the Swiss Alps, a number of skulls and assorted limb bones of the cave-bear were found (Schmidt 1934). This cave probably could not have been occupied during Middle Paleolithic Age winters, because of its altitude, and thus may suggest a periodically visited ritual site. The arrangement of bear skulls within the cave also suggests some ritual usage. At Peter's cave in Unterfranken, Germany, additional evidence of intentional isolation of a cave-bear skull is found (Swan 1974; Singer and Wymer 1982; Milisaukas 1978). Finally, excavation of Regourdou in Southern France revealed the burial of up to twenty cave-bears in a pit underneath a one-ton rock slab. An entire skeleton of a cave-bear may have originally been placed on top of the slab (Bergounioux 1958).

The first claimed evidence of possible ritual associated with human remains is a product of Neandertal man. At Monte Circeo, in Italy, a Neandertal skull was apparently placed within a raised circle of stones. Stiner (1991) provides a detailed evaluation of the Monte Circeo cave site while arguing against its intentional construction. At Teshik-Tash in Uzbekistan a Neandertal infant skull was found which may have been surrounded by six pairs of Siberian mountain-goat horns (Movius 1953). These may have been placed upright in a circle surrounding the skull.

Though bichromatic residues are uncontroversial, and most experts are convinced by the evidence for burial, there is significant skepticism concerning the existence of ritual sites, and they are more easily explained as peculiarities of the site in which they are found (Trinkaus and Shipman 1993). An interesting perspective of this development is that all three artifact types are equally possible since they demonstrate the same unifying characteristic—the isolation or display of unaltered natural objects, i.e., for burial and body painting, the dead and living human body, respectively; for ritual sites, cave bear skeletons or human skulls. Thus, each of these artifact types—despite controversy—exactly demonstrates the predicted manifestations of the evolutionary stage of protoconceptualization.

The presence of crude bone flutes has been described in Neandertal deposits, though a consensus of archaeologists doubts their reality (Conard, Malina, and Münzel 2009; D'Errico et al 2003; D'Errico, Villa, Pinto, and Idarraga 1998). The presence of instruments in early Upper-Paleolithic Age deposits is well documented, but the Middle-Paleolithic Age evidence is meager and highly controversial. Most archaeologists believe that disturbances in thin occupation layers admixes Upper-Paleolithic-Age deposits with Neandertal remains. Music—broadly defined as production of sounds not normally created by the involved species—is found as intentional mimicry in many animals including bottle-nosed dolphins (Reiss and McCowan 1993), harbor seals (Ralls, Fiorelli, and Gish 1985), and African grey parrots (Cruikshank, Gautier, and Chappuis 1993). The intentional creation of a musical instrument would represent a qualitative departure from all other well-recognized Middle-Paleolithic-Age artifacts. The present theory would suggest that this is not possible, and the skepticism amongst archaeologists—for technical reasons related to rarity and disturbances of the excavated layers—supports this view.

Middle-Paleolithic-Age correlations

Although many fanciful meanings have been ascribed to early human burial, it most simply indicates recognition of some property of an individual that exists independent of the body. Since the category of an individual consists of a single object—the body of the individual—recognition of a property of an individual independent of the body recognizes a category's existence independent of its elements, or protoconceptualization. By identifying the minimal mental capacity capable of producing an artifact as the capacity indicated by the presence of the artifact, burial is best interpreted as an example of protoconceptualization (figure 1). The absence of burial prior to this era must mean that the body had no meaning beyond its existence as an object, which, in turn, implies that the mental capacity of protoconceptualization had not yet been achieved.

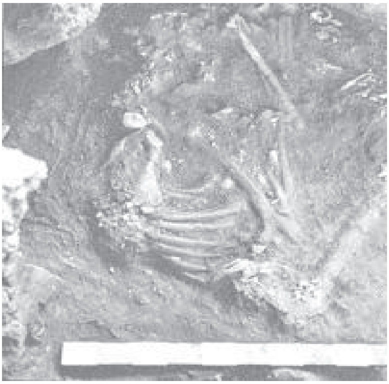

Figure 1. Neandertal burial at Shanidar cave, Iraq c. 60,000 BP. Intentional burial indicates recognition of some property of an individual independent of the body. Since the category of an individual consists of one object—the body—burial is recognition of the existence of a category independent of its member, i.e., protoconceptualization.

In the case of the living indivdual, the situation is slightly more complex. Since a protoconcept must be a member of the category it represents, only the physical body can act as the protoconcept for the human self. In this unique case, both the subject—the proto-I—and the object—“me”—reside in the body of the individual. Distinguishing the two necessitates isolating or displaying the object that is “me,” as with any other protoconcept. The presence of dichromatic pigments in Middle-Paleolithic-Age deposits is thought to indicate that Neandertal man practiced body painting and the coloring of crude fur clothing. These are the most elementary methods of differentiating the proto-I from its object, thereby recognizing the subject’s existence.

Protoconceptualization also is the minimal mental capacity necessary to explain cave-bear and human skull ritual sites—should they exist. In this case the isolation and display of an unaltered naturally occurring object—cave-bear skeletons and human skulls— demonstrates the recognition of a category of cave bears and humans independent of any particular bear or person—*prima facie* evidence of protoconceptualization.

In summary, the innovations of the Middle-Paleolithic Age (i.e., crude bichromatic decoration, human burial, and ritual sites devoted to cave-bear skeletons and human skulls) are all naturally explained by protoconceptualization, and the appearance of protoconceptualization would predict such artifacts. These innovations demonstrate that categories of objects have achieved an independent existence from any member of the category. Evidence for this change is found in the obvious new meaning assigned to unaltered natural objects beyond their purely objective existence. It is not relevant if all, or only some, of the innovations described can be validated. Rather, the mental capacity necessary to produce all of these artifacts is the same and therefore they are potential products of the Neandertal mind. The presence of these artifacts implies mental development at least to the level of protoconceptualization. By assuming that stages of mental evolution are expressed as soon as they appear, the Middle-Paleolithic Age can be termed the Age of Protoconceptualization.

Upper-Paleolithic Age

The beginning of the Upper-Paleolithic Age is heralded by the ascendancy of *Homo sapiens sapiens* and can be conveniently divided into the Aurignacian, Solutrean, and Magdalenian eras. Although these terms refer to well-defined tool industries, they are used in this paper in a less rigorous manner, i.e., as synonyms for early, middle, and late Upper-Paleolithic Ages, respectively. The artifacts of the Upper-Paleolithic Age sequentially demonstrate reproductions of recognizable objects in a physical medium, progressing from unitary representations (contingent concept-space) to compositions (independent concept-space). This identifies the Upper-Paleolithic Age as the Age of Conceptualization.

Upper-Paleothic-Age archaeology

The Upper-Paleolithic Age is when physically modern humans began developing modern mental capacities. Nonutilitarian artifacts of the Upper-Paleolithic Age can be classified in five categories. In approximate order of their appearance the categories are; personal ornamentation, statuettes, block engraving and block painting, discrete cave-wall images, and compositional representations in cave paintings and in portable engravings such as late examples of bâtons de commandement and spear-throwers. These five artifact categories can be conveniently grouped in two broad classes—personal ornamentation (Marshack 1972); and statuettes, paintings, and engravings (Rieck 1934). The bone flutes mentioned above are also found in Upper-Paleolithic-Age deposits. Though their intentional construction indicates a novel mental capacity, their exact conceptual explanation is problematic due to the less concrete nature of music and its appreciation.

Personal ornamentation is the most consistently encountered, and most numerous, of early Upper-Paleolithic Age remains. Ornaments are first identified in the Chatelperronian culture, a transitional industry, but are most widespread beginning with the Aurignacian industry (Marshack 1972). In number, diversity, and complexity the ornaments provide a marked contrast with the meager and crude decorations found in the Middle-Paleolithic Age. The types of ornamentation include beads of pierced animal teeth, shells, and fossils, as well as some amber. See, for example, Leroi-Gourhan (1961) and Hahn (1972). Ochre blocks were heated to produce a range of colors, and perforation of these blocks implies the use of tattoos (Péquart and Péquart 1960).

The Aurignacian culture produced block engravings and statuettes (Rieck 1934), including Central European and Russian "Venus" statuettes (Delporte 1979). The engravings are rudimentary and demonstrate superposition of images and negligent treatment of the final product. The largest concentration of engraved blocks is at La Marche (Pales 1976) with similar engravings found at Limeuil (Capitan and Bouyssonie 1924).

The Solutrean era, or middle Upper-Paleolithic Age, was a short-lived civilization whose most important contributions are the eyed-sewing needle, the bow and arrow, and the ornamental laurel-point blades (Pfeiffer 1972). Personal ornamentation continues with characteristic Solutrean emphasis, as does the Aurignacian palimpsest engraving and painting, as well as careless treatment of these artifacts.

The Magdalenian, or final, era of the Upper-Paleolithic Age produced the largest number and variety of nonutilitarian artifacts, and may be divided typologically into three phases. The early part of the Magdalenian era is continuous with Solutrean and Aurignacian cultures in terms of both engraving and painting, although with substantially increased production. In the middle portion of the Magdalenian era unitary cave-wall decoration appears, equivalent to the engravings and paintings of the early phase. The animals are the same representations previously encountered in block art and statuettes. Abstract signs are found in miniature art and in block art, but are most common in cave-wall decorations. Geometric signs include dots; barbs, harpoons, or hooks; triangular, quadrilateral, or pentagonal signs cleaved by a vertical median line; and other broad or narrow designs. These designs are displayed separately, juxtaposed to animal images, or superimposed on animal images. Superimposed signs are most often 'v'-shaped with or without a central shaft, and have been traditionally interpreted as representing wounds. The percentage of the 'wounded' animals is only 4% of total animals displayed, but shows marked regional variability, for example, the total reaches 25% at the cave of Niaux (Leroi-Gourhan 1982). Anthropomorphs are also first found in the middle Magdalenian phase and are equally distributed between block art and cave-wall paintings (Leroi-Gourhan 1982). These are not common in cave art, with only about 150 total examples. There are few realistic human images in the Paleolithic Age, which contrasts sharply with extremely realistic renderings of Paleolithic-Age fauna. Most anthropomorphs are distorted in some way. A few are distorted animals, and a few distorted men, but most are part human-part animal composites. The sorcerer of Les Trois Frères is probably the most famous of these examples, and consists of human limbs, owl's face, horse's tail, and reindeer's antlers (Breuil 1979). Other similar human forms include a humanoid with the head and tail of a bison from Le Gabillou and one with deer antlers and tail from Lourdes (Leroi-Gourhan 1982). Several images are also found with tails extending from the shoulders in place of a head. These are located at Hornos de la Peña, Pech-Merle, and Pergouset (Leroi-Gourhan 1982). Human distortions are also found with marked prognathism and other facial distortions.

The typologic peak of the Magdalenian era reveals two important developments. The deliberate surmounting of obstacles apparently played a significant part in late Magdalenian cave painting (Sieveking 1979; Pfeiffer 1972). Artists often chose surfaces that were extremely difficult and inconvenient where they would be forced to work in uncomfortable and awkward positions. Most known examples of cave painting are in dark areas that had to be artificially illuminated, and nearly all the latest examples add a prominent element of inaccessibility to the dark location. For example, the most impressive Niaux reproductions begin more than 600 yards within the cave, and could only be reached after traversing a long and difficult arch-shaped tunnel. The cave paintings are scattered throughout the unlit portion of the cave, ending more than 1200 yards from daylight (Breuil 1979). In addition, paintings show a compositional character with very similar themes throughout the distribution of the decorated caves. The compositional nature of the cave paintings was first noted by André Leroi-Gourhan (Leroi-Gourhan 1968b). Although there has been considerable argument concerning both his statistical analysis and his interpretation of the compositions, he makes a convincing argument about the similarity of form and content in Magdalenian deep-cave art (Stevens 1975; Parkington 1969). The compositional nature of deep-cave painting has the support of two other factors. It is indirectly supported by the compositional nature of the coeval parietal engravings, indicating that true composition was present in this era. A simple compositional stage is also the logical preliminary step to complex compositions such as those found at Lascaux (Campbell 1986).

The final innovation of the late Magdalenian era was compositional engraving. These are portable bone carvings that demonstrate multiple, non-superimposed images whose similarity in theme strongly suggests a unified meaning (Marshack 1970a).

In summary, the major innovations of the Upper-Paleolithic Age, in typologic, and approximate temporal, sequence are personal ornamentation, animal statuettes and block engraving, superimposed cave-wall engraving and painting, engraved and painted composite beings, compositional paintings of the deep caves and compositional engravings. Though individual explanations of these artifacts will be presented, it is important to recognize that it is only the progression from unitary representations to compositional representations that is directly predicted by the theory of mental evolution.

The Magdalenian era also witnessed a rapid and substantial increase in population with new and more distant sites being occupied, yet the end of the era was sudden. An abrupt change in climate may have precipitated the cultural demise, but this cannot be the entire explanation as similar climatic changes had occurred throughout the Upper-Paleolithic Age without such dramatic social consequences. (Pfeiffer 1972) The disappearance of cave painting, and other sophisticated and complex Upper-Paleolithic-Age artifacts, is thought by some to be the result of a Mesolithic dark age where nonutilitarian artifacts are of poor quality, mainly limited to abstract designs (de Sonneville-Bordes 1979; Milisaukas 1978). In contrast, rapid and revolutionary transition to agriculture and animal domestication characterize the utilitarian aspects of the Mesolithic Age. An explanation of this apparent paradox is suggested by the present theory of mental evolution—no decline in mental development, or expression, occurred at the end of the Magdalenian era, but rather a developmental breakthrough that resulted in the function of the engravings and cave paintings becoming obsolete.

Upper-Paleolithic-Age correlations

From its onset, the Upper-Paleolithic Age demonstrates a prominent increase in the diversity and number of nonutilitarian artifacts, and this process continues unabated until the Mesolithic Age where essentially all of these artifacts disappear. The current theory attempts to explain the abstract mental capacity that is indicated by the appearance of these nonutilitarian artifacts. It cannot explain the detailed thought processes involved in the production of each specific artifact. So, for example, the Venus statuettes are single, recognizable reproductions whose characteristics are assembled in a physical concept-space and therefore clear examples of contingent conceptualization by this definition. What exactly these statuettes meant to early Upper-Paleolithic-Age humans is indeterminant and not relevant. Similarly, the abstract symbols found in some cave wall paintings are consistent with a conceptual explanation, though it is impossible to interpret them. These differ from other examples of contingent conceptualization in that they are not immediately recognizable, but presumably they were to the humans who produced them. Though some speculative ideas are presented as possible explanations of these classes of artifacts a specific explanation is not necessary.

Personal ornamentation

The appearance of personal ornamentation provides artifactual evidence of the existence of a concept—the definition of a category. The concept here is the subject "I," and the natural choice for its physical concept-space is the body. In all other cases, a true concept is easily separable from a protoconcept of the same category, since the latter is a member of a category, and the former is a reproduction in a different medium. In this case, however, as with the protoconcept "I" and the category "me" at the stage of protoconceptualization, subject and object coexist in the body, and a way must be found to distinguish them. As body painting provided this differentiation at the prior evolutionary stage, personal ornamentation differentiates the concept "I" from the object "me" at this higher level of mental functioning. The only way to distinguish the protoconcept and concept of an individual is the sophistication or complexity of the body's decoration. The multicolored tattoos and vast array of personal ornaments that characterize the archaeologic record of the Upper-Paleolithic Age contrast strongly with the dichromatic body painting and dyeing of skins associated with the Middle-Paleolithic Age. This advance provides evidence of the mental evolution from recognition of the category of an individual to its definition.

Statuettes, paintings, and block engraving

Statuettes, paintings, and engravings are discrete, easily recognizable objects reproduced in a physical medium (figure 2). These characteristics are precisely the predicted consequences of conceptualization in a contingent concept-space and are *prima facie* evidence of the mental capacity of conceptualization.

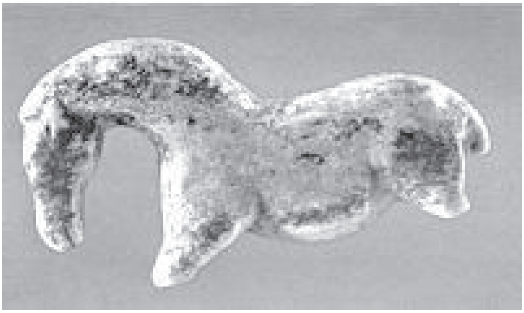

Figure 2. Vogelherd horse. Vogelherd, Germany, c. 35,000 BP. The sculpture of a horse must contain adequate attributes to define a horse because it is seen as one. The minimal mental capacity indicated is contingent conceptualization, in which the concept-space—the carved ivory—and the concept "horse" are inseparable.

Specific characteristics of images produced on cave walls and engraved in stone blocks provide additional support for the conceptual nature of early Upper-Paleolithic-Age reproductions. Discrete cave paintings and block engravings nearly universally demonstrate superposition of images, often to the point of complete obfuscation (Capitan and Bouyssonie 1924). In addition, many block engravings were broken and tossed aside, apparently used for paving or building, like any other stone (Pales 1976). It seems likely that these creations would have been more carefully preserved if humans capable of abstract thought had produced them with an artistic purpose. A more probable explanation is that the paintings and engravings function as concepts inhabiting discrete concept-spaces. These artifacts can be compared with notes that are written at a particular time for a particular purpose. They can then be thrown away or overwritten, with only the last message having any meaning.

Discrete cave-wall decorations demonstrate the palimpsest effect seen in block art, with the subjects of the decorations being animals, geometric forms, anthropomorphs, and animal-man composite monsters. The animals can be interpreted as the same simple concepts encountered in other discrete reproductions. Abstract signs may be concepts without physical attributes where a naturalistic representation is not possible—some examples might be storms, Spring, earthquake, etc. Superimposed "wound" signs may be used to emphasize a particular attribute of the animal on which they occur. More frequent occurrence of "wound" signs in advanced cave art suggests that signs may be used to increase the '"ocabulary" of simple concept images.

The fact that nearly all monstrous decorations are humanoid anthropomorphs suggests that the concept to be defined includes attributes of humanity. These composite images may be an attempt to emphasize or combine important attributes of an individual while restricted to a contingent concept-space. Such emphasis cannot be very complex due to the limitations of a single image. It may have been this limitation imposed on increasing mental capacity that forced recognition of an independent physical concept-space consisting of the entire cave wall where many concepts could be combined in a composite image.

Compositional reproductions

The appearance of carved and painted compositional reproductions characterize the final phase of the Upper- Paleolithic Age (Stevens 1975; Leroi-Gourhan 1968a). This achievement is the necessary and sufficient predicted consequence of the emergence of an independent physical concept-space (Figure 3).

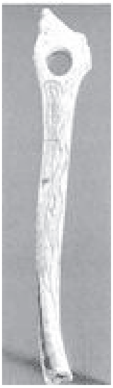

Figure 3. The Bâton of Montgaudier. Montgaudier, France, c. 12,000 BP. This compositional carving contains multiple animals that are seen in the Spring (Marshack, 1970a). The minimal mental capacity indicated by a compositional reproduction is the recognition of a concept-space independent of any particular concept.

Summary of Upper-Paleolithic-Age correlations

In summary, artifactual classes appearing in the Upper-Paleolithic Age are naturally explained by conceptualization, and the present theory of mental evolution would suggest that the appearance of conceptualization must be accompanied by some such artifacts. Personal ornamentation and discrete reproductions are *prima facie* evidence of this process where the concept, and the space where it is assembled, are inseparable. The advance from discrete reproductions to a compositional stage is explained as a further generalization recognizing that a concept-space exists independent of any particular concept. In fact, an independent physical concept-space is necessary and sufficient for composition to exist. The recognition of the contingent and independent physical concept-spaces in the Upper-Paleolithic Age label this era the Age of Conceptualization.

Mesolithic-Age Archaeology and Correlations

At the end of the Paleolithic Age and beginning of the Mesolithic Age—approximately 12,000 years ago—all forms of naturalistic reproductions abruptly disappear (Milisauskas 1978). Simultaneously, the domestication of plants and animals (Bailey and Spikins 2008) and the rise of cities (Düring 2011) begin to appear and provide evidence of rapidly advancing mental capacity. According to this theory, language—as the expression of abstract concepts—also appeared at this time. The disappearance of Paleolithic "art" has been difficult to reconcile with the rapid advance of material culture in the Mesolithic Age, since art is often considered to be the epitome of cultural expression. This theory offers an explanation. Paleolithic "art" disappeared because it did not function as art. Rather, it served as the increasingly complex expression of concepts in an evolving physical concept-space whose role became immediately obsolete with the appearance of language (Table 1).

EPOCH	HOMINID	STAGE OF MENTAL EVOLUTION	PREDICTED /ACTUAL UNIFYING TRAIT	NONUTILITARIAN ARTIFACTS
PALEOLITHIC AGE				
LOWER **c. 2,000,000-c. 100,000 BP**	*Homo habilis* *Homo erectus*	Categorization	None	None
MIDDLE **c. 100,000-c. 40,000 BP**	*Homo sapiens neanderthalensis*	Protoconceptualization	Naturally occurring objects isolated or displayed	Burial Ritual sites Body painting, skin dyeing
EARLY UPPER **c. 40,000-c. 17,000 BP**	*Homo sapiens sapiens*	Conceptualization in a contingent physical concept-space	Discrete, recognizable reproductions of natural objects	Statuettes Cave paintings and engraving Personal ornamentation
LATE UPPER **c. 15,000-c. 12,000 BP**	*Homo sapiens sapiens*	Conceptualization in an independent physical concept-space	Composition	Carved and painted compositions
MESOLITHIC AGE **c. 12,000-c. 8,000 BP**	*Homo sapiens sapiens*	Conceptualization in an abstract concept-space	Disappearance of naturalistic reproductions	No naturalistic reproductions

Table 1. The archaeology of mental evolution

Conclusion

This investigation has three significant results—one theoretical and two applied. The former is the comprehensive structure suggested for mental evolution that unambiguously and analytically defines mental capacities, including language. No such unambiguous definitions have been previously suggested, and no analytically defined sequence of mental capacities leading to language and consciousness has been proposed. This provides a novel basis for scientific—rather than philosophical—discourse. The analysis suggests that the development of consciousness is not the discontinuous appearance of a new capacity—unrelated to preceding mental functions—but rather an inevitable, logical consequence of an incremental and analytic sequence whose culmination in an abstract concept-space provides revolutionary capacities that are the elements of conscious thought. The contrast with philosophical discussions of consciousness could not be more stark.

The applied significances are reciprocal consequences resulting from the exact correlation of predicted and actual artifacts. The theory's definitions—when tied to archaeology—explain the artifactual record of the Paleolithic Age, and simultaneously, archaeology provides a datable chronology for the stages of mental evolution.

The definitions of mental capacities in the sequential levels of mental evolution provide a unique interpretation of the meaning and sequence of early human nonutilitarian artifacts. Although many explanations for individual artifacts or artifact classes have been offered, no coherent hypothesis for their chronological sequence in the Paleolithic Age currently exists (Bahn 2012; Blum 2011; Conkey 2010; Davidson and Noble 1989; Halverson 1987; Marshack 1972). The theory also explains the abrupt disappearance of the spectacular "art" of the Paleolithic Age with the rapid advance of other aspects of material culture.

The theory's definitions—once tied to an archaelogical chronology—establish a temporal origin of consciousness and language independent of any philosophical or linguistic assumptions or prejudices. Though the conclusions are heterodox, they are validated consequences of a previously nonexistent comprehensive theory that provides—at a minimum—an unambiguous basis for disagreement. Although other theories posit a late origin of langauge and consciousness, none is based on an analytically defined process of mental evolution (Jaynes 1976). This theory suggests that modern mental capacities evolved more than 100,000 years after physically modern humans; 30,000 years after their ascendancy in the Upper-Paleolithic Age; and that language appeared approximately 12,000 years ago. It thus implies that, while consciousness and language are the *sine qua non* of humanity, they were not coincident with the evolution of *Homo sapiens sapiens*.

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Chapter IV

Limits of Knowledge

A. Language and the Limits of Historical and Scientific Knowledge[117]

Abstract: The purpose of this paper is to suggest that subtle and essential uncertainties in language determine the limits of science and history and thereby define the boundaries of research in the history of science. Historical research, in the strict sense of *history* as opposed to *pre-history*, begins with examination of written records. There is a host of problems in the interpretation of the historical record, but underlying all of these is the simply stated yet complex question of the meaning of words in historical documents. Since this is where the practice of history begins, this problem delimits the boundaries of historical knowledge. In this paper I will examine structural ambiguities in the meaning of words, explain how they arise, and provide independent evidence for the validity of the analysis.

Introduction

The goal of this workshop is to provide some guidance for the reading and writing of the history of neuroscience. My contribution to this endeavor will be to investigate an obvious but critical stage in the practice of the history of any science. That is, I will examine the meaning of words and symbols in scientific and historical documents and thereby identify limits to what can be accomplished in historical investigations. Though not essential for day-to-day work, this global perspective should be reflected in the way an investigator approaches any historical problem. But there is another reason for considering this topic and this constitutes the second part of my presentation. The difficulties in interpretation that appear in an historical context are actually problems inherent in language itself. They not only

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[117] This article was published in the Journal of the History of the Neurosciences 2001;11(1): 49-55.

impose limits on the practice of history, but also establish boundaries to what can be expressed in any form. These constraints have consequences for the nature of science and history, the possibility of a final scientific theory and a single correct history. This demonstrates a relevance of historiographic studies for modern scientific discourse that is not commonly recognized.

Materials and Methods

There are many difficulties in the interpretation of the historical record, but underlying all of them is the primary problem of the meaning of words and symbols in historical and scientific documents. Since the communication of knowledge requires words and symbols, any lack of precision at this fundamental level will determine limits to what ultimately can be expressed. I will use an example of the Babylonian term for epilepsy to illustrate this problem, and trace its origin to the nature of language itself - whether historic or modern, and whether poetry, prose, history, or the most abstract symbolic languages of physics and mathematics. In this paper I will examine the structural ambiguities in the meaning of words and symbols, explain how they arise, and provide independent evidence for the validity of the analysis. I hope to convince you that the subtle, yet essential uncertainties in language that complicate the interpretation of historical documents have consequences that also determine the limits of science and history.

Before I begin, however, I want to clarify two general aspects of this presentation beginning with a comment on nomenclature. History and science are determined by the meaning of words and symbols that refer to observable natural events and so for the purpose of this analysis I will use *history* and *science* interchangeably, as well as the terms *word*, *symbol*, and *concept* that describe these natural events. Second, it may seem that this topic is more appropriate for philosophy than science or history. I will illustrate why this is not the case by one variant of a favorite story of the most famous 20th century resident of Copenhagen, Niels Bohr. He used to differentiate a scientist from a philosopher in the following manner. A scientist begins by knowing a little about something, and learns more and more about less and less until finally he knows everything about nothing. A philosopher on the other hand, starts out knowing a little about something and learns less and less about more and more until finally he knows nothing about everything.[118] Since I intend to discuss a lot about almost nothing, this is science, not philosophy.

So, how do we know what the words or symbols of an historical document mean? It may seem that by choosing to write about the history of a science we have at least solved one major potential problem. That is, natural science begins with the observation of recurrent natural events. Thus, for example, when in Article 278 of the code of Hammurabi, the word *bennu* is used for a disease that may be epilepsy, we know what is referred to because we also can observe epilepsy.[119]

Presumably the sensory data received by an observer of a seizure is the same for a Babylonian or a modern neurologist, but the meaning of words used to describe a natural event are more a result of perception than reception. The meaning of the Babylonian word, *bennu*, is formed by an observation filtered through the entire social and cultural context that influences its perception. Every aspect of Babylonian life, from notions of the nature of health and disease, to religious and social structures including hierarchy and kinship, affects it. In other words, the meaning of *bennu* is determined by filtering an extrinsic recurrent natural event, epilepsy, through the Babylonian model of the world. Though portions of this model can be discovered, and in fact this is an important goal of historical research, it is clearly not possible to know the entire context of Babylonian life constituting that model of the world. Therefore it is not possible, in principle, to know the complete meaning of the Babylonian word *bennu*. You might say, so what? Epilepsy is epilepsy and what we cannot know is small compared to the commonalities of an observed seizure, and even this small amount can be reduced by further study. However, as we shall see, the magnitude of the uncertainty is less relevant than the fact that the ambiguity illustrated in this particular case is a structural feature of language.

To see this process more clearly, picture a series of identical objects, say some identical Steiff stuffed zebras, and place each one in front of a separate distorting fun house mirror, each mirror different from all others. All

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[118] A more traditional version of this story differentiating an expert and a philosopher can be found in Pais (Pais, 1991, p. 421).

[119] *Bennu* appears to be the Babylonian generic term for epilepsy. It is first encountered in the code of Hammurabi from the early 18th century BCE (Sigerist, 1951, p. 398) where conditions for the return of a slave with this affliction are enumerated. A medical text from c. 1067-1046 BCE known as *Sakkiku* describes in some detail various types of epilepsy and their diagnostic significance. Translation of the relevant tablets was published in 1990 (Kinnear Wilson & Reynolds, 1990). An exhaustive analysis of epilepsy in Babylonia can be found in Stol (Stol, 1993).

reflected images of the stuffed zebras are distorted differently, but each can be recognized as a stuffed zebra, and the more closely one mirror resembles another, the more similar will be the two resulting images. Additionally, since all mirrors distort the zebra in some way, the true nature of the stuffed zebra cannot be reconstructed from any or all of the reflected images. I claim that a similar process occurs with the meaning of words and symbols in the history of science. The stuffed zebras represent a recurrent natural event, the distorting mirror is the model of the world shared by a particular society, and the image seen in the mirror is the meaning of the word describing the natural event in that society. Just as in the analogy, the words used in different societies will recognizably specify the same recurrent natural event and will be more closely alike the more two societies resemble each other. But also like the analogy, all meanings are distorted in an indeterminate manner by the entire societal context that influences their perception.

There are two important consequences of this fact. First, our observation of a recurrent natural event does not give us enough information to completely determine the meaning of the word describing the same event in another society. And second, since all observations are distorted, no word or symbol used to describe a natural event completely and precisely describes it.

To summarize thus far, the word or symbol denoting any recurrent natural event specifies more information than the simple sensory data. The information is modified and expanded by multifarious contextual associations and interpretations characteristic of the society in which the observation occurs. In this sense, the meaning of the word overspecifies the observation. For example, the meaning of the Babylonian word, *bennu*, consists of the Babylonian associations and context evoked by the observed seizure.

My perspective so far has been from the outside in, i.e., understanding the meaning of a word from outside the society. I would now like to turn to a different perspective to investigate how the meaning of a word used by a society is generated from the individuals that comprise it, i.e., from the inside out.

Societies are composed of individuals, and each individual also possesses his own model of the world. No two people have the same collection of experiential or contextual components for the meaning of any given word. For example, though the English word *epilepsy* labels a particular disease, each individual's complete definition of epilepsy depends on the whole set of his unique experiences and associations. If this is so, then what does the word *epilepsy* actually mean? It must have a consensual definition. That is, the meaning of the word *epilepsy* is formed by the intersection of all individuals' unique associations that form their personal definitions of epilepsy. Since a society shares a great deal of context, two members of a society will share a more complex idea of epilepsy then would either person with a member of a different society. And, of course, the society of neurologists will share an even more complex definition. But since the meaning of the word *epilepsy* consists of the common features shared by a group of individuals, this exact meaning does not exist for any single member of the group. Each individual has experiences and associations with epilepsy that are not part of the group definition. In this sense, the meaning of a word used by a society underspecifies any individual's definition.

Returning to the Babylonian *bennu*, every Babylonian had a different set of associations and experiences with epilepsy and the Babylonian meaning of the term consists of the common elements. Since this is a smaller collection than of any single individual, the Babylonian definition underspecifies any individual's definition.

In summary, by looking at the meaning of the Babylonian word, *bennu*, we have found three interrelated characteristics of any word or symbol in any language. First, it cannot be known completely. Second, it overspecifies the observation, containing contextual elements unique to that society, and third, it underspecifies the definition of any member of that society since it consists of only the aspects common to all members. This brings us to the most important point of this essay. The meaning of a word or symbol, as it appears in a document or any other form of interpersonal communication, has a strange existence suspended between the individual and the observed world, partially reflecting extrinsic and intrinsic realities, but not accurately reflecting either. It cannot completely reflect external reality because the model of the world through which it is filtered distorts this reality, and it cannot precisely reflect the internal reality of any individual because it is restricted to only those elements held communally. It is this existence apart from the actual realities of the physical and personal worlds that imposes limits on scientific and historical knowledge.

A clear example of the difference between the meaning of words and symbols and the events they specify again may be found in the work of Niels Bohr, this time on the interpretation of the mathematical language of quantum mechanics. Bohr struggled with this problem from the first appearance of quantum mechanics in 1925 until about 1931 when he nearly resolved these issues to his own satisfaction. Aage Petersen (1963, p.12) published Bohr's mature ideas on this subject in which Bohr said, "There is no quantum world. There is only an abstract quantum physical description. It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can say about nature." In other words, the "abstract quantum physical description," that is, the mathematical language of quantum mechanics, cannot accurately describe "how nature is." Bohr tells us that the language of quantum mechanics exists in a different realm than external reality and is part of "what we can say about nature." What is true of the rigorous language of physics is even more true of natural language—we gain from language the ability to communicate with others, but the price we pay is a lack of precision in the description of external natural events.

Discussion

Even accepting that the meaning of a word or symbol does not exactly capture either the external event it describes or the personal impressions it evokes, it still may seem that this is not a big enough problem to cause undue concern. But we are now ready to explore some consequences of this subtle finding of semantic ambiguity. To begin, I will examine the independent evidence for the validity of this analysis. The details of this evidence need not be understood in order to appreciate its significance. The same ambiguity we have identified in the language of history and science is actually present in the most distilled form of human concepts, i.e., the symbols of mathematical logic. This strongly supports the notion that the problems I have discussed are not illusions or artifacts, but rather a fundamental part of the nature of any language.

In 1936, Alfred Tarski revolutionized the field of logic by providing rigorous criteria for defining the notion of truth. He states that a sentence is logically true if it is true in all models, and an argument is logically valid if the conclusion is true in every model in which the premises are true. This has become the unquestioned basis of model theory, set theory, and the rest of modern formal mathematics. His definition makes intuitive sense even without an exact definition of what is meant by a model. Relatively recently, however, it has been shown that Tarski's notion of truth is inadequate.[120] It

[120] The problem with Tarski's definition of truth identified by Etchemendy (Etchemendy, 1990) is not quite as I describe it here. He contends that no formal scheme for the definition of truth, semantic or syntactic, is adequate because the ultimate truth or falsity of a proposition is simply due to the way the world is. This implies that there is an unambiguous description of how the world is, which is exactly what I am arguing against. Therefore, I would make this statement a little more ambiguous by suggesting that truth or falsity is due to the way the world is described. Although this has no effect on Etchemendy's argument, I have not sufficiently justified its extension in what follows, and my conclusions should not be attributed to him.

overspecifies some meanings so that some things that are not true are called true, and underspecifies others so that some things that are true are called false. It turns out these inaccuracies are due to the problematic relationship of logical variables to the external events that they represent. If we interpret the word *model* in an intuitive sense to include a society's model of the world discussed above, i.e., the fun house mirror, then, as we have seen, any such model must have exactly this problem of over- and underspecification. The reason is the same—words or symbols or concepts exist in a realm apart from external and internal realities. The discovery of this problem at the foundation of mathematics supports the hypothesis of fundamental ambiguities in the structure of language. Even when reduced to their most distilled and abstract form, logical symbols suffer from an inherent vagueness because they are suspended between the external and internal worlds. Since the words and symbols of mathematics, science and history are simply specific examples of logical concepts; they inherit the same underlying ambiguity. In other words, the structural ambiguity of the most general logical concepts validates the structural ambiguity in the specific concepts of history and science. At least three important consequences arise from this fact.

First, if logical truth cannot be unambiguously defined, then surely there can be no such thing as absolute truth, since an absolute truth would necessarily be a logical truth. Therefore, proponents of an absolute truth are deranged and their proclamations should be ignored. If scrupulously followed, this path would eliminate most of the intolerance, suffering and persecution characterizing the human race. Second, and more directly relevant, the cyclically occurring pronouncements about the "end of history" and the "end of science" are prima facie absurd. These pronouncements are found at least every century and as John Horgan's (1996) recent book, appropriately titled *The End of Science* has demonstrated, we have still not learned our lesson. A final scientific or historical truth obviously cannot be ambiguous, yet any scientific or historical knowledge is expressed by words or symbols that contain an ineradicable structural ambiguity that results from the way the meanings of words relate to the external events they specify. Therefore there can be no end to science or history because no type of language, be it mathematical, scientific, historical, or natural, can express such a final truth.

Third, this fundamental ambiguity provides an interesting perspective on recent public debates about the nature of science and history.[121] One

[121] A classic example of this debate began after Alan Sokal published a parody of contextual physics (Sokal, 1996a, pp. 217-252), then revealed the hoax (Sokal,

extreme view is post-modern relativism or social constructivism, in which science and history are reduced to social constructs. In this scenario, science or history is so completely contextualized that social whim replaces historical or scientific progress. Another extreme is a form of scientific realism. Here, science is supposed to discover an objective reality completely eliminating context. From this perspective, it is only a matter of time until any scientific question has a final answer.

These two viewpoints are equally unsupportable. Social constructivism and scientific realism each focuses on only one part of the nature of the meaning of words and symbols that I have described. The words and symbols that communicate historical and scientific knowledge exist in a netherworld separate from, and inaccurately capturing, both external and internal realities. They contain both an extrinsic reality and a contextual component, but emphasizing one to the exclusion of the other is simply incorrect. There is expanding scientific and historical knowledge, but there can be no endpoint to history or science. Each era builds on the accumulated knowledge of the past, but is endowed with its own unique context. When historical events and scientific observations are filtered through this model of the world, the result is new history and new science, with the same fundamental limitations.

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CHAPTER V

NEUROLOGY AND MODERN CONSEQUENCES OF THE THEORY

A. Hughlings Jackson, Concomitance, and Mental Evolution[122]

The Victorian neurologist John Hughlings Jackson (1835-1911) created a theory of brain evolution whose explanatory power and predictive value have not been exhausted by a century of clinical observation. Hughlings Jackson strictly separated functions of the brain from those of the mind and chose psychophysical parallelism, which he called the doctrine of concomitance, as the expression of their relationship. His evolutionary analysis suggested an ordinal structure of the mind, but it could not be empirically validated, and hence he rejected it. The goal of this paper is to identify an error in Jackson's analysis, and demonstrate that when corrected, Hughlings Jackson's theory of nervous system evolution coupled with concomitance yields a theory of mental evolution that is novel and heuristic.

Diagnostic neurology became an accurate empirical science when its scope was limited to unambiguous biological questions.[123] The explicit recognition that neurophysiology is confined to consistently observable sensorimotor events, to the exclusion of variable mental events, first appeared in the theoretical system devised by the Victorian neurologist John Hughlings Jackson (1835-1911). He described an evolutionary structure of

[122] This paper was published in J Hist Neurosci 1994; 3: 169-176, and presented, in part, at the 4th European meeting of the World Federation of Neurology Research Group on the History of Neurology, Graz, Austria, 29 May 1993.

[123] Hemiparesis, paraplegia, and other signs of what we now know as neurological disease are found in ancient medical writings, beginning with the Egyptians. However, ancient, medieval, and renaissance systems of diagnostic cerebral localization conflated physical and metaphysical symptoms which compromised diagnostic accuracy. By limiting itself to purely sensorimotor physiology, neurology became a tolerably consistent diagnostic system. For more on these topics, see Stengel (1963), York and Steinberg (1993), and Riese and Hoff (1950).

the nervous system wherein the physical body is represented, re-represented, and re-re-represented, at successive functional levels.[124] A formal expression of this theory is depicted in Table 1. Nervous system evolution, as Hughlings Jackson conceived it, consists of evolutionary levels and a process of moving from level to level. Two principles underlying this theory are that stages of evolution demonstrate increasing complexity, increasing definiteness, and increasing interconnections,[125] and that higher levels exert an inhibitory control over lower levels.[126] The representational structure of brain evolution may be described as ordinal in the sense that successive levels are strictly ordered by inclusion.[127] The practical clinical consequence of this evolutionary hierarchy is that pathological states are characterized by two types of observable symptoms—positive and negative. Negative symptoms are due to loss of a higher function and positive symptoms result from release of a lower level from inhibitory control.[128] For example, in thalamic pain syndrome, sensory loss in the distal limb is the negative element while constant pain in the affected part is the positive element.

Though Hughlings Jackson limited the focus of clinical neurology to sensation and movement, he recognized the reality of mental states and mental illness. As a physician interested in diseases of the mind and body he needed to define the relationship between sensorimotor functions of the brain and functions of the mind. He considered both Cartesian dualism and the mind-brain identity theory, but settled on psychophysical parallelism, which he termed the doctrine of concomitance.[129] This doctrine has its roots

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[124] Hughlings Jackson published in a variety of Victorian medical journals. His student, James Taylor, edited a selection of his most important papers (Hughlings Jackson (1956); hereafter referred to as Selected writings). See Selected writings vol. II, pp.41-42. Also see Smith (1982b), York and Steinberg (1993).

[125] This principle was proposed by Herbert Spencer and developed more fully by Hughlings Jackson. See Selected writings II, pp.46, 80. See also Smith (1982a), York and Steinberg (1993), and Spencer (1910).

[126] "The higher nervous arrangements evolved out of those lower, and keep down those lower" Selected writings II, p.58.

[127] Ordinality of numbers is differently defined. For a simple example, see Halmos (1960) p.75. The ordering in Hughlings Jackson's evolutionary system is equally valid, however.

[128] "The symptomatology of nervous diseases is a double condition: there is a negative and a positive element in every case" Selected writings II, p.46. Also see Harrington (1987) p.206-247.

[129] Hughlings Jackson's analysis of mind-brain theories can be found in Selected writings II, pp.84-85. Also see York and Steinberg (1993), Engelhardt (1975), Elkind (1989).

in the philosophy of Leibniz, and was probably communicated to Hughlings Jackson through his teacher

PARTITION
B= {b1,b2, . . ., bn} = B0 = partition of body

REPRESENTATION
R(B)= {{b1},{b2}, . . ., {bn}} = B1

RE-REPRESENTATION
R(R(B))= {{{b1}*,{b2}, . . . , {bn}}, {{b1},{b2}*, . . . ,{bn}}, . . . ,
{{b1},{b2}, . . . , {bn}*}} = B2 = {B11, B12, . . ., B1n}
where the second index indicates the emphasized
element of the representation B1

RE-RE-REPRESENTATION
R(R(R(B)))= {B21, B22, . . ., B2n} = B3 where the second index, i,

* indicates the emphasized element of B2, i.e., B1i

Table 1: Hughlings Jackson's theory of brain evolution**.** The body, B, is first partitioned into separate parts, (b1,b2,...,bn), which are then each represented at the lowest level of evolution which is, *in toto,* the collection of these representations. At the middle level, each element consists of the entire representation, R(B), of the lowest level, with a different body part emphasized. The complete middle level consists of the collection of these representations with all parts emphasized. Each element of the highest level of evolution contains an entire copy of the middle level (re-representation) with a different element of the middle level (representation) emphasized. The system described is ordinal in the sense that each element of each level is a copy of the entire previous stage.

Thomas Laycock, who in turn was exposed to it while studying at Gottingen.[130] In one interpretation of the doctrine of concomitance, each evolutionary level of the brain has a corresponding evolutionary level of the mind.[131] Since Hughlings Jackson identified consciousness as the concomitant

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[130] See Laycock (1860) p.183, Englehardt (1975), Greenblatt (1965), Isler (1991), York and Steinberg (1993). All consider various aspects of the doctrine of concomitance.
[131] The interpretation of the doctrine of concomitance wherein each mental state has a concomitant nervous state, and vice versa, is attractive because it is symmetric and independent of any preconceived notions of brain and mind. Under such a doctrine, the complete structure of nervous system evolution (evolutionary levels and a

of the highest level of brain evolution, subconscious mental states must exist as the concomitants of the lower levels of nervous system evolution (Table 2). After a decade of consideration, however, Hughlings Jackson rejected this view. He came to believe that there were no unconscious mental states.

Why did Hughlings Jackson come to reject the consequences of his own logic? The simplest explanation is his strict empiricism and intellectual rectitude. Comments of his closest friends, and the character of his writings indicate that Hughlings Jackson maintained a strict code of intellectual honesty, and was firmly entrenched in the empiricism of his era. He was unwilling to accept any conclusion that was not demonstrable clinically.[132]

The intellectual standards of Hughlings Jackson, may, in this case, have been misapplied. A consideration of the assumptions underlying his logic reveals a possible analytical error. Hughlings Jackson assumed that the functional structure of the mind is exactly analogous to the functional structure of the brain. Applying this analogy to diseases of the nervous system, pathological states involving the loss of consciousness should be accompanied by positive mental symptoms caused by the release from inhibitory control of sub-conscious mental states. Hughlings Jackson recognized there was a problem with his analysis when he could not observe such mental states in unconscious patients. He could explain this negative result either by altering his assumed structure of the mind, or altering the doctrine of concomitance which he believed predicted that structure.[133] He

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process connecting levels) is concomitant to a complete structure of mental evolution (evolutionary levels and a process connecting levels). The doctrine of concomitance may then be seen as a bijective mapping of nervous system level to mental level, and nervous system process to mental process. Hughlings Jackson initially accepted this view, and it is the perspective of the present analysis. However, he later restricted the interpretation of concomitance to require only that every mental state has a correlative nervous state, thus being agnostic on the existence of unconscious mental states. He finally concluded that consciousness is the sole mental function, limiting concomitance to only the highest level of nervous system evolution. In his final analysis, every mental state at the highest level of evolution has a correlative nervous state, but not all brain states have a mental correlative. At the middle and lowest levels of nervous system evolution, no brain states have correlative mental states.

[132] For discussion of Hughlings Jackson's rejection of the unconscious, see York and Steinberg (1993)

[133] There is no direct evidence that Hughlings Jackson consciously considered possible explanations for the absence of positive (unconscious) mental symptoms. This may have been because he wasn't primarily interested in theorizing about the mind, or because he failed to see any alternative structures of the mind consistent with the doctrine of concomitance, or both.

followed the latter course, rejected the general interpretation of the doctrine of concomitance and restricted what he called the range of concomitance to the highest level of nervous system evolution. However, it is possible that it is not the doctrine of concomitance that incorrectly predicted the form of mental evolution, but rather an inaccurate interpretation of what concomitance implied.

Hughlings Jackson's assumption of functional identity between brain and mind may be too concrete. He thought that the doctrine of concomitance implied that mental evolution, like nervous system evolution, consisted of the process of ordinal representation of an unknown object, or substrate[134] (Table 3). But representation is only one possible ordinal function and concomitance may be considered more generally to require only a form of ordinality. Positive and negative symptoms are a consequence of ordinal representation of the physical body, but other ordinal relations may not produce observable clinical symptoms. The absence of positive mental symptoms in unconscious patients does not exclude an ordinal structure of the mind.

For a theory of mental evolution to be concomitant with Hughlings Jackson's theory of brain evolution, it must only consist of an ordinal function acting successively on a fundamental substrate (Table 4). If the brain integrates sensory input and by reflex generates a motor response, then the afferent function of the brain can be considered as reconstruction of an increasingly definite, increasingly integrated, and increasingly interconnected image of the external world.[135]

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[134] For a discussion of representation in the nervous system, see York and Steinberg (1994) and Smith (1982b).

[135] That Hughlings Jackson considered the brain to be a sensorimotor machine is clear. The history of this idea is discussed in York and Steinberg (1994).

BRAIN		*MIND*
HIGHEST LEVEL	<—— concomitance ——>	CONSCIOUSNESS
MIDDLE LEVEL	<---- concomitance(?) ---->	UNCONSCIOUS STATE 1
LOWEST LEVEL	<---- concomitance(?) ---->	UNCONSCIOUS STATE 2

Table 2: Hughlings Jackson's prediction of the unconscious. The doctrine of concomitance suggests that each level of nervous system evolution has a concomitant level of mental evolution. Since Hughlings Jackson identified the concomitant of the highest level of nervous system evolution as consciousness, this implied that the lower levels must have subconscious, or unconscious, concomitants.

BRAIN EVOLUTION	*MENTAL EVOLUTION*
$R(B), R^2(B), R^3(B)$	$R(X), R^2(X), R^3(X)$
where, R = representation B = body	where R = representation X = some object

Table 3: Hughlings Jackson's mental evolution. Hughlings Jackson believed that the doctrine of concomitance implied that mental evolution, like nervous system evolution, must consist of a process of representation of an unknown object, analogous to the body. When his clinical observations did not support such a structure, he rejected the existence of the unconscious.

BRAIN EVOLUTION	*MENTAL EVOLUTION*
$R(B), R^2(B), R^3(B)$	$G(X), G^2(X), G^3(X)$
where R = representation B = body	where G = some ordinal function X = some object

Table 4: Mental evolution generalized. By interpreting the doctrine of concomitance in a slightly more general manner, it can be seen to require only that mental evolution consist of an ordinal function, like representation, acting on some object or substrate.

In theory, the function of the mind is to interpret these images, and therefore reconstructed images are assumed to be the substrate of mental evolution in the same way that the body is the substrate of brain evolution. The function in the mind that is the concomitant of representation in the nervous system must therefore interpret internal images by producing an ordinal hierarchy that will be identified with mental states, providing their definitions. In this manner, an ordinal process of internal interpretation of reconstructed images is concomitant with the brain's ordinal representations of the body.

Intuitively, increasing mental capacity may be seen as an increasing ability to generalize, or to identify equivalences. We therefore propose that the functional analog of representation is generalization. That is, as the body is represented and re-represented in the brain, so elements of internal images are generalized and re-generalized in the mind.

The most elementary constituent of an internal image is an object, and thus the analog of a partition of the body in brain evolution is a partition of internal images into separate objects. Mental evolution then proceeds so that each step represents an equivalence identified in the preceding stage. First categories of similar objects are recognized (categorization).[136] This is concomitant to representation of the body in Hughlings Jackson's lowest level of brain evolution. Second, the equivalence forming a category is defined (conceptualization).[137] This step is concomitant to the re-representation of the body in Hughlings Jackson's middle level of brain evolution. Individual definitions must exist somewhere—a place we will call the concept-space. The formation of an abstract concept-space is

[136] For example, a category of horse is recognized by an individual based on the observed similarities of previously encountered horses. Functionally, a newly encountered object (a horse) is recognized as a member of this category, and can therefore be counted on to demonstrate the same characteristics as other horses. Subcategories can also be recognized as similarities in separate object categories—for example recognition of a similarity in horse and dog categories leads to recognition of a subcategory of tail. Note that subcategorization is identical to recognition of fine detail and that the more basic a detail, the larger is its equivalence class (e.g., the equivalence class of 'tail' contains all object categories that have a tail). A threshold is reached when enough fine detail is recognized to unambiguously specify the equivalence of routinely encountered object categories. The special recognized categories that uniquely decompose these object categories we call attributes.

[137] A definition of a category's equivalence is a weighted collection of attributes. Definition of the category's equivalence is the same as specifying the category independent of its members.

defined as consciousness and corresponds to Hughlings Jackson's highest level of brain evolution.[138]

In summary, a concomitant relation of brain and mind demands that mental evolution be described by three successive actions of an ordinal function on a fundamental substrate. A formal structure for mental evolution can be generated by defining the fundamental substrate of the mind as internally reconstructed images of the external world, and the function acting on this substrate as generalizing the elements of these images. A concomitant theory of mental evolution is thereby produced as shown graphically in Table 5.

BRAIN	*CONCOMITANCE*	*MIND*
Highest level	<———>	Consciousness
Middle level	<———>	Conceptualization
Lowest level	<———>	Categorization
Partition of body	<———>	Partition of internal image into objects

Table 5: Concomitance and mental evolution. By defining the substrate of mental evolution as internal images of the external world, and by identifying the ordinal function as generalizing elements of these images, an heuristic theory of mental evolution is obtained. In this schema, internal images are first partitioned into separate objects, analogous to the partition of the body in nervous system evolution. Collections of similar objects are then recognized (categorization), concomitant to representation of the body. The equivalence relation underlying categorization is then defined (conceptualization), concomitant to re-representation. A concept is a collection, which is collected in a concept-space (see footnotes 13 and 14). We define the formation of an abstract concept-space as consciousness, concomitant to the highest level of nervous system evolution.

[138] Other concept-spaces can be identified in the phylogeny of mental evolution. For example, the appearance of miniature carvings in the early Upper-Paleolithic Age is evidence of conceptualization by this definition, with the stone being a physical concept-space wherein the attributes of the carved animal are brought together. That the category of the animal is adequately specified by the carving is demonstrated by its recognizability.

Conclusion

By distinguishing sensorimotor functions from the ambiguous and subjective aspects of mental function Hughlings Jackson laid the groundwork for a consistent and accurate scientific discipline. To account for the mind-brain relation he used a doctrine of concomitance whose application to his theory of brain evolution yielded a potential structure for the mind. This structure predicted certain clinical events in unconscious patients. When he failed to observe these events, Hughlings Jackson rejected the logical consequences of his own ideas.

We believe this rejection was based on an analytic error. A more general interpretation of concomitance yields a theory of mental evolution that is consistent with Hughlings Jackson's approach and has heuristic consequences.[139] A direct result of this analysis is that brain and mind can be viewed as strictly related ordinal structures, and hence may both be considered manifestations of a more fundamental unitary process. That is, they are complementary.[140]

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[139] The theory here described, when applied to the archaeology of human phylogeny, yields a consistent interpretation of the sequential appearance and individual meaning of Paleolithic-Age nonutilitarian artifacts. The analytic nature of the definitions of mental states also diminishes ambiguity in the statement and discussion of traditional problems in the philosophy of mind.

[140] The idea of complementarity as a philosophical principle was enunciated by Niels Bohr. For a discussion of the potential applicability of complementarity, see Bohr (1928).

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B. The Origin of Scientific Neurology and its Consequences for Modern and Future Neuroscience[141]

Abstract: John Hughlings Jackson (1835-1911) created a science of brain function that, in scope and profundity, is among the great scientific discoveries of the nineteenth century. It is interesting that the magnitude of his achievement is not completely recognized even among his ardent admirers. Although the clinical applications of his science are utilized every day by thousands of practitioners around the world, the principles from which bedside neurology is derived have broader consequences—for modern and future science—that remain unrecognized and unexploited. This paper summarizes the scientific formalism that created modern neurology, demonstrates how its direct implications affect a current area of neuroscientific research, and indicates how Hughlings Jackson's ideas form a path toward a novel solution for an important open problem of the brain and mind.

Introduction

The antecedents of most modern medical disciplines—including neurology—can be retrospectively traced for thousands of years to the earliest historical civilizations (Sigerist, 1951; Temkin, 1971). Though it is impossible to know how the originators of these ancient ideas viewed them (Steinberg, 2001), from our present perspective, it is possible to recognize some elements of current notions in these mixed magical/religious, philosophical, and empirical structures. Most would agree that the neurological concepts of early Egypt and Mesopotamia were not fully scientific—and modern neurology is—so, at some intervening stage, neurology became a science. The demarcation between pre-scientific and scientific systems can be drawn at any point in this extended development depending solely on a preferred definition of science. As long as the utilized definition is explicit and unambiguous, any such choice is defensible, and can be judged by its heuristic value. For the present purposes, a science will be defined as a circumscribed body of knowledge that is organized by a reproducibly testable and predictive theory containing explicit axioms and methods. This definition is unambiguous and encompasses a commonalty of most modern sciences. By these criteria, the science of neurology began with John Hughlings Jackson—his circumscribed body of knowledge is the human nervous system, his tripartite method is explicit, his axiom is that the

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nervous system is exclusively sensorimotor, and his reproducibly testable and predictive theory is weighted ordinal representation. This identification does not in any way denigrate nor minimize the contributions of the many whose work preceded—and formed an essential basis—for Hughlings Jackson's ideas. Classifying the neurological model in which their work occurred as pre-scientific does not reflect on any aspect of their insights or discoveries, but only acknowledges that all elements of a science—as here defined—had not yet coalesced. For example, the accomplishments of Nicholaus Copernicus (1473-1543) and Galileo Galilei (1564-1642) are not diminished in significance, though, according to this definition, the science of physics began with Isaac Newton (1643-1727). It is not the individual's work that is pre-scientific, it is a retrospective evaluation of the context in which this work transpired. The identical research could occur within either a pre-scientific or scientific model. This type of analysis identifies the origins of modern ideas, and therefore is intrinsically anachronistic. Its utility is scientific and heuristic, not historical.

Hughlings Jackson's creation of a science of the brain remains one of the great intellectual accomplishments of the nineteenth century, and one whose implications have even yet been incompletely exploited. This paper will explore the origin of his neuroscience, identify an unrecognized modern consequence, and indicate how his ideas can yield a potential resolution of a currently open question.

The Science of Neurology

Hughlings Jackson's Tripartite Method

Hughlings Jackson began his exclusive focus on diseases of the nervous system in the early 1860s, probably at the suggestion of Charles-Édouard Brown-Séquard (1817-1894) (Hutchison, 1911). At this time there was no specialty of neurology, and, as Hughlings Jackson immediately recognized, there was also no conceptual framework for the study of diseases of the nervous system (Hughlings Jackson, 1863a). By June of 1864 he had developed a methodology for investigating neurological disease and along the way he had discovered several important ideas that would form part of his neuroscience (Hughlings Jackson, 1864).

In 1859, Hughlings Jackson joined his fellow Yorkshireman Jonathan Hutchinson (1828-1913) in London, and soon formed a lifelong friendship. First Hutchinson, and then Hughlings Jackson, became reporters for the Medical Times and Gazette—a weekly London medical journal. From the issue of 19 January 1861 the column titled "Reports of medical and surgical practice," carried their joint byline (Hutchinson and Hughlings Jackson, 1861). As a medical reporter, Hughlings Jackson attended lectures by Brown-Séquard and was familiar with his method of pre- and postmortem case analysis. This analysis utilized what may be called the phrenological assumption whereby the nervous system is assumed to consist of anatomically discrete units, each with specific function. Acknowledging the utility of the phrenological assumption, Hughlings Jackson began collecting cases of what we would now term focal lesions that were restricted to functional units of an anatomic organ (Hughlings Jackson, 1862). A year prior to his explicit formulation of a complete neurological method, he began to investigate disorders of speech and language (Hughlings Jackson, 1863b). This was a fortuitous choice because it brought immediately into focus the problem of brain functions and mental functions—a relationship whose lack of clarification had prevented a systematic analysis of neurophysiology for millennia. By 1864, Hughlings Jackson had developed his tripartite analysis of neurologic disease consisting of anatomy, pathology, and physiology. Specifically he advocated studying every case as presenting:

1. DISEASE OF TISSUE (Changes in tissue)
2. DAMAGE OF ORGANS
3. DISORDER OF FUNCTION (Hughlings Jackson, 1864)

Hughlings Jackson's tripartite methodology, and a study of speech and language, led him to the important realization that a consistent and predictable science of the nervous system was possible only if it was seen as an exclusively sensorimotor machine.

Sensorimotor Machine—Axiom of Hughlings Jackson's Neurology

Hughlings Jackson came to believe that the nervous system was restricted to only sensory and motor functions. This idea is an essential prerequisite for a science of neurology and is the axiom of Hughlings Jackson's clinical neurophysiology.

Charles Bell (1774-1842), Francois Magendie (1783-1855), and Marshall Hall (1790-1857), among others, contributed significantly to what became known as the Law of Reflex Action (Bell, 1811; Magendie,1822; Hall, 1837). Thomas Laycock (1812-1876) suggested in 1844 that the law applied to the entire nervous system but did not exclude the possibility that metaphysical agents such as the soul coexisted in the cortex (Laycock, 1845). Finally, in 1884, Hughlings Jackson expunged the metaphysical from neurophysiology by stating that the entire nervous system was an exclusively sensorimotor machine (Hughlings Jackson, 1884). By limiting the study of neurology to observable events of the senses and movement, Hughlings Jackson provided the essential axiom for a science of the nervous system.

Weighted-Ordinal Representation

The restriction of neurophysiology to sensorimotor events is necessary but not sufficient to provide a functional description of the nervous system. For the latter, Hughlings Jackson turned to contemporary ideas of evolution. He was influenced by the applications of elements of Darwinian evolution to diverse systems by Herbert Spencer (1820-1903) (Hughlings Jackson, 1884). Hughlings Jackson adopted the language of evolution and applied it to an organizational hierarchy consisting of four characteristics: increasing complexity, increasing definiteness, increasing integration, and increasing interconnections. His clinical neurophysiology consisted of three levels—lowest, middle, and highest—that represent the sensorimotor structure of the body.

Hughlings Jackson's evolutionary analysis first appeared in 1874 (Hughlings Jackson, 1874-1876). In twenty-one papers—all published in the Medical Press and Circular between 1874 and 1876—Hughlings Jackson presented the simultaneous incremental development of multiple ideas that would form his final evolutionary neurophysiology. At the same time, he was considering the specific nature of the body's representational hierarchy and the way the different functional units within each level are related.

Hughlings Jackson incorporated and expanded part of William H. Broadbent's (1835-1907) 1866 hypothesis concerning bilaterally acting muscles (Broadbent, 1866). In particular, he recognized that the representations of the body in the nervous system must have different weightings. In his 1890 Lumleian lectures, Hughlings Jackson revisited his earlier thought processes;

> Some years ago I inferred …. that both sides of the body are represented in the right half of the brain (I still say "right" for convenience) … and the left and right sides of the body were differently represented in the right half of the brain. (This I have stated seems to me to be but an expansion and modification of the principle of Broadbent's well-known hypothesis as to the double representation of the bilaterally acting muscles.) (Hughlings Jackson, 1890)

Hughlings Jackson theorized that each part of the body was not represented exclusively at one location—as in a homunculus—but rather each must be a heavily weighted element in a complete representation of the body. Maximal plasticity is possible if every functional unit of the nervous system at one level is a weighted copy of the entire next lower level. In other words the somatotopic representation must be ordinal (York and Steinberg, 1994; York and Steinberg, 1995). Thus, the lower, middle, and highest levels represent, re-represent, and re-re-represent the body, respectively. This representational scheme is shared by the afferent sensory systems (Hughlings Jackson, 1876). Additionally, he realized that if differential weighting was dynamic it could provide an explanation of recovery after brain damage—a well-known clinical phenomenon (Hughlings Jackson, 1884). When one area of the brain is damaged, other units can increase their weighting of the affected region thus compensating for the loss of function (York and Steinberg, 1995).

In 1884 Hughlings Jackson delivered the Croonian lectures to the Royal College of Physicians in which his complete theoretical structure for clinical neurophysiology was presented (Hughlings Jackson, 1884). Weighted ordinal representation provides a consistent and reproducible foundation for a science of neurology and successfully explains neuroscientific discoveries that could not have been imagined in Hughlings Jackson's time. His restriction of neurology to sensorimotor physiology both made a science possible and also suggested a novel and sophisticated relationship between the brain and mind.

Concomitance

The experiments of a valid science must be reproducible. Consequently, in a clinical science of neurology, the experiments of nature (or neurological testing) require that the physiology of the brain be purely sensorimotor—the inclusion of uncharacterized processes results in the possibility that identical lesions or stimuli will produce inconsistent symptoms or responses. It was the presence of such metaphysical elements that hampered the progress of neurology for millennia. But clearly mental processes do arise from the brain—and they can affect sensorimotor responses—so the inevitable question arises of the relationship between functions of the brain and mind.

In his Croonian lectures Hughlings Jackson addressed this problem (Hughlings Jackson, 1884). He believed brain and mind were related by a doctrine of concomitance—they were like two clocks initially set to the same time, but running independently—in other words, completely correlated but causally unrelated. The term *concomitance*, and the two-clock hypothesis (along with other equivalent analogies), were an invention of

Gottfried Leibniz (1646-1716) (Leibniz, 1902). Though exactly how Hughling Jackson became aware of these ideas is not certain, one possible source was his teacher Thomas Laycock who was familiar with them from the time he spent studying in Gottingen, Germany (Laycock, 1860). Hughlings Jackson believed brain and mind were completely correlated because it seems quite obvious that mental processes accompany brain processes, and he believed they were causally unrelated because he thought that conservation of energy prevented non-physical mental activity from provoking physical action.

Hughlings Jackson expressed an explicit lack of interest in metaphysical questions (Hughlings Jackson, 1887). Though he did have specific reasons for rejecting the other mind-brain hypotheses of which he was aware—now known as Cartesian dualism and the mind-brain identity theory (Hughlings Jackson, 1887)—a particularly attractive feature of the doctrine of concomitance was that it allowed him to completely separate clinical neurology from the difficult metaphysical issues involved in mental processes. Even so, he discussed implications of concomitance for the ideas of conscious and unconscious thought, and struggled for a decade (from 1878-1887) with what he termed the *range of concomitance* (York and Steinberg, 1993). Hughlings Jackson had no doubt that consciousness was the concomitant of the highest level of nervous system evolution, and he therefore sought a structure of the mind consisting of evolutionary levels whose sequential representation resulted in this most complex, most definite, most integrated, and most interconnected mental state (Hughlings Jackson, 1887). He ultimately despaired of this effort (York and Steinberg, 1993), but his ideas form a template for future progress that is the topic of the penultimate section of this investigation.

Hughlings Jackson and Cognitive Imaging in Modern Neuroscience

This section presents a four-part argument for the relevance of Hughlings Jackson's ideas in a focused discipline of modern neuroscience—the specific use of cognitive imaging to understand the nature and content of mental processes. The first part demonstrates how the characteristics of Hughlings Jackson's concomitance are shared by a sophisticated modern view of the relation of brain and mind—i.e., the mind as an emergent property of the brain. In fact, given the linguistic context of his time, it is difficult to imagine a more accurate statement of these modern principles. Next, the nature of emergence and the rationale for considering the mind as an emergent phenomenon are discussed. Third, the implications of the mind as an emergent property are enumerated. Finally, these implications are used to demonstrate that some aspects of modern cognitive imaging are inconsistent with an emergent description of cognition. The sum of these four linked arguments, in sequence, is that Hughlings Jackson's ideas of more than a century ago led to the conclusion that a particular area of modern neuroscience must be modified.

To understand Hughlings Jackson's contribution to current neuroscience, his ideas must be translated into modern terms. This process is not an attempt to speculate on what Hughlings Jackson may have thought about aspects of contemporary neuroscience, but rather to take his explicit published ideas and place them within the context of an existing scientific formalism. In the language of modern science, Hughlings Jackson's concept of concomitance is equivalent to a description of the mind as an emergent property of the brain. In Hughlings Jackson's concomitance, brain activity is correlated with cognitive functions but is causally unrelated—identical to the situation in an emergent system. Though emergence may seem somewhat strange from a biological or neuroscientific perspective, these phenomena are diverse and omnipresent in the natural world and include superconductivity, ferromagnetism, and quite possibly the universe itself (Laughlin, 2004). But what exactly is emergence?

The term *emergence* has been applied loosely in philosophy and popular science literature, and can have different meanings even in scientific disciplines. In the present context, emergence has a more restricted definition—a property is emergent if it is independent of its substrate, and exhibits divergent (critical) long-range correlations. The defining characteristic of emergent properties is universality, i.e., emergent phenomena are independent of the substrate from which they emerge. An equivalent statement is that an emergent system cannot be understood in terms of a microscopic description of its substrate—a reductive description of an emergent property is not possible. Emergent properties appear at (2^{nd}-order) phase transitions—criticality, self-organized criticality and scaling behavior are other terms that are broadly synonymous. The appearance of emergence is experimentally manifest by critical behavior of long-range correlations within the substrate.

Emergent phenomena are not easy to grasp, and even the simplest examples involve physical properties that are not commonly encountered. A fairly familiar example is superconductivity. In certain metallic and ceramic compounds—near absolute zero—quantized sound waves (quasiparticles called phonons) couple with conduction electrons to form extended two-electron systems—known as Cooper pairs—that can flow with no resistance. Characteristic of all emergent phenomena, superconductivity: 1. is independent of the substrate from which it emerges, 2. cannot be derived from a microscopic analysis of its substrate—i.e., it has no reductive description, and 3. demonstrates critical behavior of long-range correlations at a 2nd-order (superconductor-insulator) phase transition.

But, how do we know that the mind is an emergent phenomenon? We know that cognitive properties are emergent by identification of its experimental hallmarks. Emergent phenomena are recognized by critical behavior of long-range correlations. In the case of the brain, emergence is identified by correlations of global electrical and /or magnetic activities. Such long-range correlations have been found in many experiments, and sophisticated analysis identifies critical behavior within the data sets (e.g., Varela et al., 2001; Berthouze et al., 2010; Linkenkaer-Hansen et al., 2001). The correlations and criticality are the experimental signatures of emergent systems. Although long-range correlations and criticality have not been identified in conjunction with specific mental processes, their presence is highly suggestive of emergent behavior within the brain.

If mental functions are emergent properties of the brain, what can we conclude? The most important conclusion is that brain activity can tell us nothing about the nature of mental processes. No knowledge of brain activity, irrespective of detail and resolution, can advance the understanding of any mental process—i.e., no microscopic description of a substrate can elucidate an emergent property. All that can be determined is the human brain machinery that is utilized to perform a mental function. Thus, it is impossible to gain an understanding of any aspect of cognition by examining scans of the brain. This fact was elegantly stated by Alan Ropper, a neurologist at Harvard, when he noted, "The mind is an emergent property of the brain and cannot be 'seen' in images." (Ropper, 2010).

If Hughlings Jackson's concomitance of brain and mind is equivalent to a description of mind as an emergent property of the brain, then what does it imply for modern neuroscience? With the advent of high-resolution physiologic imaging technologies such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), it has become possible to visualize (presumed) correlates of brain activity—glucose metabolism and blood flow, respectively—in health and disease. Essentially coincident with the appearance of this technology was its use for investigating cognitive, as well as sensorimotor, aspects of the nervous system. While the study of sensorimotor functions—e.g., movement of a finger or recovery from motor stroke—are uncontroversial, there are significant problems with extending imaging to cognitive processes. If there is no causal relation between brain and mind—as indicated by concomitance and emergence—then no information about the mind can be gained by studying the brain.

In essence, this simply reflects the logical asymmetry of cause and effect. It is important to note that this, of course, does not diminish the importance of research programs that ask how the brain performs a particular mental function or that attempt to demonstrate a statistical correlation between cerebral activity and cognitive traits. The problems arise when an attempt is made to use functional imaging to investigate the nature of the tested cognitive function. In some cases, e.g., mental arithmetic, the function—arithmetic—is known and, though nothing new about arithmetic can be learned, the localized brain machinery employed to perform simple problems can be ascertained from imaging results. But in most other cases—such as consciousness, confabulation, moral judgment, creativity, and artistic expression—it is a characterization of the function that is of interest. In these circumstances, functional imaging cannot provide any information on the nature or content of the processes involved. Yet, often, modern cognitive imaging proceeds as if this was possible. Even when the authors are careful to explicitly state that they are recording brain correlates of mental functions, the conclusions—or significance—claimed for their results often implicitly demonstrate their belief that some knowledge of the tested process has been achieved. This analysis is usually denoted as the correlation of "structure and function," and has attained a broad consensus in the cognitive imaging community. Though termed a correlation, it indicates a causal relation of brain structures and mental processes (Gazzaniga, 2004).

In addition to interpretive problems in academic research, of greater concern are suggested uses of cognitive imaging in society. There are proposals for the use of fMRI as a lie detector (Lee et al., 2002), a determinant of awareness in the chronic vegetative state (Owen et al., 2007), and recommendations for applications of functional imaging in the law, economics, and society are increasing (Donaldson, 2004). Though statistical correlations of cerebral activity and observable behaviors are valid, the sample sizes are small relative to comparable data from, e.g., a polygraph, or other forms of psychological testing in these disciplines. Beyond statistics, characterization of a mental process by fMRI is not possible—recorded activity can provide no information on the content of a thought. The sophisticated technology—and stunning images—provide an apparent scientific imprimatur for the preferred interpretation of the results, but obscure their actual meaning. In these cases—as opposed to sensorimotor imaging—the evidence of our eyes is illusory and must be supplemented by the correct interpretive framework. These particular applications of functional imaging provide only statistical information concerning the experimental query, and their illusion of more profound science may—unintentionally—result in harmful precedents. Phrenology (Rafter, 2005) and eugenics (Dikotter, 1998) are two examples of the potential dangers of the societal institutionalization of incompletely characterized science.

Hughlings Jackson, Mental Evolution, and a Future Neuroscience

In the previous section, the importance of Hughlings Jackson's doctrine of concomitance was its implications for the physics of the human mind and brain. In this section it is applied to the details of his specific structure of evolutionary neurophysiology, in a three-step process, to create a novel model of mental evolution. First, concomitance is shown to be equivalent to a complementary duality found in other well-characterized physical systems. Next, using Hughlings Jackson's structure of nervous system evolution, the nature of the duality implied by concomitance is made explicit. Finally, with the dual character of brain and mind identified, Hughlings Jackson's ideas again form the basis for creating an evolutionary hierarchy of the mind that parallels exactly his hierarchy of the nervous system. The result is a system for mental evolution that provides unambiguous definition of mental capacities and their relationships to each other, and has testable predictions. No such scientific structure of the mind has been previously proposed. In this manner, a future direction for neuroscience in the field of mental evolution is identified by explicitly following the development of Hughlings Jackson's ideas. Though the details of the system so generated are beyond the scope of this paper, the point argued here is that Hughlings Jackson's verbatim comments can provide a path to a novel solution of a currently open question of general interest and importance.

In modern terms, the combination of correlation and acausality that characterizes concomitance defines a type of duality called complementarity. Duality should not be confused with dualism. It is not a philosophical assumption, but a meta-scientific principle that played a prominent role in the quantum revolution of the 1920s (Bohr, 1928) and does so currently in the most advanced modern physical theories (Maldacena, 1998). Complementarity results from unity at a higher level of abstraction. For example, heads and tails, night and day, and particle and wave, are common examples of acausal correlation due to underlying unity—specifically, the unity is found in the structure of a coin, rotation of the earth, and the formalism of quantum mechanics, respectively. However, simply recognizing that mind and brain are complementary does not provide any information about the nature of their duality. This duality is found in the logic of reflex action and cognition.

As a sensorimotor machine, all nervous system functions are reflex actions, and the logic of reflex action is deduction. This can be seen in many ways, but probably the simplest and most rigorous is the following. A reflex is defined by the following syllogism, “If sensory stimulus *x* occurs, then motor response *y* will occur.” Thus, given stimulus *x* we are assured of response *y*. Of course, nothing limits the complexity of *x* or *y* and hence this same description applies to spinal reflexes as well as the most complicated and highly integrated action of the highest centers. The above syllogism is an example of *modus ponens*, the rule of inference defining deduction—if *p* then *q p,* therefore *q*. Thus, a sensorimotor machine is a deductive machine.

Intelligence—a generic term for mental capacity—can be succinctly defined as the facility of induction, i.e., increasing intelligence is manifest by the increasing capacity to identify a general pattern shared by a set of specific observations. The greater the mental capacity, the more rapidly and accurately general laws can be induced from specific occurrences. Thus, the process of the mind is induction and the mind is an inductive machine.

This construction accurately reflects the complementarity of brain and mind since logic can be divided into the dual elements of induction and deduction—like night and day, heads and tails, and particle and wave. Since complementary pairs result from a unity at a higher level of abstraction, it is an interesting exercise to contemplate what logical unity manifests itself as induction and deduction, or mind and brain.

As Hughlings Jackson realized, the brain and mind are completely correlated but entirely distinct. In modern terms, they can be seen as two machines of antipodal character—the former deductive and the latter inductive—acting in concert. Each sensorimotor event is the substrate for a generalization, and each generalization is tested by additional sensorimotor events. For example, a single instance of a complex sensorimotor event such as finding water near a stand of willow trees results in an induction that water can, in general, be found in these circumstances. When water is next required, the induction is tested by looking near a stand of willows. Inductions accompany the reflexes of all levels but are most apparent in the highest centers where their occurrence is responsible for the mental processes that are humanity’s most distinguishing capacities.

Hughlings Jackson’s ideas form a template for the investigation of the currently open question of the origin and nature of the human mind. No claim is made that the future direction of neuroscience, *in toto*, is a consequence of Hughlings Jackson’s theories, only that his ideas can help resolve this single, currently open, question. Within this context, the value of this development lies not in a comprehensive description of the structure of mental evolution so derived—those details can be found elsewhere (Steinberg, 1999; Steinberg and York, 1994)—but rather in a demonstration that Hughlings Jackson's ideas, when followed assiduously, have continued relevance for important problems that remain unsettled a hundred years after his death.

For a theory of mental evolution to be concomitant with Hughlings Jackson's theory of brain evolution, it must consist of an ordinal function (concomitant with representation) acting successively on a fundamental substrate (concomitant with the body). If the brain integrates sensory input and by reflex generates a motor response, then the afferent function of the brain can be considered as reconstruction of an increasingly definite, increasingly integrated, and increasingly interconnected sensory map of the external world. In theory, the function of the mind is to interpret these images, and therefore reconstructed images are assumed to be the substrate of mental evolution.

The mind must therefore interpret internal sensory patterns by producing an ordinal hierarchy that will be identified with mental processes, providing their definitions. An important consequence of this structure—contrary to existing cognitive theories—is that the definitions of mental functions so derived are unambiguous and analytic—i.e., each is defined solely in terms of those that precede it. In this manner, an ordinal process of internal interpretation of reconstructed images is concomitant with the brain's ordinal representations of the body. However, the nature of the ordinal function—concomitant with representation—must still be identified.

Intuitively, increasing mental capacity may be seen as an increasing ability to identify equivalences i.e., to generalize. In this manner, the functional analog of representation is generalization. That is, as the body is represented and re-represented in the brain, so elements of internal images are generalized and re-generalized in the mind. With the substrate and ordinal function of mental evolution established, the specific levels of evolution—concomitant with the levels of nervous system evolution—can be determined.

The most elementary constituent of an internal image is an object, and thus the analog of a partition of the body in brain evolution is a partition of internal images into separate objects. Mental evolution then proceeds so that each step represents an equivalence identified in the preceding stage. First categories of similar objects are recognized (categorization). This is concomitant to representation of the body in Hughlings Jackson's lowest level of brain evolution. Second, the equivalence forming a category is defined (conceptualization). This step is concomitant to the re-representation of the body in Hughlings Jackson's middle level of brain evolution. Individual definitions must exist somewhere—a place that can be called a concept-space. The formation of an abstract concept-space is defined as consciousness and corresponds to Hughlings Jackson's highest level of brain evolution.

The open question of the nature and origin of the human mind has engaged the attention of many disciplines. Among these are studies by anthropologists (Jerison, 1976), philosophers (Jaynes, 1973), and psychiatrists (Ey, 1962; Dewhurst and Beard, 2003). The work of Henri Ey (1900-1977) is particularly interesting because it explicitly utilizes the formulation of Hughling Jackson's evolutionary neurophysiology and concomitance to explore mental phenomena. To a significant degree, the present formulation of mental evolution could be seen as an actualization or model for his conceptual vision. However, there is little intersection in content between the current proposal and these investigations other than the common topic of concern. Though the insights are in all cases interesting and perceptive, they do not produce a system that is testable, analytic, or predictive.

In summary, a concomitant relation of brain and mind demands that mental evolution be described by three successive actions of an ordinal function on a fundamental substrate. A formal structure for mental evolution can be generated by defining the fundamental substrate of the mind as internally reconstructed images of the external world, and the function acting on this substrate as generalizing the elements of these images. The details of this development, and its explanatory and predictive value for specifics of human mental evolution—e.g., the nature and temporal origin of language and consciousness, and an explanation of Paleolithic Age artifacts—can be found elsewhere (Steinberg, 1997; Steinberg 1999). This brief overview is meant to demonstrate the relevance of Hughlings Jackson's ideas—when explicitly followed—as a template that provides a new direction for investigating mental evolution—a currently unresolved problem in neuroscience.

Conclusion

Hughlings Jackson created a new science—a clinical neurophysiology—whose bedside applications have relieved suffering for untold millions. His insights into the brain and mind—though couched in contextual terms of social Darwinism and concomitance that today seem prejudicial and outmoded—are, when closely examined, more sophisticated than current notions and more consistent with current knowledge of the natural world.

His ideas are not only manifestly useful 100 years after his death, but, if acknowledged, would transform a specific discipline of modern science and provide heuristic perspectives on the important open question of the origin and nature of the human mind.

The significance of these observations lies not only in the acknowledgment of the perspicacity of a Victorian scientist—and his potential contributions to specific aspects of modern and future neuroscience—but also demonstrate the need for continued vigilance when applying science to society. The complex technology and visually stunning pictures from advanced imaging devices may obscure the crucial step between image and meaning. When confined to the realm of research science the consequences of any misinterpretation are mostly aesthetic. However, as applications extend out of the laboratory, these issues come with a potential cost to individual rights and society. Hughlings Jackson's scientific legacy is assured, and if his ideas are carefully considered, his humanitarian impact—even if not directly acknowledged—could be of equal importance.

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C. Cerebral Localization in the Nineteenth Century—The Birth of a Science and its Modern Consequences[142]

Abstract: Although many individuals contributed to the development of the science of cerebral localization, its conceptual framework is the work of a single man—John Hughlings Jackson (1835-1911), a Victorian physician practicing in London. Hughlings Jackson's formulation of a neurological science consisted of an axiomatic basis, an experimental methodology, and a clinical neurophysiology. His axiom—that the brain is an exclusively sensorimotor machine—separated neurology from psychiatry and established a rigorous and sophisticated structure for the brain and mind. Hughlings Jackson's experimental method utilized the focal lesion as a probe of brain function and created an evolutionary structure of somatotopic representation to explain clinical neurophysiology. His scientific theory of cerebral localization can be described as weighted ordinal representation. Hughlings Jackson's theory of weighted ordinal representation forms the scientific basis for modern neurology. Though this science is utilized daily by every neurologist, and forms the basis of neuroscience, the consequences of Hughlings Jackson's ideas are still not generally appreciated. For example, they imply the intrinsic inconsistency of some modern fields of neuroscience and neurology. Thus, "cognitive imaging" and the "neurology of art"—two topics of modern interest—are fundamentally oxymoronic according to the science of cerebral localization. Neuroscientists, therefore, still have much to learn from John Hughlings Jackson

Introduction

The history of cerebral localization in the nineteenth century is the history of the origin of science. Like any science, many different perspectives on its emergence are possible, e.g., histories of its ideas, its institutions, its technologies, etc. In addition, each type of scientific history can be written from two opposing views—contextual and pedagogical. A pedagogical approach organizes the historical development of a science in a monotonic progression toward its modern structure and is therefore by definition anachronistic, while the contextual view emphasizes the human aspects of scientific discovery that are often irrational and haphazard. Contextual

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history is essential to understand the mechanics of scientific discovery, but a pedagogical organization is helpful if history is seen as an analytic tool used to validate or falsify modern scientific hypotheses. Because this is an historical and heuristic study of the ideas of cerebral localization, it has both contextual and pedagogical elements.

Although many individuals contributed to the development of a science of cerebral localization, its conceptual framework is the work of a single man—John Hughlings Jackson (1835-1911)—a Victorian physician practicing in London during the mid- to late-nineteenth century. His scientific theory of clinical neurophysiology forms the basis of modern diagnostic neurology, provides the theoretical foundation for the neurosciences, and separates neurology from psychiatry. The majority of this study examines the development of Hughlings Jackson's theory of cerebral localization. To demonstrate the importance of an historical understanding of his work, the final section will show that some disciplines of contemporary neuroscience are logically meaningless since they are incompatible with the Jacksonian axiom that makes their parent science possible.

Methodology

Hughlings Jackson began his exclusive focus on diseases of the nervous system in the early 1860s, probably at the suggestion of Charles Edouard Brown-Séquard (1817-1894) (Hutchison, 1911). At this time there was no specialty of neurology, and, as Hughlings Jackson immediately recognized, there was also no conceptual framework for the study of diseases of the nervous system (Hughlings Jackson, 1863a). By June of 1864 he had developed a methodology for investigating neurological disease and along the way he had discovered several important ideas that would form part of his science of cerebral localization (Hughlings Jackson, 1864).

When Hughlings Jackson began collecting cases of nervous system disease the accepted method was to accumulate cases of the manifestations of a single disease, regardless of its location. Thus, cases of syphilis were collected without regard to the organ affected. Hughlings Jackson recognized that this type of information was not helpful in determining how the nervous system works. Next, he turned to evaluating the symptoms of multiple pathologies as they affect a single anatomic location, e.g., the pons or cerebellum (Hughlings Jackson, 1861), He again found that there was no consistent correlation between symptoms and post mortem pathology. Finally, Hughlings Jackson realized that an anatomic organ must consist of many discrete units, each of which had a single function. Hughlings Jackson probably learned of this principle in 1862 from a lecture he attended by

Brown-Séquard where it was used in the pre-mortem diagnosis of a pontine hemorrhage (Hughlings Jackson, 1862). Thereafter, Hughlings Jackson began collecting cases of what we would now term focal lesions that were restricted to these functional units. The use of focal lesions to determine nervous system physiology formed the methodology for the nascent science of cerebral localization.

With a tool available to investigate the nervous system, Hughlings Jackson initially turned his attention to disorders of speech and language (Hughlings Jackson, 1863b). This was a fortuitous choice because it brought immediately into focus the problem of brain functions and mental functions—a relationship whose lack of clarification had prevented a systematic analysis of neurophysiology for millennia. Hughlings Jackson realized that a consistent and predictable science of the nervous system was possible only if it was seen as an exclusively sensorimotor machine.

The Sensorimotor Machine

Hughlings Jackson came to believe that the functions of the nervous system were restricted solely to sensation and movement. This idea is an essential prerequisite for a science of cerebral localization and is the axiom of Hughlings Jackson's clinical neurophysiology.

In 1811 Charles Bell (1774-1842) demonstrated that stimulation of the anterior spinal root produced movement, but the posterior root did not (Bell, 1811/1974). In 1822, François Magendie (1783-1855) showed that division of the posterior root produced sensory loss and anterior root division produced paralysis (Magendie, 1822). The resulting concept that sensation and movement are separate at the spinal cord level became known as the Bell-Magendie hypothesis.

In 1837 Marshall Hall (1790-1857) used his experimental work on amphibians to conclude that there was a connection between sensation and movement at each spinal level through the segmental reflex (Hall, 1837). He also suggested that impulses moved up and down the spinal cord, citing experiments of Robert Boyle (1627-1691) and Robert Whytt (1714-1766). The anatomical and functional separation of sensation and movement, their connection in each spinal segment, and the continuity of ascending and descending spinal pathways, became known as the law of reflex action.

Thomas Laycock (1812-1876) suggested that the law of reflex action applied to the entire nervous system including the cortex in 1839, but did not exclude the possibility that metaphysical functions, e.g., the soul, coexisted in the cortex (Laycock, 1845). Finally, in 1884, Hughlings Jackson expunged the metaphysical from neurophysiology by stating that the entire nervous system was an exclusively sensorimotor machine (Hughlings Jackson, 1884). By limiting the study of neurology to observable events of sensation and movement, Hughlings Jackson provided the essential axiom for a science of cerebral localization.

Evolution

The restriction of neurophysiology to sensorimotor events is necessary but not sufficient to provide a functional description of the nervous system. For the latter, Hughlings Jackson turned to the contemporary ideas of evolution. He was influenced by the applications of Darwinian evolution to diverse systems by Herbert Spencer (1820-1903) (Hughlings Jackson, 1884). Hughlings Jackson adopted the language of evolution and applied it to an organizational hierarchy. His evolutionary hierarchy consisted of four characteristics: increasing complexity, increasing definiteness, increasing integration, and increasing interconnections (Hughlings Jackson, 1884). He also believed, following Spencer, that higher levels exert a controlling influence on lower ones (Hughlings Jackson, 1884). Thus, destruction of a higher center results in two types of symptoms: a negative symptom from the loss of the higher function, and a positive symptom from the release of a lower center from inhibitory control. For example, in the case of an incomplete stroke affecting the leg, the negative symptom is partial paralysis and the positive symptom is spastic gait.

But this evolutionary notion of higher and lower levels is still too general to provide a useful diagnostic neurophysiology. We do not know exactly how Hughlings Jackson derived his specific evolutionary structure of the nervous system since it is presented essentially as a *fait accompli*. On the other hand, the following argument is a logical sequence resulting in his conclusion. Since Hughlings Jackson considered the nervous system to be a sensorimotor machine, its elements must contain a representation of the physical body. That is, the nervous system must be a somatotopic map of the body. At its simplest, the nervous system contains the spinal reflexes and at its most complex it consists of highly integrated and cooperative sensorimotor behavior. If these form the lowest and highest levels of the nervous system, the question is, how many levels are there in between? Given the positive and negative symptoms exemplified by paralysis and spasticity, as above, there must be at least one level between the spinal reflex and highly integrated fine control (i.e., the uncoordinated, spastic gait), and, in fact, there are no symptom complexes that require any more than one intervening level. Hence, Hughlings Jackson's suggested a clinical neurophysiology consisting of three levels—lower, middle, and highest—

that represent the impressions and movements of the body with increasing complexity, definiteness, integration, and interconnection.

Hughlings Jackson's evolutionary analysis first appeared in 1874 (Hughlings Jackson, 1874-1876). Simultaneously, he was considering the specific nature of the body's representational hierarchy and the way the different functional units within each level are related.

Weighting and Ordinality

In 1866 William H. Broadbent (1835-1907) proposed the following hypothesis as an explanation or the commonly observed absence of paralysis of muscles whose functions are bilaterally symmetric:

> That where the muscles of the corresponding parts on opposite sides of the body act in concert, or act independently, either not at all, or with difficulty, the nerve-nuclei of these muscles are so connected by commissural fibers as to be *pro tanto* a single nucleus. This combined nucleus will have a set of fibers from each corpus striatum, and will usually be called into action by both, but it will be able to be excited by each singly, more or less completely according as the commissural connection between the two is more or less perfect (Broadbent, 1866).

He suggested that there must be bilateral innervation of such muscles so that if one side of the brain is damaged, the other can compensate for the loss. Interestingly, in his paper, he contrasted his clinical observations with those of Hughlings Jackson—demonstrating that by 1866 Hughlings Jackson's reputation had reached a point where the established medical hierarchy noticed his ideas.

By 1874 Hughlings Jackson had incorporated Broadbent's hypothesis in his theoretical clinical neurophysiology by recognizing that the representations of the body in the nervous system must have different weightings (Hughlings Jackson, 1874-1876). That is, the representations of some parts of the body are strongly unilaterally weighted so that, when damaged, paralysis occurs, whereas other parts are more equally represented and therefore unilateral brain damage has less effect. This emphasized to Hughlings Jackson that, even in the dominant hemisphere, each part of the body was not represented exclusively at one location—as in a homunculus—but rather each must be a heavily weighted element in a complete representation of the body. Additionally, he realized that if differential weighting was dynamic it could provide an explanation of recovery after brain damage—a well-known clinical phenomenon (Hughlings Jackson, 1884). When one area of the brain is damaged, other units can increase their weighting of the affected region thus compensating for the loss of function. Maximal plasticity is possible only if every functional unit of the nervous system at one level contains an entire copy of the next lower level. In other words the somatotopic representation must be ordinal. Thus, the lower, middle, and highest levels represent, re-represent, and re-re-represent the body, respectively.

Medical Press and Circular 1874-1876

Though the individual elements of Jacksonian localization have been separated for this explication, in reality all of these ideas were simultaneously evolving during the period 1874-1876. This process can be followed in a series of 21 articles published in the Medical Press and Circular that were all entitled "On the scientific and empirical investigations of epilepsies" (Hughlings Jackson, 1874-1876). In this series, Hughlings Jackson can be seen progressing towards the final form of his theory of cerebral localization.

Jacksonian Cerebral Localization

In 1884 Hughlings Jackson delivered the Croonian lectures to the Royal College of Physicians in which his complete theoretical structure for clinical neurophysiology was presented (Hughlings Jackson, 1884). Weighted ordinal representation provides a consistent and reproducible foundation for a science of neurology and has successfully explained neuroscientific discoveries that could not have been imagined in Hughlings Jackson's time. His restriction of neurology to sensorimotor physiology both made a science possible and also suggested a novel and sophisticated relationship between the brain and mind.

Concomitance

The experiments of a valid science must be reproducible. Consequently, in a clinical science of neurology, the experiments of nature (or neurological testing) require that the physiology of the brain be purely sensorimotor—the inclusion of any other processes results in identical lesions or stimuli producing inconsistent symptoms or responses. The complexity of interconnections in the highest centers may make predictability practically impossible, but, in principle, all nervous system functions must be sensorimotor. But clearly mental processes do arise from the brain and they can effect sensorimotor responses, and so the inevitable question arises of the relationship between functions of the brain and mind. In his Croonian lectures Hughlings Jackson addressed this problem (Hughlings Jackson, 1884). He believed brain and mind were related by a doctrine of concomitance—they were like two clocks initially set to the same time, but running independently—in other words, completely correlated but causally unrelated. He believed the former because it seems quite obvious that mental states accompany brain states, and he believed the latter because he thought that conservation of energy prevented non-physical mental activity from provoking physical action. In modern terms, this combination of correlation and acausality defines a type of duality called complementarity. Duality should not be confused with dualism. It is not a philosophical assumption, but a meta-scientific principle that played a prominent role in the quantum revolution of the 1920's (Bohr, 1928) and does so currently in the most advanced modern physical theories (Maldacena, 1998). Complementarity results from unity at a higher level of abstraction. For example, heads and tails, night and day, and particle and wave, are common examples of acausal correlation due to underlying unity—specifically, the unity is found in the structure of a coin, rotation of the earth, and the wavefunction of Schrodinger's equation, respectively. However, simply recognizing that mind and brain are complementary does not provide any information about the nature of their duality.

As a sensorimotor machine, all nervous system functions are reflex actions, and the logic of reflex action is deduction. This can be seen in many ways, but probably the simplest and most rigorous is the following. A reflex is defined by the following syllogism, "If sensory stimulus *x* occurs, then motor response *y* will occur." Thus, given stimulus *x*, we are assured of response *y*. Of course, nothing limits the complexity of *x* or *y*, and hence this same description applies to spinal reflexes as well as the most complicated and highly integrated action of the highest centers. The above syllogism is an example of *modus ponens*, the rule of inference defining deduction—if *p* then *q*: *p*, therefore *q*. Thus, a sensorimotor machine is a deductive machine.

Intelligence—a generic term for mental capacity—can be succinctly defined as the facility of induction, i.e., increasing intelligence is manifest by the increasing capacity to comprehend a general pattern shared by a set of specific observations. The greater the mental capacity, the more rapidly and accurately general laws can be induced from specific occurrences. Thus, the process of the mind is induction and the mind is an inductive machine.

This construction accurately reflects the complementarity of brain and mind since logic can be divided into the dual elements of induction and deduction—like night and day, heads and tails, and particle and wave. Since complementary pairs result from a unity at a higher level of abstraction, it is an interesting exercise to contemplate what logical unity manifests itself as induction and deduction, or mind and brain.

To summarize, the brain and mind are completely correlated but entirely distinct. They can be seen as two machines of antipodal character—the former deductive and the latter inductive—acting in concert. Each sensorimotor event is the substrate for a generalization, and each generalization is tested by additional sensorimotor events. Inductions accompany the reflexes of all levels but are most apparent in the highest centers where their occurrence is responsible for the mental processes that are humanity's most distinguishing capacities. Brain and mind are complementary in the rigorous sense of the term and are reflections of a unity at a higher level of abstraction.

Hughlings Jackson and Modern Neuroscience

Hughlings Jackson's insights are subtle and profound and, though they are essential for the existence of neuroscience, their consequences are not always recognized by contemporary practitioners. The importance of an historical understanding of his work can be seen in two areas of modern neuroscience that are explicitly oxymoronic according to Jacksonian principles. These are cognitive imaging and the neurology of art.

Cognitive imaging attempts to study mental functions by recording the patterns of cerebral activity that occur during cognitive tasks. For example, in the case of arithmetic, after control runs are subtracted to eliminate effects of sensory input, the remaining areas of brain activation are said to be where mental arithmetic resides. Of course, what is actually imaged is the cerebral machinery used in mental arithmetic. This distinction may at first seem purely pedantic, but it is critical. In contrast to functional imaging of sensorimotor tasks, where the recorded activity of the brain and the function being studied are identical, the cerebral activation recorded during a mental task has no relation to the underlying cognitive function. This disparity in the physical manifestations of the functions of brain and mind has a natural explanation yet is a source of persistent confusion. Sensorimotor functions are determined by the unique anatomy of human sense organs and muscles—i.e., they are determined by internal realities peculiar to humans—and are therefore identically patterns of human nervous system activity. Mental functions, on the other hand, create models of the external world—i.e., they are determined by external realities that are independent of humans. Mental functions have evolved to utilize the machinery of the brain, but they cannot be defined by states of the nervous system. If they were so defined, then only a human brain could perform these functions, eliminating even the theoretical possibility of non-human intelligence. In exactly the same manner, studying the wires and beads of an abacus does not illuminate the nature of arithmetic, nor do the immense complexities of arithmetic—e.g., the various prime number conjectures—reside somewhere in the beads and wires of an abacus. As Hughlings Jackson recognized over a century ago, cognitive processes cannot be studied by examining the brain—an inductive process cannot be understood deductively any more than a wave can be understood by examining particles. What can be discovered are the particular structures of the human brain that are harnessed to perform cognitive functions, and certainly this is an interesting area of investigation—exactly equivalent to studying how an abacus, adding machine, or computer performs addition. However, this should not be confused with imaging or understanding cognitive functions themselves. The implicit assumption of cognitive imaging research—borrowed from sensorimotor imaging—that brain activity and a mental function are identical, is *prima facie* incorrect. The phrase *cognitive imaging* is logically vacuous since it is self-contradictory. It is incompatible with the essential axiom that makes a science of the nervous system possible.

This analysis does, however, raise an interesting question. Can functional imaging be used to experimentally test the proposition that brain states and mind states are identical? The answer is, that it can, if the correct question is asked of the technology. It is possible to design a relatively simple imaging experiment that would prove the non-localizability of mental functions, and provide experimental confirmation of Hughlings Jackson's insight into the complementarity of brain and mind.

The neurology of art is another explicitly oxymoronic concept. Other than the trivially mechanical parts of any artistic endeavor, art is creative and imaginative—an archetypal inductive process. A science of neurology depends on an exclusively sensorimotor neurophysiology—an archetypal deductive process. It is clear that the production of any form of art requires the integration of sensorimotor faculties, but these are unrelated to artistic creativity. Accumulation of information about the artistic or aesthetic effects associated with brain damage provides some indication of how the human mind uses the machinery of the brain to produce art. It can tell us nothing at all about the nature of art. As Hughlings Jackson discovered over a hundred years ago, artistic creativity is one of the best examples of what must be excluded to form a science of neurology—the intersection of art and neurology is empty—by definition, there can be no neurology of art.

Conclusion

After approximately four thousand years of clinical observations of nervous system pathology, and after at least two thousand years of speculation about clinical neurophysiology, John Hughlings Jackson created a science of cerebral localization in the mid-nineteenth century. The impediment to a consistent and reproducible scientific neurology was the conflation of nervous system and mental functions, which was removed by Hughlings Jackson's fundamental axiom that the brain is an exclusively sensorimotor machine. Combining astute clinical observations and the prevailing intellectual milieu of his times, Hughlings Jackson proposed a theory of weighted ordinal representation that explained—and continues to explain—observations of the nervous system in health and disease. In fact, the full consequences of his insights have not yet been assimilated, as his principles directly imply that some modern disciplines of neuroscience are explicitly oxymoronic.

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D. What Modern Neuroscience Can Learn from Hughlings Jackson[143]

Introduction

John Hughlings Jackson (1835-1911) created a scientific neurology by restricting his clinical analysis to observable events. He predicted a specific structure of the mind by applying his particular idea about how the brain and mind are related to his neurophysiologic theory, but he ultimately rejected his own analysis. Examination of his ideas reveals an analytic error whose correction yields a model of mental evolution that has verifiable predictions. Since no such predictive models presently exist, an historical investigation of Hughlings Jackson's ideas contributes to modern neuroscience.

Some historians believe that historical research can be used as a tool for modern scientific investigations, analogous to the use of mathematics in physics. This study demonstrates the validity of this theory of history, or historiography, by producing an example.

Hughlings Jackson's Neurophysiologic Theories

Hughlings Jackson described the nervous system as a sensorimotor machine with an evolutionary structure in which the physical body is sequentially represented, re-represented, and re-re-represented, at successively higher functional levels (Hughlings Jackson ,1884, p. 649; Smith, 1982b; York and Steinberg, 1993). Two principles underlie his theory: first, stages of evolution are increasingly complex, increasingly definite, and increasingly interconnected; and second, higher evolutionary levels control the function of lower levels (Hughlings Jackson, 1958, p. 80; Hughlings Jackson, 1884, p. 649; Smith, 1982a; York and Steinberg, 1993; Spencer, 1910). Since the levels are strictly ordered by inclusion, the representational structure of evolution is ordinal.

The practical clinical consequence of this evolutionary system is that symptoms of neurologic disease are double. Negative symptoms result from a loss of a higher function and positive symptoms result from release of a lower level from inhibitory control (Hughlings Jackson, 1884, p. 649; Harrington, 1987, pp. 206-247). For example, in hemiparesis, paralysis in the affected limb is the negative symptom and hyperreflexia is the positive one.

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Though Hughlings Jackson limited clinical neurology to analysis of sensation and movement, he recognized the reality of mental states and mental illness. As a practical physician he needed to define the relationship between sensorimotor functions of the brain and functions of the mind. He rejected both Cartesian dualism and the mind-brain identity theory, settling on psychophysical parallelism, which he termed the doctrine of concomitance (Hughlings Jackson, 1958, p. 85; York and Steinberg, 1993; Engelhardt, 1975; Elkind, 1989). This doctrine has its roots in the philosophy of Leibniz, and may have been communicated to Hughlings Jackson by his teacher Thomas Laycock, who had studied at Gottingen when these ideas were current (Laycock, 1860, p. 183; Engelhardt, 1975; Greenblatt, 1965; York and Steinberg, 1993). In a strong interpretation of the doctrine of concomitance, each mental state has a concomitant nervous state, and vice versa. The complete structure of the nervous system is concomitant to a complete structure of the mind, each consisting of evolutionary levels and a process connecting them. Hughlings Jackson initially accepted this interpretation, identifying consciousness as the concomitant mental state of the highest level of brain evolution, and he reasoned that subconscious mental states must exist as the concomitants of lower evolutionary levels (Table 1). After a decade of consideration, however, Hughlings Jackson rejected this view. He came to believe that unconscious mental states do not exist (York and Steinberg, 1993; Steinberg and York, 1994).

BRAIN		*MIND*
concomitance HIGHEST LEVEL	<———>	CONSCIOUSNESS
concomitance(?) MIDDLE LEVEL	<———>	UNCONSCIOUS STATE 1
concomitance(?) LOWEST LEVEL	<———>	UNCONSCIOUS STATE 2

Table 1: Hughlings Jackson's prediction of the unconscious**.** The doctrine of concomitance suggests that each level of nervous system evolution has a concomitant level of mental evolution. Since Hughlings Jackson identified the concomitant of the highest level of nervous system evolution as consciousness, this implied that the lower levels must have subconscious, or unconscious, concomitants.

Comments of his closest friends, and the character of his writings, indicate that Hughlings Jackson maintained a strict code of personal intellectual honesty, and was firmly entrenched in the philosophical empiricism of his era. (Buzzard, 1911; Hutchinson, 1911) He was unwilling to accept any conclusion that was not demonstrable clinically.(York and Steinberg, 1993; Young, 1970) As a result, Hughlings Jackson came to reject the consequences of his own logic.

In this case, Hughlings Jackson's intellectual standards may have been misapplied. Hughlings Jackson assumed that the functional structures of the mind and nervous system are exactly analogous. Therefore, pathological states involving the highest level of the brain should be accompanied by positive mental symptoms caused by the release from inhibitory control of subconscious mental states. When he could not observe these states, Hughlings Jackson believed that his analysis was incorrect. He could have accounted for this absence either by altering his assumptions about the structure of the mind, or altering the doctrine of concomitance which he believed predicted that structure. He followed the latter course, rejected the strong interpretation of the doctrine of concomitance and restricted what he called the range of concomitance to the highest level of nervous system evolution. However, it may not be the doctrine of concomitance, but rather an inaccurate interpretation of what concomitance implies, that resulted in an apparent contradiction to his predictions for mental evolution.

Hughlings Jackson's assumption of functional identity between brain and mind may be too concrete. He thought that the doctrine of concomitance implied that mental evolution is described by a process of ordinal representation of an unknown object, or substrate, as illustrated in Table 2 (York and Steinberg, 1994; Smith, 1982b). Concomitance may be considered more generally to require only a form of ordinality—representation being one of many possible ordinal functions (Table 3). Positive and negative symptoms are a consequence of ordinal representation of the physical body, but other ordinal relations may not produce observable clinical symptoms. The absence of observable subconscious mental states in brain-damaged patients does not exclude an ordinal structure of the mind.

BRAIN EVOLUTION	*MENTAL EVOLUTION*
$R(B), R^2(B), R^3(B)$	$R(X), R^2(X), R^3(X)$
where, R = representation B = body	where R = representation X = some object

Table 2: Hughlings Jackson's mental evolution. Hughlings Jackson believed that the doctrine of concomitance implied that mental evolution, like nervous system evolution, must consist of a process of representation of an unknown object, analogous to the body. When his clinical observations did not support such a structure, he rejected the existence of the unconscious.

BRAIN EVOLUTION	*MENTAL EVOLUTION*
$R(B), R^2(B), R^3(B)$	$G(X), G^2(X), G^3(X)$
where R = representation B = body	where G = some ordinal function X = some object

Table 3: Mental evolution generalized. A more general interpretation of the doctrine of concomitance requires only that mental evolution consist of some ordinal function acting on some object or substrate.

A theory of mental evolution concomitant with Hughlings Jackson's theory of brain evolution must specify a substrate and an ordinal function. As a sensorimotor machine, the brain integrates sensory input and by reflex generates a motor response. Therefore, its afferent function is reconstruction of an increasingly definite, increasingly integrated, and increasingly interconnected sensory map of the external world as it impinges on the body. The function of the mind is to interpret this reconstruction. Therefore, reconstructed sensory maps are assumed to form the basis, or substrate, of mental evolution in the same way that the body is the substrate of brain evolution. The function of the mind that is concomitant to representation in the nervous system must therefore interpret sensory maps by producing an ordinal hierarchy.

But what is the ordinal mental function? Increasing mental capacity is characterized by an increasing ability to generalize, or to identify the equivalence between seemingly unrelated objects or ideas. Therefore the mental analog of somatotopic representation is generalization. As the body is represented and re-represented in the brain, so elements of internal sensory maps are generalized and re-generalized in the mind. Mental states are unambiguously defined as the stages of this ordinal hierarchy.

A Theory of Mental Evolution

The concomitant theory of mental evolution introduces the idea of a concept-space, and differentiates between recognition and definition. Simply put, a concept-space is the place where concepts exist. This idea may seem unnecessary, since the concepts of modern humans exist in an abstract mental space and it is difficult to imagine any other form for them to take. Characteristically, when something is known by only one example, it is difficult to separate form from content. But a concept is entirely distinct from the place where it resides. A concept can be viewed as a collection of attributes that define membership in a category—how or where this collection is assembled is not defined. Because a concept is independent of its representation, it can exist in many forms, just as a subject represented in a photograph, painting, drawing, dream, and sculpture is distinct from the subject itself. Before an abstract space existed, a collection of attributes was assembled in a modified physical object which then became a concept-space. For example, the concept-space of a miniature sculpture of the Upper Paleolithic Age is the carved stone displaying the physical characteristics of an animal.

The stages of mental evolution strictly differentiate the processes of recognition and definition—recognition involves comparison, while definition involves specification. For example, recognition of an object as a horse requires a mental comparison between it and previously encountered horses. Recognition does not require an awareness of the characteristics that define a horse, or even that such characteristics exist. In contrast, definition of a horse requires specifying exactly what characterizes “horse-ness.” A recognizable reproduction of a horse must adequately specify “horse-ness,” since it is seen as a horse.

A concomitant theory of mental evolution may be generated in the following manner. First, internal sensory maps are partitioned into separate objects (analogous to Hughlings Jackson’s partition of the body into anatomic centers). Then, three stages of mental evolution are formed by repeated generalization (analogous to the three stages of nervous system evolution reached by repetitive representation) (Hughlings Jackson, 1884, p. 649; York and Steinberg, 1993, 1994; Steinberg and York, 1994). The stages of mental evolution are termed categorization, conceptualization, and consciousness. Once internal sensory maps are partitioned into objects, each step is formed by an equivalence identified in the preceding stage. First, the mind recognizes categories of similar objects (categorization), then it recognizes there are attributes that characterize a category (protoconceptualization), then it explicitly specifies these attributes (conceptualization). At this stage of mental evolution, the explicit characteristics determining membership in a category are embodied in physical objects where the material of a representation, i.e., the concept-space, is inseparable from the concept itself (contingent physical concept-space). Next the mind recognizes the concept-space as a separable entity from the concept it carries (independent physical concept-space), and finally the concept-space is defined (abstract concept-space). The formation of an abstract concept-space is consciousness. The lowest and middle levels of mental evolution have internal structure—the former includes protoconceptualization as a form of categorization, while the latter includes the contingent and independent physical concept-spaces as forms of conceptualization.

The example of a horse can again clarify a complete mental evolutionary sequence. First, the mind recognizes a particular horse as a separate object, i.e., as separate from the ground, sky, trees, etc. Next, it recognizes a category of horses which serves as a standard of comparison to determine if a newly encountered object is a horse. Once the mind recognizes a horse category, the process of protoconceptualization recognizes that there is an underlying similarity of horses that causes them to be classified together, i.e., protoconceptualization is the recognition that a category exists independent of any of its members. This mental ability is demonstrated by the use of a single horse, or horse part, to represent the category of horse. The protoconcept, horse, must be a particular horse since only a member of this category manifests the similarity underlying all horses, which cannot yet be specified.

The concept, horse, is the explicit collection of attributes that determines whether an object is a horse. Since the collection of attributes is explicit, a concept need not be represented by a member of the category it conceptualizes. At first, the collection is brought together in a modified object, e.g., a carving of a horse, which must contain sufficient physical attributes to define a horse because it is recognized as one. The modified physical object that carries the concept is a physical concept-space. At this stage, the physical concept-space accommodates only a single concept, and is inseparable from it (i.e., the carving and the carved stone are inseparable), and, in this sense, the physical concept-space is contingent. In the next stage of mental evolution, the mind recognizes that a carving of a horse and a carving of a bull have something in common, i.e., the capacity of the underlying material of the carving to accommodate either a bull or a horse. The recognition of the existence of a concept-space independent of any particular concept is necessary and sufficient for the innovation of composition, in which a horse and bull appear together in a single unified representation.

Once the mind recognizes a concept-space as an independent entity, it can be defined. The definition is, as before, a collection of attributes, but one attribute specifies an unlimited carrying capacity of the space. Since no physical space is infinite in extent, this can occur only in an abstract space. It is the formation of an abstract, mental space that is consciousness. A result of this process is the mental collection of characteristics of a horse that is elicited by the modern word *horse*.

In summary, a concomitant relation of brain and mind requires that mental evolution be described by three successive actions of an ordinal function on a substrate. A formal structure for mental evolution is created by defining the substrate of the mind as internally reconstructed sensory maps of the external world, and the function acting on this substrate as generalizing the elements of these maps. Table 4 shows graphically a concomitant theory of mental evolution.

BRAIN	*CONCOMITANCE*	*MIND*
Highest level	<———>	Consciousness
Middle level	<———>	Conceptualization
Lowest level	<———>	Categorization
Partition of body	<———>	Partition of internal image into objects

Table 4: Concomitance and mental evolution**.** By defining the substrate of mental evolution as internal sensory maps of the external world, and by identifying the ordinal function as generalizing elements of these maps, an heuristic theory of mental evolution is obtained. In this schema, internal sensory maps are first partitioned into separate objects, analogous to the partition of the body in nervous system evolution. Collections of similar objects are then recognized (categorization), concomitant to representation of the body. The equivalence relation underlying categorization is then defined (conceptualization), concomitant to re-representation. A concept is a collection, which is collected in a concept-space. The formation of an abstract concept-space is consciousness, concomitant to the highest level of nervous system evolution.

Archaeologic Predictions

The theory of mental evolution predicts that specific non-utilitarian archaeologic artifacts, and only these artifacts, should be found in the chronological order corresponding to its evolutionary stages. The first stage, categorization, predicts the absence of non-utilitarian artifacts. Since a category is simply a recognized collection of similar objects, and is functionally a standard of comparison, a category has no independent existence.

The second stage, protoconceptualization, is the recognition that there is an equivalence underlying a category, i.e., the recognition that a category exists independent of its members. Since the equivalence that forms a category is recognized, but not defined, only a member of the category that manifests the unspecified equivalence can be a protoconcept. Thus, the process of protoconceptualization predicts the appearance of unaltered natural objects which are intentionally isolated or displayed—each representing the category of which it is a member.

The third stage of mental evolution is contingent conceptualization, in which an explicit collection of attributes specifies a category's defining characteristics. The collection must be assembled somewhere, or it is not a collection, and the place where it is assembled is a concept-space. At this stage only physical objects can act as a concept-space. Therefore, the contingent physical concept-space predicts the appearance of reproductions or representations of recognizable objects in a physical medium.

The next stage of mental evolution recognizes that a concept-space can exist independent of any particular concept it carries. The recognition of an independent physical concept-space is necessary and sufficient to allow composition, in which more than one concept coexist in a unified concept-space. This evolutionary stage predicts compositional reproductions.

In principle, a concept-space allows interaction of an unlimited number of concepts. This is possible only in an abstract space, and hence the final stage in the mental evolutionary sequence is the appearance of an abstract concept-space. Conceptual manipulations are vastly facilitated in an abstract space since concepts can be juxtaposed and hypotheses tested mentally, rather than by manipulating physical representations. As a result, the theory predicts that evidence of rapidly advancing mental capabilities will be found, and all physical forms of concepts will disappear.

Verification of Mental Evolution in Archaeologic Artifacts

Stone tools are the only human artifacts found until the end of the Lower-Paleolithic Age and the ascendance of *Homo sapiens neanderthalensis*. This means that tool-producing hominids defining the genus Homo (i.e., *Homo habilis* and *Homo erectus*) were only quantitatively more mentally advanced than other animals, which use and manufacture tools of various levels of sophistication (Beck, 1980). Though human tools are more modified, more varied, and more permanent than those produced by other animals, the differences are quantitative rather than qualitative.

The Middle-Paleolithic Age is defined by the supremacy of *Homo sapiens neanderthalensis*, approximately 100,000 years before the present (BP), and is characterized by the appearance of three artifactual innovations: 1. the presence of "ritual sites" devoted to cave bears and human skulls (Schmidt, 1934; Bergounioux, 1958; Movius, 1953); 2. intentional burial (Swan, 1974, p.151; Solecki, 1975); and 3. the use of natural pigments (Dart and Beaumont, 1969; Singer and Wymer, 1982, p.117). Though the existence of ritual sites is controversial (Trinkaus and Shipman, 1993), intentional burial (Lévêque and Vandermeersch, 1980), and the use of pigments are not disputed. All three artifact classes clearly demonstrate isolation or display of unaltered natural objects (i.e., cave bear skeletons or human skulls, human bodies, and naturally occurring pigments). Thus, Neandertal innovations are naturally explained as examples of protoconcepts, confirming the predicted second step in mental evolution.

The beginning of the Upper-Paleolithic Age, and the dominance of *Homo sapiens sapiens*, is characterized by two classes of nonutilitarian artifacts—personal ornamentation (Leroi-Gourhan, 1961; Marshack, 1972) and statuettes, paintings, and engravings (Capitan and Bouyssonie, 1924; Rieck, 1934). Though the explanation of personal ornamentation is more subtle, involving specification of the uniqueness of an individual, statuettes, paintings and engravings are *prima facie* evidence of contingent conceptualization, being recognizable reproductions in a physical medium. These artifacts confirm the predicted next stage of mental evolution.

In the past these artifacts have commonly been explained as "art," but two prominent features make an aesthetic explanation unsatisfactory. Cave-wall reproductions are characterized by superimposition, often to the point of unrecognizability, and block engravings demonstrate a disregard by the engraver for the finished product (Pales 1976). These factors argue against an aesthetic motivation and for a conceptual one. By analogy, a handwritten note may be overwritten or crumpled and thrown away after use if its purpose is linguistic rather than aesthetic. Similarly, a proto-linguistic explanation of these artifacts is more consistent with the data than an aesthetic one.

The appearance of carved and painted compositional reproductions characterize the final phase of the Upper- Paleolithic Age. (Leroi-Gourhan, 1968; Marshack, 1970) There is some disagreement about compositional cave paintings (Stevens, 1975), but most authorities agree on the compositional nature of carved spear-throwers and carved segments of horn or bone known as bâtons de commandement. The appearance of compositional representations is the predicted consequence of the evolution of an independent physical concept-space.

At the end of the Upper-Paleolithic Age, approximately 12,000 years ago, all forms of naturalistic reproductions disappear. Simultaneously, rapidly advancing mental capacity is evidenced by domestication of plants and animals, and the rise of cities. It has been difficult to reconcile such an advance in material culture with the disappearance of "artistic" expression, since art is often considered to be a mark of higher intellectual function. A change in weather patterns has often been cited as the cause, but similar meteorological events had occurred many times throughout the Upper-

Paleolithic Age without similar cultural effects. (Pfeiffer, 1972) In contrast, exactly these coincident events are predicted by the appearance of the abstract concept-space. The facility, and consequent complexity, of concept manipulation in an abstract space predicts both increasing mental capacities and the simultaneous disappearance of obsolete forms of the concept-space. Language, which is the expression of abstract concepts, rapidly replaces Paleolithic "art," which is the expression of physical concepts.

In summary, the concomitant theory of mental evolution predicts a sequence of archaeologic artifacts corresponding to expression of its hierarchical stages, i.e., display or isolation of unaltered natural objects (protoconceptualization), unitary reproductions of recognizable objects (contingent physical concept-space), compositional works (independent physical concept-space), and the disappearance of these artifacts (abstract concept-space). In the archaeologic record, these, and only these, artifact classes characterize, respectively, the Middle-Paleolithic Age (*Homo sapiens neanderthalensis*, c.100,000 BP), the dawn of the Upper-Paleolithic Age (*Homo sapiens sapiens*, c.40,000 BP), the last phase of the Upper-Paleolithic Age (c.15,000 BP), and the Mesolithic Age (c.12,000 BP). From this perspective, the Upper-Paleolithic Age is the time during which physically modern man was developing mentally modern capacities—a development that took nearly 30,000 years. Archaeologic correlations provide corroboratory evidence for the theory of mental evolution, and the theory provides an explanation of the individual artifact classes and their sequence.

Conclusion

Hughlings Jackson laid the groundwork for a consistent and accurate scientific discipline by separating sensorimotor functions from mental functions, and believed that a doctrine of concomitance described their relationship. When applied to his theory of brain evolution, a structure for the mind results which predicts the expression of subconscious mental states in brain-damaged patients. When Hughlings Jackson failed to observe these states, he rejected the logical consequence of his own ideas. However, this rejection was based on a simple analytic error. A more general interpretation of concomitance results in a theory of mental evolution that is consistent with Hughlings Jackson's approach and has heuristic consequences.

This example demonstrates that history can be used as a tool to investigate modern scientific problems. In this case, an historical analysis of Hughlings Jackson's ideas yields a predictive theory of mental evolution.

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Appendix 1

An Astrobiological Theorem[144]

Abstract: The structure of the human brain reflects multifarious random influences of terrestrial and phylogenetic history, yet the higher mental functions correlated with this unique cerebral neurophysiology are generally assumed to embody universals common to intelligences independent of biological substrate. This assumption is deeply embedded in scientific and popular cultures and is the axiom of scientific programs such as the search for extraterrestrial intelligence (SETI). However, this idea has not been explicitly investigated. The present study proves that any sufficiently advanced organism of non-zero, finite volume (with boundary) must have a 'natural' logic equivalent to sentential (propositional) calculus (SC). This commonalty arises from the essential transduction from external to internal milieu that must occur at any organism's boundary surface. This transduction encodes SC in sensory data and the proof demonstrates that any internal inductive construct—including mathematics and physics—inherits this logical bias. The topological origin of deductive logic not only demonstrates a universal commonality subject to very weak constraints, but also demonstrates a surprising biological origin of foundational principles in mathematics and physics.

Introduction and Axioms

The demonstration of a commonalty of logical structures in arbitrary organisms under weak topological constraints is in two parts. The first is a proof that the process of transduction from external to internal milieu encodes sentential calculus (SC) in sensory data. It is well known that SC is quite robust, and appears in many guises—probably most familiar in switching circuits, as shown by Claude Shannon in his 1937 Master's thesis [1]. Therefore, the proof that sensory transduction is equivalent to SC—though necessary, and occupying the bulk of the paper—is not particularly

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surprising. The second part—containing the astrobiological significance of this equivalence—arises from a demonstration of the persistence of the logical bias of SC in all inductive constructs of an organism that form its internal model of the external world. The first axiom of this analysis is that the external world can be known only as such an internally constructed model. The second axiom is that the internal model is ordinally and inductively derived—i.e., each level of increasing complexity results from an equivalence identified in a preceding stage. However, particular details of the model's construction—and its many additional consequences [2,3,4]—are not directly relevant to the current proof. Given the two axioms, the theorem demonstrates that topological exigencies impose a commonalty of logic shared by any physical organism.

Though the conclusion of this proof is consistent with the orthodox assumption of a commonalty amongst diverse intelligences, this agreement is fortuitous and actually arises by correcting an error in the common view. Though rarely, if ever discussed, natural scientists implicitly consider the external world and its internal model to be isomorphic—informally, interchangeable or equivalent. Therefore, an alternate intelligence observing the same universe should share the more abstract (and non-idiosyncratic) elements of the internal model, e.g., mathematics and physics, and it has been traditionally thought that effective communication with such an organism would proceed by use of these disciplines. However, this fundamental assumption—i.e., the isomorphism of external world and internal model—is, in fact, incorrect. The functional relationship between the external and internal worlds is actually the composition of two maps—decomposition (discretization/transduction) and reconstruction. Since the former of these has no inverse, an isomorphism cannot exist, and the external universe and its internal model are incommensurable. Therefore, any extrapolations from human perspectives cannot be assumed, but must be carefully verified. Subject to weak topological constraints, this proof demonstrates that there is a commonalty underlying any organisms' internal model of the universe, but its origin is entirely distinct from that currently supposed, and as a result, the proof has consequences for the sciences of mathematics and physics that have not been recognized.

The topological origin of SC has other consequences independent of the existence of extraterrestrial, or alternate, intelligence. The theorem provides new perspectives on classic problems in natural science and mathematics, in particular, the nature of mathematical forms, and the utility of mathematics in physics. The biological origin of these perspectives identifies an unexpected and interesting connection between fundamental sciences.

The proof originates in the observation that any organism can know the external world solely as an internally constructed model. A prerequisite for such a reconstruction is a process of transduction at the interface between external and internal worlds—a boundary that must exist in any physical organism. In humans, the sensory organs perform this function. The transduction apparatus converts a small portion of the multifarious ambient information into a common internal form (e.g., bioelectric impulses) from which the external world is internally reconstructed. The external world must be discretized, selectively filtered, and internally reassembled before it is knowable, and this process has consequences that can be formally analyzed.

Overview

This investigation first generalizes aspects of human sensory transduction that apply to any organism. The external stimulation of an arbitrary organism becomes a pattern of activation of its transducing units. Some complex patterns of stimulation will be identical to less complex patterns, while others may not be so reducible. Analysis of the equivalence of activation patterns by formal rules that characterize the transduction process results in a calculus of stimuli.

After interpreting its symbols, the calculus is proved to be equivalent to the sentential calculus of deductive logic. This shows that transduction creates a logical structure that is embedded at the first stage of perception of the external world. It is then demonstrated that any inductive construct internally created from sensory data must preserve the calculus of stimuli, and thereby preserve the logical bias established by sensory transduction. An astrobiological theorem results from the essential nature of transduction for any organism whose structure satisfies very weak topological constraints.

The proof, then, consists of the following steps: first, abstract principles common to all systems of sensory transduction are isolated; second, a calculus of stimuli is presented that identifies the equivalence of different activation patterns; third, the symbols of the calculus are interpreted; fourth, it is proven that under this interpretation the calculus of stimuli is equivalent to SC; fifth, it is proven that any inductive constructs created from sensory data retain the logical bias of SC; finally, it is concluded that any sentient physical organism must have a system of logic equivalent to SC.

A Generalized System of Sensation

Sensory transduction is the discrete filtering of continuous and diverse external information into a common internal mode from which the external world can be reconstructed. The filtering is accomplished by activation of a set of reactive elements of an organism in response to specific external stimuli. Activation of one element may result in the inhibition or activation of other elements, by its action alone or by summation with other elements. In order to account for interactions of basic transducing elements, a transducing unit will be defined as a collection of interacting elements. Any element may be its own unit, as well as part of many other units. The specific details of the structure of transducing units, however, are not germane to the present analysis. The calculus depends on only two fundamental aspects of transduction—1. activation of a transducing unit can be considered a binary process, wherein the unit is either active or not, and 2. different patterns of activation are equivalent. Note that any logical constraints imposed by the binary case apply equally to a system with graded responses of the transducing units since this circumstance is described by the conjunction of the propositions (unit 'a' is active) & (unit 'a' has output 'x').

A Calculus of Stimuli

In the following, set-theoretic symbols are used for clarity and convenience, but the use is mereologic—the symbols refer to actual physical objects, and parts of these objects. Let $A^* = \{a^*_i\}_{i\in\omega}$ be the transducing units of an arbitrary organism. For each finite organism there will be an 'n' such that $a^*_i = \emptyset$ for $i>n$. Let $\wp(A^*)$ = power set of A^*. Let activation of a transducing unit a^*_i be denoted by a_i. Note that if $a^*_i = \emptyset$, then $a_i = \emptyset$.

Activation of a transducing unit is evidenced by output from the unit. Let the following two operations be defined:

1. $a_i\, a_j$ - concatenation, simultaneously activating a^*_i and a^*_j, concatenation is commutative (comm). In the set $\wp(A^*)$, this means activating the element $(a^*_i) \cup (a^*_j)$ where the union is in $\wp(A^*)$.

2. $[a_i]$ - complement, activating $p^* \in \wp(A^*)$ such that $p^* = A^* \setminus a^*_i$ with "=" meaning "the same element as" in $\wp(A^*)$.

A stimulus can now be defined as follows:

1. a_i is a stimulus
2. $[a_i]$ is a stimulus
3. $a_i\ a_j$ is a stimulus
4. any finite application of 1-3 is a stimulus

Let a,b,c,...,etc. represent stimuli generated by the above rules.

With "=" meaning "the same pattern of activation as," with "A" representing activation of the entire set A*, and with Ø representing absence of activation of any element of A*, the following primitive equalities, which characterize transduction, are easily verified as consequences of the definitions of concatenation and complementation:

I. a a = a

II. [[a]] = a

III. [a] a = A, [[a] a] = Ø

IV. A a = a A = A, Ø a= a Ø= a

V. [a b] b = [a] b

Activation of the entire set A* and the empty activation, Ø, cannot be obtained by a finite application of rules 1-3 above and therefore as stimuli, A and Ø are used as diminutives for the identities, A ≡ [a] a, and Ø ≡ [[a] a].

Any stimulus can be reduced to an irreducible stimulus by the application of I-V above. Some stimuli are reducible to activation of the entire set A*, and some are reducible to the empty activation, Ø. The collection of stimuli that reduce to the stimulus, A, by application of I-V, I will call STIM$_A$. As examples, I will now reduce the following seven stimuli, the choice of which will be clear shortly:

1. [a] [b] a:

[a] [b] a = [a] a [b]	comm
[a] a [b] = A [b]	III.
A [b] = A	IV.

2. [[a] [b] c] [[a] b] [a] c:
    [[a] [b] c][[a] b] [a] c = [[a] [b] c] [b [a]] [a] c comm
    [[a] [b] c] [b [a]] [a] c = [[a] [b] c] [b] [a] c V.
    [[a] [b] c] [b] [a] c = [[a] [b] c] [a] [b] c comm
    let d = [a] [b] c, then
    [d] d = A III.

3. [[[a]] [b]] [b] a:
    [[[a]] [b]] [b] a = [a [b]] [b] a II.
    [a [b]] [b] a = [a [b]] a [b] comm
    let c = a [b], then
    [c] c = A III.

4. [[[a] [b]]] a, or [[[a] [b]]] b:
    [[[a] [b]]] a = [a] [b] a II.
    [a] [b] a = [a] a [b] comm
    [a] a [b] = A [b] III.
    A [b] = A IV.

5. [[c] a] [[c] b] [c] [[a] [b]]:
    [[c] a] [[c] b] [c] [[a] [b]] = [[c] a] [b [c]] [c] [[a] [b]] comm
    [[c] a] [b [c]] [c] [[a] [b]] = [[c] a] [b] [c] [[a] [b]] V.
    [[c] a] [b] [c] [[a] [b]] = [a [c]] [c] [b] [[a] [b]] comm
    [a [c]] [c] [b] [[a] [b]] = [c] [a] [b] [[a] [b]] V., comm
    let d = [a] [b], then
    [c] d [d] = [c] [d] d = [c] A comm, III.
    [c] A = A IV.

6. [a] a b, or [b] a b:
    [a] a b = A b III.
    A b = A IV.

7. [[a] c] [[b] c] [a b] c:
    [[a] c] [[b] c] [a b] c = [[a] c] [[b] c] c [a b] comm
    [[a] c] [[b] c] c [a b] = [[a] c] [[b]] c [a b] V.
    [[a] c] b c [a b] = [[a] c] c b [a b] II., comm
    [[a] c] c b [a b] = [[a]] c b [a b] V.
    [[a]] c b [a b] = a c b [a b] II.
    a c b [a b] = [a b] a b c comm
    let d = a b, then
    [d] d c = A c III.
    A c = A IV.

An Interpretation of the Calculus

The symbols of the calculus of stimuli can be interpreted in the following manner:

1. let $\{a_i\}_{i\in\omega}$ be identified with the set of sentential variables $\{p_i\}_{i\in\omega}$
2. let concatenation be interpreted as the logical connective "or," i.e., $a_i\ a_j \equiv p_i \vee p_j$ where 'a_i' is identified with 'p_i' and 'a_j' with 'p_j'
3. let [ ] be interpreted as the logical connective "not," i.e., $[a_i] \equiv \sim p_i$ then,
4. the logical connective "and" becomes, $p_i \wedge p_j \equiv [[a_i]\ [a_j]]$
5. the logical connective 'imply' becomes $p_i \rightarrow p_j \equiv [a_i]\ a_j$

Note that for any realization, R, of SC, $R(f_A) = \mathbf{1}$ and $R(f_{\emptyset}) = \mathbf{0}$, where f_A and $f_{\emptyset}$ are the formulas of SC obtained from $A \equiv [a]\ a$, and $\emptyset \equiv [[a]\ a]$.

The common properties of the logical connectives are retained in this interpretation, and any stimulus can be translated into a formula and vice versa. It must be shown, however, that the translations are unambiguous, and, more importantly, that reduction of a stimulus preserves the realization of the translated formula.

Equivalence of the Calculus of Stimuli and SC

Lemma 1

Every stimulus translates to a unique formula of SC, and vice versa.

pf: The proof is by induction on the number of logical connectives and elementary operations.

1. Every formula translates to a unique stimulus.
   a. sentential variables translate to atomic stimuli, $p_i \rightarrow a_i$
   b. suppose that ϕ and ψ translate uniquely to a and b, then $\phi \vee \psi$ and $\sim\phi$ also translate uniquely.
      1. $\phi \vee \psi$ translates uniquely to a b
      2. $\sim\phi$ translates uniquely to [a]
2. Every stimulus translates to a unique formula.
   a. atomic stimuli translate to sentential variables, $a_i \rightarrow p_i$
   b. suppose that a and b translate uniquely to ϕ and ψ, then a b and [a] also translate uniquely.
      1. a b translates uniquely to $\phi \vee \psi$
      2. [a] translates uniquely to $\sim\phi$

Lemma 2

Reduction of a stimulus s preserves the realization of f_s, the formula of SC derived from s.

pf: It must be shown that $R(f_s)= R(f_{s'})$ if s reduces to s' by application of rules I-V. The number of applications of I-V in the reduction of s to s' is finite since s is finite. If each reduction can be shown to preserve realization, $R(f_s)=R(f_{s1})=...=R(f_{sn})=R(f_{s'})$ and, therefore, $R(f_s)= R(f_{s'})$. It suffices to show both sides of the equality sign in I-V have the same realization. The symbols $\wedge$ and $\vee$ are the operations meet and join when connecting realizations, and R^c is the complement of R, both in the Boolean Algebra, **2**.

I. $R(f_a\vee f_a)= R(f_a) \vee R(f_a)= R(f_a)$

II. $R(\sim(\sim f_a))= R(\sim f_a)^c= R(f_a)^{cc}=R(f_a)$

III. $R(\sim f_a\vee f_a)= R(f_a)^c \vee R(f_a)=\mathbf{1}= R(f_A)$

$R(\sim(\sim f_a \vee f_a))= R(\sim f_a \vee f_a)c= (R(f_a)^c \vee R(f_a))^c= \mathbf{1}^c= \mathbf{0}= R(f_Ø)$

IV. $R(f_A) \vee R(f_a)= \mathbf{1}\vee R(f_a)= R(f_a) \vee\mathbf{1}= R(f_A)$

$R(f_Ø) \vee R(f_a)= \mathbf{0} \vee R(f_a)= R(f_a) \vee \mathbf{0} = R(f_a)$

V. $R(\sim(f_a\vee f_b)\vee f_b)= R(\sim(f_a\vee f_b))\vee R(f_b)= (R(\sim f_a)\wedge R(\sim f_b)) \vee R(f_b)= (R(\sim f_a)\vee R(f_b)\wedge (R(f_b))^c\vee R(f_b))= (R(\sim f_a)\vee R(f_b))\wedge \mathbf{1}= R(\sim f_a)\vee R(f_b)= R(\sim f_a\vee f_b)$

If R is any realization of SC, and if a stimulus, s, reduces to A, then $R(f_s)= \mathbf{1}$.

pf. Let s'= A in Lemma 2, then $R(f_s)= R(f_A)$. But, $R(f_A)= \mathbf{1}$. Therefore, $R(f_s)=\mathbf{1}$.

The seven previous stimuli examples can now be translated as:

1. $\phi\rightarrow (\psi\rightarrow\phi)$
2. $[\phi\rightarrow(\psi\rightarrow\chi)]\rightarrow[(\phi\rightarrow\psi)\rightarrow(\phi\rightarrow\chi)]$
3. $(\sim\phi\rightarrow\sim\psi)\rightarrow(\psi\rightarrow\phi)$
4. $(\phi\wedge\psi)\rightarrow\phi$, ορ $(\phi\wedge\psi)\rightarrow\psi$
5. $[\chi\rightarrow\phi]\rightarrow[(\chi\rightarrow\psi)\rightarrow(\chi\rightarrow[\phi\wedge\psi])]$
6. $\phi\rightarrow(\phi\vee\psi)$, ορ $\psi\rightarrow(\phi\vee\psi)$
7. $[\phi\rightarrow\chi]\rightarrow[(\psi\rightarrow\chi)\rightarrow([\phi\vee\psi]\rightarrow\chi)]$

The preceding is an axiom system for SC [6]. In other words, the axioms of SC when translated are elements of $STIM_A$.

I will now show that the collection $STIM_A$ and the collection of provable propositions of SC (PROV) are identical under the translation described. Since SC is complete, this will demonstrate that PROV = $STIM_A$ = TAUT, where TAUT is the collection of tautologies of SC. In conjunction with the preceding Lemmas, this will demonstrate that the calculus of stimuli is equivalent to SC.

Theorem 1

PROV $\supseteq$ $STIM_A$

pf: It must be shown that any stimulus that reduces to A translates to a provable formula of SC.

a. the stimulus may translate to an axiom of SC in which case the proof is complete.

b. if the stimulus, s, does not translate to an axiom of SC, then let the formula it translates to be fs. Let R be any realization of SC. $R(f_A)$ =**1**, and since s reduces to A, by Lemma 3, $R(f_s)$ =**1**. That is, $f_s \in$TAUT. But SC is complete, so TAUT = PROV. Therefore, $f_s \in$PROV, and

PROV $\supseteq$ $STIM_A$.

Theorem 2

$STIM_A$ $\supseteq$ PROV

pf. It must be shown that any provable formula of SC translates to a stimulus that reduces to A.

This will be proved by induction on the length of proof, i.e., either the provable formula is an axiom of SC, or if f translates to a stimulus, s; f→g translates to a stimulus, s'; and g, translates to a stimulus, t; and both s and s' reduce to A, then t also must reduce to A.

a. all axioms when translated to a stimulus reduce to A as shown in the seven examples of the first section.

b. f translates to s reduces to A and g translates to t. Since f→g reduces to A, [s] t = A. But s reduces to A so [A] t = A. [A] = Ø, so Ø t= A and therefore, t = A, and

$STIM_A$ $\supseteq$ PROV.

Theorem 3

PROV = $STIM_A$ = TAUT

pf: PROV = TAUT by completeness of SC. Theorems 1 and 2 indicate $STIM_A$ = PROV. Therefore,

PROV = $STIM_A$ = TAUT.

The preceding accounts for all of the necessary preliminaries for one result of this development.

Theorem 4

The calculus of stimuli is equivalent to SC

pf. Interpret the calculus of stimuli as described and apply Lemma 1 and Theorem 3.

Though this assures the equivalence of SC and the calculus of stimuli, it does not imply that the inductive constructs—including the natural sciences—derived from sensory data necessarily retain this logical bias. It is this latter fact that ensures the commonalty of logic underlying the models of the external universe created by organisms satisfying very weak topological constraints.

An Astrobiological Theorem

This proof is based on two axioms: 1. the external world can be known only as an internal model, and 2. each stage of model-building is inductive—i.e., the process of increasing complexity is successive identification of equivalence. The first stage of internal reconstruction of the external ambience involves the identification of separate objects within the global patterns of activation. It first must be shown that objects, as equivalence classes of subsets of the global patterns of activation, retain the logical bias of the calculus of stimuli. It then must be proven that any further inductions derived from objects preserve the calculus of stimuli.

Theorem 5

Any internal inductive construct derived from sensory data preserves the calculus of stimuli.

pf. Proof is by induction on the length of the inductive chain.

1. Let $\sum_1, \ldots, \sum_n$ represent separate patterns of global activation of the same organism so that they represent different

activations of the same set of transducing units, A*. Let $a_1 \subseteq \sum_1$, … , $a_n \subseteq \sum_n$ be "n" stimuli that are identified as representing the same object. I.e., $a_1 \approx_i \ldots \approx_i a_n$ where "$\approx_i$" means equivalent under the induction "i." By definition, the equivalence relation "$\approx_i$" must contain all elements that are shared by a_1 ,… , a_n i.e., the conjunction of a_1, …, a_n. It must be shown that if a_1, … , a_n are described by the calculus of stimuli, then so is $[[a_1] \ldots [a_n]]$. The stimulus $[[a_1] \ldots [a_n]]$ is a pattern of activation of A*. Since $a_m \subseteq \sum_m$ of A* is a stimulus for m=1, … , n, successive applications of rules 2 and 3 imply $[[a_1] \ldots [a_n]]$ is a stimulus. By above theorems and lemmas, the equivalence class induced by "$\approx_i$" preserves the calculus of stimuli.

2. Let P_1, … ,P_r be equivalence classes obtained by a sequence of inductions "$\approx_{iP11} \ldots \approx_{iP1s}$" , … ,"$\approx_{iPr1} \ldots \approx_{iPrt}$" respectively. Each $\eta_m \in P_m$ for m=1, … , r is of the form $(a_1 \approx_{iP11} \ldots \approx_{iP1s} \eta_1)$, … , $(a_r \approx_{iPr1} \ldots \approx_{iPrt} \eta_r)$ for some patterns of activation of the transducing units, a_1, … , a_r. The calculus of stimuli is retained in P_1, … , P_r by assumption and, therefore, η_1, … , η_r are valid stimuli. Let R be an equivalence class of P_1, … , P_r under some equivalence relation "$\approx$", then it must be shown that the calculus of stimuli is retained in R. Now R must contain some shared elements of P_1, … , P_r under "$\approx$", i.e., for some $\zeta_1 \in P_1$, … , $\zeta_r \in P_r$ with $\zeta_k \subseteq \eta_k$, $[[\zeta_1] \ldots [\zeta_r]]$ must be shown to be a stimulus. By successive applications of rules 2 and 3 this must be so since all η_1, … , η_r are stimuli (by assumption) and therefore so are ζ_1, … , ζ_r. By preceding theorems and lemmas, the equivalence class R preserves the calculus of stimuli.

The essence of this theorem is that all objects, relationships, and interactions forming the internal model of the external universe constructed from sensory data contain an encoded logic resulting from the necessity of transduction at the boundary surface. Therefore, the laws discovered governing the models of the external world—themselves being inductive constructs—also contain this logical bias.

Theorem 6

Any sufficiently advanced organism of non-zero, finite volume (with boundary) has embedded in its model of the world a logical system equivalent to SC.

pf. Let A* be the set of transducing units of an arbitrary organism. Because an organism of non-zero finite volume (with boundary) must convert the external milieu to an internal one, A* is not empty. Interpret the calculus of stimuli as described, and apply Theorem 4 and 5.

The astrobiological theorem demonstrates that there is a logical bias embedded in the most elementary unit of sensation and that this bias is faithfully transmitted to any internal inductive construct originating in sensory transduction. By the theorem's axioms, all that can be known of the external world is such an internal model, and this model is inductively created. Therefore, SC forms the 'natural' logic in the model of the world of any organism with a boundary surface. This fact has consequences for a variety of scientific issues and the following comments illustrate different perspectives on some classic problems in mathematics and physics.

Constructive and Formal Mathematics

The relationship between structure and logic identified in the theorem suggests a synthesis of mutually exclusive ideas about the nature of mathematics. For example, the theorem retains the universal nature of mathematical forms found in formal or platonic theories. However, universality is not due to independent external existence of these forms, as platonists generally believe, but rather to a universal necessity to convert the external world to an internal one. Conversely, an epistemological origin of mathematics is confirmed, supporting constructive notions, but this is not a purely human limitation, as the constructivists imply, since it applies to any physical organism. Finally, intuitionist philosophies contend that logic is derived from experiential, finitary mathematics and is not reliably applied to infinitary cases. This results in the distrust of indirect proofs and such logical principles as the excluded middle. The theorem again suggests areas of agreement and disagreement with this philosophy. Contrary to the intuitionist view, logic is synthetic *a priori* relative to mathematics since it arises from the physical structures of sensation. However, it is exactly this origin in the objects of perception that would seem to limit its reliable utility to the finitary perceptible universe, in agreement with the intuitionist viewpoint.

In summary, an attractive aspect of the astrobiological theorem is the synthesis it offers for several disparate ideas about the nature of mathematics. Perspectives that were mutually exclusive are shown to arise as simply a difference in emphasis within a more general structure.

Utility of Mathematics in Physics

Eugene Wigner (1902-1995) eloquently expressed the perplexity engendered by the apparently fortuitous utility of mathematics in physics [7]. This has become even more apparent in string theories in which, apparently, the only reality is the mathematics. The astrobiological theorem may suggest, at least phenomenologically, why this relationship exists. Since a logical system is embedded in the most elementary form of perception, any inductive structure internally reconstructed from these elementary percepts, including physics, is subject to this initial constraint. However, this same constraint, being metamathematical, limits the (natural) deductive forms of mathematics. This, of course, does not impy that other logical systems cannot be conceived and investigated, as obviously is the case, but rather that SC is, in a sense, a 'natural' logic that is a consequence of physical structure. In this interpretation, the utility of mathematics in physics is due to a similar logic embedded at the first stage of perception. Physics, which describes the external world, and mathematics, which some believe is a human creation, are coherent because both contain a logic whose origin is a consequence of physical, topological structure.

Quantum Mechanics

The mathematical description of non-relativistic quantum mechanics was completed in 1925 superseding the collection of empirical observations and *ad hoc* assumptions known as the old quantum theory [8,9,10]. Upon completion of this project it was realized that the formal structure contained significant interpretive problems. The explanation of these difficulties engaged the greatest scientific minds of the previous century, without satisfactory resolution [11,12,13].

The Copenhagen interpretation of quantum mechanics [9], supported by experimental violation of Bell's inequalities [14], implies that there is a fundamental interaction between perception and reality as manifested, for example, in measurement systems, non-local causality, and the reality of unobserved quantum processes. However, this explanation is verified only by the phenomena it is supposed to explain—there is no independent evidence that such an interaction is possible. Of course, it is not essential that other similar processes be known. On the other hand, the astrobiological theorem does provide independent evidence supporting the possibility of such an interaction. By explicitly demonstrating a logical bias introduced by physical structure, it provides a particular example of a constraint on observable reality imposed by perception.

Conclusion

An abstract description of the process of sensation is shown to be equivalent to the logic of sentences. In this way, SC can be considered a consequence of physical structure. This logical bias is faithfully preserved in any internal inductive constructs based on sensory data, and therefore, any sufficiently advanced physical organism will share a form of SC. This proves a theorem about extraterrestrial intelligence. In addition, the formal consequences identified by the theorem suggests new interpretations and, therefore, new areas of research in physics and mathematics.

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APPENDIX 2

THE ORIGIN AND NATURE OF TIME

The Neurology of Time[145]

Abstract: This investigation unifies and explains the different characteristics of time by carefully examining the stepwise construction of an internal model of the external world. An attempt to clarify the nature, origin, and types of time from a neurological perspective is heterodox, but, since the external world can be known only as an internal reconstruction, and since the reconstruction machinery is neurological, this—a relation traditionally considered to be unequal or nonexistent. Since the birth of western philosophy in ancient Greece, an understanding of objects and time has been sought in their ontology—i.e., whether they are real or ideal—and as a consequence their relationship, if any, has been subordinate. However, the process of internal reconstruction demonstrates that objects and time are complementary in the rigorous sense of the term—both arise from a single neurological process. This common origin suggests a hierarchy of types of time concomitant with a hierarchy of increasing generalization of objects. The elements of this hierarchy will be seen to correspond to types of time that have been previously identified.

Introduction

The nature and origin of time have been topics of scientific and popular interest for millennia. Within these discussions, a consistent source of confusion is the conflation of several distinct aspects of temporality, presumably as a result of their inclusion under the common term *time*. The least ambiguous appearance of time is as a mathematical variable in physical theories, and it may seem strange to seek a general explanation within the medical science of neurology. However, knowledge of the external world can only be obtained through an internally constructed

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model—including all physical theories and their components—and the substrate of that internal model is neurological.

The fundamental elements of physical theories are defined by their characteristics within the theoretical structures. When the explanatory power and predictive accuracy of a theory is demonstrated, its component elements, as defined, tend to be accepted as real. One result of this process is what has been called the disappearance of time.[146] In the twentieth century, time as defined in the theories of relativity has banished the notion of an universal 'now', and has been incorporated on a nearly equal metaphysical basis to space.[147] Even more destructive to an unification of the experiential and natural aspects of temporality have been the advances in dynamical quantum theories. A Lagrangian, or "action," approach first devised by Richard Feynman (1918-1988) in his pioneering work on quantum electrodynamics (QED) defines a frozen spatiotemporal universe in which paths directed forward and backwards in time are essential for calculation of finite interaction matrix elements.[148] Though Hamiltonian formulations of QED have also been proposed[149], these have proved less heuristic than Feynman's sum-over-paths technique in the development of complete unification schemes such as superstrings.[150]

The progressive exclusion of the experiential character of time has been disturbing to some philosophically-minded physicists and mathematicians. In particular, Kurt Gödel (1906-1978) believed this fact alone indicated that time in our universe cannot be real.[151] Whether real or ideal, the concern with temporality has most often been ontological. Clearly though, the reality of time as expressed in modern physical theories is progressing in an

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[146] "... it would only be a straightforward continuation of the development from classical physics to relativity theory, if this last objective remnant of time too were to disappear." K Gödel (unpublished) in [1] p.39.

[147] The sole factor distinguishing time from space is the sign in the Minkowski metric.

[148] "This view is quite different from that of the Hamiltonian method which considers the future as developing continuously from out of the past. Here we imagine the entire space-time history laid out, and that we just become aware of increasing portions of it successively." [2].

[149] See Schwinger [3] and Tomonaga [4]. The different approaches to QED were shown to be equivalent by Dyson [5].

[150] See [6].

[151] He demonstrated this by creating a rotating universe solution to the field equations of general relativity in which time as we know it is impossible. Gödel's argument is that if general relativity is the best description of our universe, and if another universe consistent with general relativity is possible that does not allow time, then temporality must be inessential, and hence ideal. See Gödel [7] p.202.

incorrect direction for an unified explanation of its diverse aspects. For this reason I have chosen an approach to an unification of experiential and natural time in which ontological questions are ignored. That is, the following discussion is valid whether or not time is real or ideal.

I will demonstrate that different characteristics of time appear as a natural consequence of an internal reconstruction of the external universe.[152] I will show that sensible objects and time are complementary in the rigorous sense of the term—both arise from a single process. This common origin suggests a hierarchy of temporal types concomitant with a hierarchy of increasing generalization of objects. The elements of this hierarchy will be seen to correspond to previously identified aspects of time.

Evolution of the Idea of Time

Time, as presently understood, includes at least three distinct characteristics[153]—duration or persistence, a relational structure of before and after (B-series), and the *nunc fluens* of past, present, and future (A-series).[154] The evolution of the idea of time in western natural philosophy can be seen as the amalgamation of the metaphysical independence from sensible objects of duration with the measurability of the B-series, and the denial of the A-series. The character of the different aspects of time, and the process by which they have reached their present status, is best appreciated by a brief historical recapitulation.

For the pre-Aristotelian Greeks, duration was not a part of time and was by definition unmeasurable. It was considered to be an attribute of an undifferentiated pre-universe and was therefore metaphysically independent of all elements of the perceptible universe.[155] Time (*chronos*) was, on the

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[152] How external temporality is reflected in sensory data is the only ontological question about time which is germane to the present argument. For the present purpose, it is possible to remain agnostic about time's reality or ideality, however, since I will show that the types of time can be explained without reference to its ontology.

[153] Other types of time have been identified. See [8] for a complete discussion.

[154] JME McTaggart (1866-1925) in [9] separates time into a fixed universal B-series of before and after, and a perpetually flowing universal A-series of past, present, and future. McTaggart's A- and B-series are universal in the sense that they exist independent of our perception of them, though he used this fact to attempt to prove time is not real. In his system, duration is incorporated into B-series time. McTaggart's classification will be used in the rest of this paper, though the A-series as here defined cannot be universal.

[155] "... it was movement or duration without beginning, end, or internal division - not time ... but only the shapeless and unformed raw material of time…" [10] vol.I p340.

other hand, defined as the measure of motion and could not exist in the absence of motion. Thus, time was a metaphysical subordinate to sensible objects.[156] A- and B-series time are arguably present in the philosophies of Plato and Aristotle, although there is no recognition that these two characteristics are separable.

Duration, as a principle distinct from time, can be traced from the Milesian Anaximander (c.600 B.C.) through Pythagoras (c.570-c.500 B.C.) and the Pythagoreans, to Plato (427-347 B.C.). A common belief of these philosophers is that the perceptible universe is formed from a timeless primordial material that is in sempiternal, unmeasurable, motion. Duration is a fundamental property of this primeval substance.

Anaximander was, like the other Milesians, a monist who believed the universe is composed of a single element (*arche*), which he termed the *apeiron* (unlimited).[157] The *apeiron* is timeless, though constantly moving.[158] Out of the *apeiron* is distilled the physical universe, and time appears as measurement of the orderly motion of the heavenly bodies.[159] Anaximander does not describe how an undifferentiated and unlimited *arche* becomes differentiated and limited, but this problem is explored by Pythagoras and the Pythagorean school. The Pythagoreans believed the *apeiron* is unformed matter and unformed time, not delimited by number or structure. The *peras*, or limit, by drawing from the *apeiron*, imposes number, which is the structure of physical objects, and the measure, which is time.[160] Plato believed that motion existed before the universe in an unmeasurable and timeless chaos,[161] while time is the measure of motion and came into being with the perceptible universe.[162]

Aristotle (384-322 B.C.) rejected the existence of a primordial *arche,* i.e., he believed the sensible universe is uncreated and eternal.[163] In this he followed the presocratic philosopher Parmenides (c.515-c.450 B.C.).[164] He

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156 For the Greeks, a universe of objects was conceivable without time, but no universe of time was possible without objects. Motion without time was not intrinsically contradictory, but time without motion was impossible. Cf. *ibid.* p.338.
157 For Thales the arche was water, for Anaximenes, air. See [11] p.22-27.
158 Cf. [10] vol.I p.337.
159 Cf. *ibid.* p.87.
160 [12] p.46.
161 Timaeus 30 A [13] p.55.
162 Timaeus 37 D,E [13] p.77.
163 On the Heavens I, xii, [14] pp. 111-129.
164 Parmenides rejected the notion of apeiron, recognizing that the physical universe required an external source upon which to draw only if it was incomplete in itself. He consistently emphasizes the peirata, or limits, as the ultimate timeless reality of objects and suggests that change or becoming is an illusion - as is time which is the

therefore did not accept a metaphysically independent notion of duration separate from time. Instead, his arguments appear to define duration as a standard measure, i.e., a B-series element.[165] Thus, at the beginning of western philosophy, polar positions on time and duration were posed—a metaphysically independent duration, unmeasurable and separate from B-series time, and duration that is incorporated in B-series time, metaphysically subordinate to sensible objects.

Time as the measure of motion is B-series time. No extant comments on a potentially divisible structure of time (A-series and B-series) exist before Plato. In Plato's dialogues, and to a somewhat greater extent in Aristotle, recognition of A-series temporal characteristics first appear. There is no clear distinction between the A- and B-series, however, and even their presence is subject to some ambiguity. Plato recognizes past, present, and future as aspects of Becoming, and refers to time as a "... movable image of Eternity."[166] To the extent that this refers to a *nunc fluens*, Plato can be said to have identified the A-series. However, in the next passage, he identifies these characteristics as actual motions delimited by number and hence a true A-series is not defined.[167]

Evidence for a recognized *nunc fluens* is stronger in Aristotle than Plato, though it is still equivocal. Aristotle perceives an asymmetry between past and future wherein the past is fixed and the future is substantially undetermined.[168] This progressing asymmetry is interpreted by some as McTaggart's A-series.[169] Though this characteristic is necessary for McTaggart's A-series time, it is not sufficient. For example, the time defined in a Hamiltonian formulation of QED evolves continuously from fixed past to incompletely determined future, but because it is relativistically covariant, it cannot specify an unique *now*, and therefore cannot be an A-series.

In summary, the Greeks recognized atemporal duration as a metaphysically independent entity, and B-series time as the measure of motion, which is

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measure of change. For a discussion of Parmenides' cosmogony, see [10] vol.II p. 48.

[165] See [15].

[166] Timaeus 37D *op. cit.* p.77.

[167] "... 'was' and 'will be,' , on the other hand, are terms properly applicable to the Becoming, which proceeds in Time, since both of these are motions. ... Becoming has attached to the things which move in the world of Sense, these being generated forms of Time, which imitates eternity and circles round according to number." Plato, *ibid.* 38A p.77.

[168] On the heavens I, xii *op. cit.* p.127.

[169] Cf. [15].

metaphysically dependent on objects. Whether Plato and Aristotle recognized A-series time is problematic. I believe both correctly identified characteristics of an experiential *nunc fluens*, but these characteristics are inextricably entwined with measurability and are not unambiguously stated.

The next advance in the natural philosophy of time defines a B-series time nearly independent of objects, thus retaining measurability while approaching the metaphysical independence of duration. This was accomplished by the Scholastic philosopher John Duns Scotus (1266-1308). Duns Scotus amalgamated (B-series) time and duration by using a concept of potential time. He insisted that potential time exists even in the state of absolute rest, and could measure the duration of that rest.[170] However, since the existence of time still depends on the potential for objective motion, Duns Scotus did not completely free temporality from its dependence on objects.[171] Though he does not explicitly discuss A-series time, his successor, Peter Aureol (1280-1322), who adopted the idea of potential time, did mention A-series characteristics.[172] As with Plato and Aristotle, however, he conflates A- and B-series elements.

The advance to a modern view of the natural philosophy of time occurs by the complete separation of measurable time from objects, incorporating the metaphysical independence of duration. Isaac Newton (1642-1727), whose natural philosophy rests upon three fundamental metaphysical principles—absolute motion, absolute space, and absolute time—was responsible for this modern perspective.[173] Absolute time is the measurable time of universal physical theories and "... flows equably without regard to anything external, and by another name it is called duration."[174] In other words, absolute time is an amalgam of duration's metaphysical independence and B-series' measurability. A-series time is not included in this definition (except as conflated in the term *flows*), but is probably part of what Newton calls apparent or common time. Though Newton' `s philosophy is not

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[170] "For even to this uniform immobile existence there corresponds a proper measure, which is time." [16] Question xi, 23 p.263.

[171] "... even if no body is in movement, a body can always behave in the same fashion, while being capable of behaving in one fashion or another... There corresponds to this invariable disposition a proper measure which is a time." [16] p.296.

[172] "On the other hand, the past and future, ... have no being if the mind does not conceive them. Therefore, ... time and movement are beings only in the mind." P Aureol in [17] pp.300-301.

[173] The earliest statement of these principles is probably in the "De gravitatione et aequipondio fluidorum." See [18] pp.121-156.

[174] [19] p.6.

comparable in quality to his physics[175], the notion of a time that is measurable, independent of all else in the universe, and excludes the A-series, is retained in physical theories to this day.

In summary, the evolution of the idea of natural time has followed a consistent trajectory—it has been progressively separated from its dependence on objects while maintaining its measurability. The experiential aspects of time have been suppressed, leaving a temporal structure in modern physical theories in which commonly recognized characteristics have disappeared. In the following section I will attempt to retrieve the experiential character of time while retaining duration and the B-series. The sequence of duration, B-series, and A-series will be shown to be part of a hierarchy corresponding to a similar hierarchy of objects and concepts.

Complementarity of Objects and Time

The perspective of the following is epistemological and evolutionary.[176] I believe that knowledge begins with sense perceptions but that it is not limited to these perceptions. I interpret the *a priori* aspects of knowledge to refer not to specific things that are known, but rather to a functional necessity imposed by the structure of the human organism.[177] In addition, I believe that knowledge is inductively hierarchical, as in Aristotle's relation of objects to concepts.[178] Extending Aristotle's view, I will suggest that the same generalizing function producing concepts from sensible objects also forms sensible objects from undifferentiated sensory data. It is in this latter process that the complementarity of objects and time is found.

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[175] For example, there are difficulties in reconciling the notion of absolute motion and absolute space. Cf. [11] vol.V p.154.

[176] The evolutionary perspective is essential so that the stages of evolution can be seen to arise successively through phylogeny. Thus it is only the simplest cases of objects and concepts that are considered and not the higher-order abstract concepts of modern scientific or philosophic discourse. This investigation is focused on the emergence of temporality in the earliest stages of mental evolution.

[177] This is also the viewpoint of Copleston [11] vol.VI p.57 and is implied by Kant [20] p.25 when he states that *a priori* knowledge results from the "formal capacity of the subject being affected by objects."

[178] "Clearly it must be by induction that we acquire knowledge ... , because this is also the way in which general concepts are conveyed to us by sense perceptions." Post. Anal. II, xix, 100b [21] p.261.

The human sensory apparatus provides a discrete series of "images" of the ambiance.[179] The discrete nature of these global percepts is fundamental[180] and can be best appreciated by an example of visual processing. If visual perception were continuous, then the illusion of continuous motion in a movie would be impossible since its interstices would be perceived. But, these discrete, multi-modal sensory constructs are unrelatable perceptual instants. The perceived continuity of discrete, undifferentiated global percepts requires a generalization that identifies equivalences in their elements.[181]

By identifying an equivalence of specific elements in separate global percepts the process of generalization creates an object and that object's time. Each object is an equivalence class formed by an equivalence relation among elements of the global percepts. Merging elements of separate global percepts "squeezes out" their separateness, since by inducing that the elements are the same object, whatever causes their separate appearance must be excluded. Thus, by forming the category of object, "simultaneously" an additional category is formed—the category consisting of the separateness of the global percepts of the object. The formation of any single object, by an operation of inclusion (sameness), is coupled to an operation of exclusion (separateness) and is sufficient to define this separateness. Separateness is defined individually for each object identified and is what I call object-time. An object and its time are complementary notions since the same process defines them.[182]

With objects of perception defined, a (mental) evolutionary system can be hypothesized so that each step represents an equivalence identified in the preceding stage; first objects are identified (objectification), then categories of similar objects are recognized (categorization), then the equivalence underlying a category is recognized (protoconceptualization), then the

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[179] This metaphor is not accurate in the sense that an image normally presupposes a completed form and someone to look at it. The problems with this type of "Cartesian theater" are discussed in detail in [22]. His argument is not relevant to the present development.

[180] Grünbaum [23] has emphasized the "atomistic" nature of experience, and Whitrow [8] p.74, defines a "mental moment" as the limit of perceptual distinguishability. Reichenbach [24] p.8, also favors this view.

[181] An element in a global percept, that will be generalized to an object, is an intuitively clear but very complex entity. It is beyond the scope of this inquiry to discuss how elements in two percepts could be identified.

[182] Another way of stating this is that identifying elements in separate global percepts gives the element persistence which "simultaneously" defines object and object-time.

equivalence forming a category is defined (conceptualization).[183] A definition of a category's equivalence is a weighted collection of attributes, with an attribute being defined as a special type of maximal category.[184] Recognition of the equivalence underlying a category is the same as recognizing a category's existence independent of its members; definition of the category's equivalence is the same as specifying the category independent of its members.[185] Protoconcepts cannot be manipulated independent of physical objects. Since the equivalence underlying a category is recognized but not specified, only a member of that category (that demonstrates the equivalence) can represent it.[186] A concept is free of physical objects since the equivalence of the category is specified and can be recreated in many forms.[187] An evolutionary advantage of conceptualization

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[183] See Hartman [25] p.220-271 for some arguments against an Aristotelian analysis of objects and concepts. The present system does not require an externally fixed set of concepts to discover and, therefore, Hartman's objections are not transferable to this account. In addition, the present formulation provides a continuity between concepts and pre-conceptual stages thus avoiding the eristic paradox.

[184] Subcategories can be recognized as similarities in separate object categories - for example recognition of a similarity in horse and dog categories leads to recognition of a subcategory of tail. Subcategorization is identical to recognition of fine detail and the more basic a detail, the larger is its equivalence class (e.g., the equivalence class of "tail" contains all object categories that have a tail). A threshold is reached when enough fine detail is recognized to unambiguously specify the equivalence of routinely encountered object categories. The special recognized categories that uniquely decompose these object categories I call attributes. A definition of a category's equivalence is a weighted collection of attributes. For more on these topics, see [26] and [27].

[185] This process is the same as recognizing or specifying that there is a "tree-ness" that is common to all trees, but exists apart from any particular tree. It is the equivalence relation underlying the category of trees. The equivalence is not known, nor does it exist, *a priori* but is created as a product of increasing mental capacity.

[186] The appearance of protoconceptualization in mental evolution would be identified by the isolation or display of unaltered natural objects, indicating that a member of a category is being used to represent the equivalence underlying that category. Exactly such artifacts are first found in the Middle-Paleolithic Age as products of Neanderthal man, i.e., burial and "ritual" sites. See [26].

[187] In modern conscious man, concepts exist in an abstract mental space. Other, physical forms of conceptualization are possible, however, and can be identified in Upper-Paleolithic-Age artifacts. For example, the animal statuettes that first appear in this era are *prima facie* evidence of conceptualization, by this definition, since they must contain adequate attributes to define an animal category if they are recognizable. These topics are discussed in [26].

is the ability to manipulate categories of objects (through their concepts) without manipulating the physical objects that compose them.

Because objects and time are complementary, the evolutionary hierarchy for objects suggests a concomitant hierarchy for time. Object-times, concomitant with objects, are related to durations[188] and characterize the rates of change in the global percepts.[189] Given the collection of object-times (categorization), a further equivalence can be recognized. Recognition of the equivalence of object-times results in what I will call uniform time, concomitant with protoconcepts. That is, uniform time is the recognized nature common to all object-times, and independent of any object-time. It is the common time in which all objects are embedded, but it cannot be manipulated separately from these objects. Uniform time is relational, but not measurable, and is a rudimentary B-series.[190] There is an additional equivalence in the hierarchy of time giving rise to conceptual time. Concomitant with concepts, concept-time is the time of conceptual relations.[191] Conceptual time allows a separable standard duration that can be measured through the concept of number (See note 46). Conceptual time is characterized by a measurable relational structure of events, i.e., before and after, but does not include the *nunc fluens*. In other words, conceptual time is McTaggart's B-series.[192]

There is a privileged category in both object and time sequences that consists of a single object and object-time—the physical body of an individual and its object-time. The category of the object, "me," is

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[188] The duration of object-times is not metaphysically independent of objects, nor is it metaphysically subordinate to objects, it is complementary.

[189] Intuitively, object-time is a ratio of the physiological interval separating global percepts and the degree of change of the object between successive percepts—the faster something changes, the shorter its fundamental duration measured by object-time. An object-time is relative and the standard of reference is that of the perceiver, i.e., the object-time of the object "me."

[190] Measurement requires the concept of number. The protoconcept of a number is a recognized equivalence of categories with equal cardinality, but since it is not defined, it cannot be separately applied for quantification.

[191] A conceptual copy of the perceived world is possible wherein each individual object is represented by its concept (i.e., the specification of the category that consists of only that object). Conceptual time is most simply viewed as the B-series time of this duplicate world.

[192] Conceptual time is internally derived and therefore individual, yet since it is measurable, it can be externalized by the creation of clocks and physical theories. It is the unambiguous correlation between individuals of this externalization that gives conceptual time its existence independent of any individual. This is the origin of the universal character of McTaggart's B-series time.

generalized to the protoconcept, proto-I, and the concept, (the subject) I.[193] This sequence applied to the object-time of "me" gives rise to a *nunc fluens*. This A-series is not universal, rather it is the time of the personal existence, i.e., the time of the concept I. This I-time is the conceptual member of the specific temporal sequence concomitant with me, proto-I, I.

The object-time complementary to the object, me, forms a privileged category with a single member, as does the object category. This object-time provides an unmeasurable standard duration (see note 45). In uniform time, the proto-I is embedded in its B-series of events that forms the life history of the individual. The concept, I, is the locus of direct experience perceived as separate from, but centered in the body. The I-time is the time of this experience, that is, the experiential aspects of the life history as experienced by, I. Since direct experience is of the perpetual now, I-time is of the flowing now, i.e., a personal A-series.

Conclusion

Since ancient Greece, philosophers have been faced with the problem of reconciling seemingly incompatible ideas about time such as the ever-changing structure of events as past, present, and future, and a fixed relational structure of before and after. In addition, there is the metaphysical independence from sensible objects needed for the time of universal physical laws. By viewing the natural philosophy of temporality from an ontological perspective, it has been necessary to exclude A-series time, and merge B-series time and duration. I have suggested that these characteristics of temporality can be retained and unified in an evolutionary hierarchy of increasing generalization.

By extending the relation of sensible objects and concepts to the formation of objects from undifferentiated global percepts, I have shown that objects and time are complementary. A more detailed hierarchy of mental evolution is then hypothesized with the different types of time defined through a concomitant series.

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[193] The protoconcept, or concept, of the single-element category of an individual is the defining characteristics of that individual, just as a protoconcept or concept of the category of horses is the defining characteristics of horses. The proto-I and I exist independently of the object, i.e., independent of the physical body of the individual. Similar to all protoconcepts and concepts, the category gains an existence independent of any member of the category it generalizes. The difference between proto-I and I is only important in this development for the concomitant types of time. It does have archaeologic significance, however. See [26].

The present definitions of characteristics of time differ from previous formulations in two important ways. First, time as duration is not independent of the perceptible universe as in pre-Aristotelian philosophy and post-Newtonian physical theories, nor is it dependent on the objects of perception as in Aristotle, but rather time and objects are complementary. Second, A-series time cannot be universally defined—not because relativity won't allow it, but because it is not possible to define an equivalence of the experience of time between individuals.[194] Thus, the A-series time defined epistemologically is not McTaggart's, though it retains all of his characteristics but universality.

Three fundamental aspects of time are duration, B-series time, and A-series time. In the present analysis these three unique attributes arise in a simple hierarchical sequence. Object-time (duration) arising complementarily to objects, uniform time (B-series) arising from recognizing the equivalence of object-times, and conceptual time (measurable B-series) arising by defining that equivalence. When applied to the privileged category consisting of a single object (the physical body) the conceptual I-time is seen to represent the temporality of experience—the *nunc fluens* and a personal A-series.

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[194] McTaggart's A-series is the commonality of the experience of time existing independent of any particular personal experience of time. That is, it is the equivalence relation underlying the category of all personal A-series. However, since there is no communal mind in which such a category can exist, McTaggart's A-series is impossible at the present stage of mental evolution.

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