Voice Classification by Phonetography

A Manual for Voice Testing, Education, Therapy and Research

Hugo Lycke

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Cambridge Scholars Publishing

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FOREWORD

As a young medical student, I was a member of many singing choirs, giving some solo performances (as a tenor). Taking singing lessons at the local music academy with some minor voice problems as an unexpected result, provided my first insight about the possible importance of an exact voice classification.

As a fervent opera, operetta and musical lover, I attended many theatrical performances in different European countries. For many years I was an active member of 'Youth Opera' , E.C.O.V. (European Centre for Opera and Vocal Arts), and the study-group "Musical Theatre", both situated in my native city Ghent (Belgium). These experiences allowed me to get in contact with the world of theatre and also had an impact on the choice of my future studies. So, in 1963 I graduated as a Speech-Voice-Language Therapist, at the H.R.P.B., A.Z. University Ghent, on a rather atypical thesis: "The Dysodia - functional disorders of the singing voice".

As a secretary of the Belgian Professional Association for Speech Therapists for many years, with a special mandate for the organization of national and international conferences, I noticed, to my great consternation, that less than 5% of all speech therapists and E.N.T. specialists were really interested in the singing voice. That's why, being invited to give an academic speech at the Royal Conservatory of Ghent (1975), in the presence of the Belgian Minister of Education, I launched the term "*the missing link*" to situate the important role of a specialized speech and voice therapist between the singing teacher and the E.N.T. specialist.

A few years later I did a lot of vocal tests with opera singers during the "Wagner-Festspiele", Internationales Jugendfestspieltreffen, Bayreuth, (Germany). Meanwhile, I participated as a choral member in the production: "Acis und Galathea" (G.F. Haendel) and I attended many conferences and masterclasses.

While at that time voice testing manuals only mentioned if the voice was normal, soft, or loud, my first experience as a student with the use of an old complex decibel meter convinced me about the importance of measuring vocal intensity in an objective way. So, after having carried out my first phonetograms in 1963, I strongly advised in my thesis that this method should be refined in future voice investigations, "by measuring the voice intensity of each tone and each half tone of the whole voice range and of all vowels, in order to obtain *a typical curve for each voice type*, thus largely facilitating the troublesome "voice classification.". This was quite a statement from a young student at that time!

It wasn't until 1968 that Waar and Damsté drew the attention of people working in the field of voice on the possibility of combining the measurement of pitch (frequency) and loudness (vocal intensity). They called the graphic result of this measurement a "phonetogram". Other names for this procedure are: Voice Area (Measurement), Voice Profile Measurement, F°-SPL Measurement, F°-SPL Profile, Voice (Range) Profile, Phonetography, Phonogram, Voice Field, Fundamental Frequency-Intensity Profile, Voice Curve, courbes vocales, Stimmfeld...

From 1978 on, the U.E.P (Union of European Phoniatricians) advised "Schallpegelmessung" as "one of the, in all cases, essential methods for the diagnosis of voice disorders, although the technical or methodological development of phonetography is not yet completed".

I witnessed the upcoming interest of the scientific world in the seventies and eighties for the many aspects of the singing voice. I became a founding member of the "International Association for Experimental Research in Singing" at the 90^{th} convention of the 'Acoustical Society of America', San Francisco, 1975.

Between 1977 and 1981, I organized, for the first time in Belgium, a series of 4 international conferences on the singing voice, with introduction and discussion of the film: "Regulatory Mechanism of Voice in Singing", produced by Prof. dr. Minoru Hirano, Kurume-University, Japan), the most famous voice specialist at that time. In 1979, Prof. dr. Minoru Hirano came to Europe for the first time, accepting my invitation to give a lecture on his fundamental research on voice before an enthusiastic audience of European phoniatricians, O.R.L. specialists and voice therapists.

As one of the few European voice therapists, I was present during four consecutive years (1977-1980) at the famous Juilliard Symposia "Care of the Professional Voice" in New York. These yearly symposia provided me with the unique possibility of an intense exchange of ideas between medical specialists, voice pathologists, singing teachers etc., with ensuing invaluable professional contacts for many years. At the same time, quite new devices for objective voice testing appeared on the market, which I tested in my own private practice.

Being asked as a member of the jury involved with the production of an international opera-project by the Royal Opera La Monnaie, Brussels and the Holland Festival, Amsterdam, I learned much about the changed opera scenery. During the auditions in Amsterdam (Stoopera), Brussels (Opéra Royal de La Monnaie), Helsinki, London, Milano, and Paris, I did screenings and voice tests with voice classification by phonetography on actors, singers, and dancers, followed by vocal coaching at rehearsals.

Working for many years as a vocal coach/voice therapist, I assisted, as a special member of the jury, at all kinds of auditions at international opera companies. This privileged position provided me with the unique opportunity to critically observe not only *what happened behind the stage*, but also to try out my own methodology of voice classification by means of phonetography on the many candidates for a major role in a new opera production. In the beginning I was only occasionally admitted as a silent observer, sitting next to important people like the manager of the opera-company, the producer, the director, the conductor, the choirmaster, the choreographer, and the repetiteurs. Their very particular attention was directed to choosing the right person for a specific role out of hundreds of candidates. However, I observed that the members of the jury frequently disagreed. They all seemed to hear something which I couldn't hear myself. For a young speech and voice therapist, this was quite frustrating. So, I continued listening to what they had to discuss *after the auditions* were finished. Then I became aware that, in many cases, those professionals didn't agree at all about *voice classification*, which was, of course, very important to assess if the candidates could apparently sing the specific scores of the written music and if they could continue these strenuous efforts, for a whole series of performances, if possible, without voice problems. Common discussions were, e.g., "was this female singer, producing some warm, dark sounds, a real mezzo or was she rather a contralto, or perhaps a soprano, because she could occasionally produce some very high pitches?" Some judges even insisted on the presence of an X-factor which some singers seemed to possess. Obviously, I was not able to measure this mysterious X-factor with my decibel meter! However, after some time, I dared to demonstrate my secret weapon: a brand-new type of decibel meter which was supposed to discriminate between apparently equal voices, in a more objective way.

A breakthrough happened when the Royal Ballet of Flanders at Antwerp started with a Musical Theatre Company, which successfully toured in Belgium and abroad for many years. For 12 years I assisted as a vocal coach on all auditions, judging several thousands of candidates from European countries, all trying to get an important role in a new musical production. I also assisted at the rehearsals and tried to help the singers, actors, and dancers with their many occurring voice problems.

One must recall that in the eighties and the nineties Musical Theatre became extremely popular in European countries. Young people were attracted to this new medium, but, unfortunately, this growing popularity came along with newly arising problems during the auditions. I was confronted then, not only by technical problems of classically trained singers, trying to master new singing techniques, specific for the new Musical Theatre, but also with all kinds of vocal performers, with or without vocal training. Especially the great variety of vocal techniques – good ones and bad ones – (think about the growing success of *belting* at that time), used by singers, actors, and dancers of the Musical Theatre, provided an excellent opportunity to experience the large diagnostic possibilities of phonetographic analysis. The revolution of this new singing theatre, depending on a new kind of performers who could sing, act, and dance altogether, also opened challenging possibilities for education and research, but also put at risk non-educated voices of young people, hoping to get famous and rich in the shortest possible time by merely imitating other non-educated voices which were, for one reason or another, successful at that time. In my opinion, the need for an objective voice classification was obvious.

I observed that almost every voice problem, which occurred during the short but very intensive rehearsals, and during the performances afterwards, primarily had to do with *voice classification*. Again, in my experience as a voice therapist, phonetographic analysis proved to be very helpful to actors, singers, singing students, singing teachers, conductors, and directors of contemporary Musical Theatre.

This original viewpoint has been stated for many years by the author, at numerous international scientific conferences, and finally resulting, many years later, in a PhD thesis on ‘Voice Classification by Phonetography’, based on a data base of more than 1000 phonetograms, proving for the first time, the real existence of three specific natural voice groups for each gender (2013). Before the official defense of my doctoral thesis at the Catholic University of Louvain (Belgium), many presentations (papers and workshops) on the same subject were given at different international conferences between 2007 and 2012: Frankfurt-am-Main (Germany), Groningen (The Netherlands), Helsinki (Finland), London (U.K.), Louvain (Belgium), Marseille (France). Paris (France), Poznan (Poland), and Stuttgart (Germany), The real apotheosis happened at the 'Cost Action 2103 International Workshop 2011 and CoMet Annual Meeting 2011' at Frankfurt-am-Main (Germany), when, for the first time, the distinct picture of three separate basic voice types appeared on the big screen, receiving a standing ovation by the Chairman, Prof.Dr.Izdebski and the whole audience.

Remarkably, exactly 50 years passed since I wrote my speech therapist's "atypical" thesis on the singing voice (1963), and the publication of my PhD thesis (2013) on the same subject! Moreover, 30 years passed since the early collecting of data for the elaboration *of an extensive pattern card of the parameters of the human voice,* now for the first time published in this manual.

The results of this complex scientific study demonstrated for the first time that parameter combinations of the voice range profile can yield a clear cluster separation to discriminate between three basic voice categories of each gender, which may serve as the *basis to resolve the riddle of voice classification.*

Hopefully, the many practical research data in this manual, collected during a lifetime, and dedicated to the amazing voice phenomenon, may inspire many readers for their own practice.

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Vocal Coach, Speech and Voice Therapist

INTRODUCTION

The human voice is an amazing phenomenon, comprising many psychological, sociological, artistic and biological aspects. Vocal possibilities and limits are based on individual biological properties. Individual vocal qualities can give rise to optimal and even high-class artistic vocal performances, while vocal restraints can cause functional and organic voice disorders.

Professional voice users, using their voice as a primary tool, are especially prone to voice problems. Vocal nodules, for instance, most often based on overload of the voice, e.g., due to an incorrect voice classification, are well-known in clinical practice. Therefore, it is important in voice and in singing education to know the physiological limits of the voice and to carefully watch them.

Chapter 1 of this manual gives an insight into the many difficulties encountered in trying to classify a voice. Chapter 2 confronts us with the considerable influence of singing education on voice characteristics. Chapter 3 indicates how, at present, music education and performance can be divided into two broad categories: Classical Music and Commercial Music, and how contemporary singing education deals with voice classification. Chapter 4 analyses the results of our study, based on three questionnaires, clearly showing the need for an objective voice classification. The many contradictory scientific publications on voice classification are analysed in Chapter 5, while Chapter 6 is dedicated to the different parameters of voice, revealed by F°-SPL Profiles. Chapter 7 stresses the importance of voice classification and its impact on voice diagnosis and therapy. In Chapter 8 an extensive analysis is given of our own procedure of F°-SPL measurement, elaborated during many years of voice testing, and based on 5 parameters, according to the method of Seidner et al.: maximum intensity measurement, minimum intensity measurement, difference between maximum and minimum intensity measurement, intensity of the singing formant, and difference between the maximum intensity and intensity of the singing formant. All data were listed in a statistically balanced step-by-step procedure of voice classification, resulting in the elaboration of an extensive pattern card of the parameters of the human voice. Our results for male and female voices, including some specific case studies, were compared to the results found in the literature and discussed in an effort to provide useful clinical conclusions. Chapter 9 provides some interesting case studies, revealing the importance of the longitudinal aspects of phonetography. Chapter 10 is dedicated to our PhD- study "Identification of Three Natural Voice Groups by Phonetography. A Data Driven Approach" (2013), proving for the first time in scientific research, the real existence of three specific natural voice groups for each gender. Recent studies, based on this relevant finding, are added. General conclusions are expressed in Chapter 11.

CHAPTER 1

SUBJECT CLASSIFICATION IN VOICE RESEARCH

Our whole thinking and reasoning - as far as it concerns general names and conceptions – consists in classifying. Even logic could be defined as the theory of classification. A fixed methodical rule for classification doesn't seem to exist. First requisite for a good system of classification is *functionality*. A second requisite for a valid system of classification - very important from a scientific viewpoint – is one requires that such a system should make possible the greatest number of *general statements.*[1] However, "great intra- and inter-individual as well as intra- and inter-investigator variations are typical in all measurements of psychophysiological phenomena in humans". [2-4]

Psychologists employ two basic kinds of classification: *qualitative* and *quantitative*. In fact, the line between the two is not entirely distinct. In addition to its value as an instrument for scientific enquiry, qualitative classification in psychology frequently produces results of considerable practical value. In a quantitative classification, categories are determined, based on different degrees of some measurable characteristics.

Classification is one of the major objectives of scientific endeavour. According to Brewer[5], in the panel discussing "The Integration of Voice Science, Voice Pathology, Medicine, Public Speaking, Acting, and Singing", "research teams should look at acoustic phenomena and their possible detectable correlates. *Further studies on e.g., voice categories (accurate descriptions)" are necessary".*

In voice research, emphasis is put on the accurate describing of the specific qualities of the subjects used in the proposed study. The more accurate this description of the subjects, the more other researchers can understand the results of the study and compare them with other attempts of the same kind. However, in voice research, the classification of the subjects remains a weak point. If we look at the actual bulk of literature on voice, we can distinguish some major policies. Every study provides reliable information on the exact *number of the subjects*, their *gender,* and their *age*. Some studies make a distinction between the so-called "*normal people*" and "*voice patients*". Few studies make a distinction between again, the so-called "*normal people*" and "*singers*". At this level the confusion becomes exorbitant. This confusion can readily be understood if we consider the following assessments:

1. The scientific validity of much of the research that is being carried out on singers has been questioned.

Hollien and Keister[6], for instance, state that: "First, to be able to generalize obtained data to singers and singing, it is necessary to study them in groups rather than just as single singers. Second, what is meant by the term "singer" must be defined and these operational definitions must be included in the published reports of the experiments so that others can understand the specific referents utilized by the scientist in his research. Third, any experiments on the behaviour of singers must include non-singers as controls. In other words, it is necessary to establish control groups and define them if the behaviour and capabilities of the singers are to be understood. Fourth, there are many specific terms that must be defined when research on singers is carried out and published."

Coleman[7], however, evokes a possible difference in research philosophies - i.e., concerning the use of large groups vs small groups. To him, utilization of small groups, particularly when the subject is used as his own control, is a valid research technique too. Other authors agree with this viewpoint, stressing the value of comparing the obtained results with those of "standard" subjects or with former results of the same subject.[8]

2. There still exists no exact definition of the singing process.

As there are many ways to produce the same tone, there is no reason to assume that there exists only one correct singing technique. Besides, the many personal and emotional aspects of singing cannot be reduced to objective numbers.[8] Some authors consider that the acoustic principles of speaking, and singing are basically the same[8-17] and do admit that the speaking and singing voice are strongly interdependent.[18-20] There are only gradual differences between speaking and singing. In speech the meaning is the main point, in singing the voice timbre is a main point.[21] A lot of verbal productions are intermediary between singing and speaking (cfr. Sprechgesang, "Parlando" singing, recitatives).[22-27]

Moreover, as Sundberg et al.[28] stated: "Most voice research in the past has focused on operatic singing, while the equally phonatory interesting type of singing cultivated in the performance of popular songs and musicals has been largely neglected by voice scientists. Therefore, the vocal techniques used in nonoperatic singing are poorly understood". Other authors[29-34] too, claim the necessity to broadening the horizon of research in singing by including various singing styles.

Hoit et al.[35] found no clear differences in variability of the respiratory function between the speaking and singing activities of professional country singers.

Belting, a method of voice production in which the vocalist "extends" the frequency range of the chest register upward, can be seen as an exaggerated use of the speaking voice or the modal register.[36-39] Different singing styles are most likely based on considerable variation of various muscles.[40]

The mechanisms involved in transformation of the speaking voice to the singing voice engage the interest of vocal coaches and voice scientists. On the other hand, training to influence aspects of the singing voice may also affect aspects of the speaking voice.[41]

According to Sundberg et al.,[42] a major difference between speech and singing is that a precise and independent control of loudness and pitch is needed in singing but not in speech. In acting and emotive speech, however, parallels between respiratory behaviour in speech and singing are obvious.[43-44] Principally loudness demands in acting seem quite like those necessary in classical singing.[47-48]

Speaking is characterized by small but steady gliding pitches around the fundamental, whereas the melody and the time are indicated in singing. In analysing single sounds of the same pitch, it is difficult to say whether these sounds are spoken or sung. One needs more sounds to do this adequately.[49] In singing, the words are presented artificially, because the composer dictates the pitch and the duration of the notes.[50-53] Vowels are dominant in singing.[54] In normal speech, lung volumes just above FRC (Functional Residual Capacity, i.e., the volume of air present in the lungs at the end of passive expiration) are normally used. In singing, a greater portion of the vital capacity is used for phonation[55] and the velopharyngeal port is closed significantly longer, especially in high pitches.[56]

Singing is supposed to involve different, and probably more careful patterns of control over both the source and the filter[57-61] as subglottal pressure not only increases loudness but also fundamental frequency.[62-64]

Although the lung pressure attained in singing may be more than four times that used in speech, air flow must be kept at a level similar to that in speech.[65] Singers are more prone to "flow phonation", thereby reducing excessive subglottic pressure.[66] Insufficient accuracy in subglottal pressure regulation will lead to singing out of tune.[67-69] Therefore, a perfect coordination between the laryngeal muscles and the respiratory muscles is essential.[70-71] This leads to the conviction that professional singers are a "physiologically and neurologically unique group of individuals".[72] However, the term "breath support" commonly used by singers is also used by actors.[73-74] In their acoustic study with three tenors, Hirano et al[75] found additional harmonics in the high frequency range besides the singing formant.

3. Phonetographic studies have demonstrated the interrelationship between different human vocalizations.

In phonetography the explicit relationship between frequency and intensity is studied. In normal speech, an increase in voice loudness also entails an increase in fundamental frequency[76-77] and vice versa, in singing. This is not surprising to Gramming[78] as a raised subglottal pressure also yields a rise in fundamental frequency. Gramming et al.[79] studied the existence of habitual pathways in the phonetogram. They also acknowledged the common observation that speakers tend to increase their loudness of speech with the ambient noise (the well-known *Lombard effect*).

Many authors[80-89] were interested in situating the position of the speaking voice in the total voice range and in trying to locate a zone of comfortable speaking in the speaking voice. To Pabon[90], the speaking voice area is the most informative area of the voice, where the most quality change variations take place.

The area of the speaking voice is generally located in the lower third of the phonetogram[91-92]. Schmidt et al.[93] confirm that only a small part of the maximum intensity range is used in connected speech, but they admit that little is known regarding the exact location of the speech intensity range within the larger range. They found a rather restricted mean intensity range of about 6 dB in a short sentence, while "highly effective" speakers have been found to have intensity ranges of 16-17 dB and trained speakers even have been found to have a mean intensity range of 20 dB in connected speech.

This brings us to the difficult subject of "*training*". In discerning an area of the shouting voice next to the transition of chest and head registers, Hacki[94] observed that the dynamics of this shouting voice area sometimes exceed the area of the singing voice. Denk and Frank[95] concluded that the limits of the dynamics of the speaking- and singing voice area approach. The larger voice and intensity range in singing depends on the singing style. But even in an animated, expressive conversation, considerable extremes of frequency and intensity can be found.[95]

In pathology, dissociation of one's speaking and singing voice is a frequently occurring cause of voice problems in singers.[96-100]

4. It is difficult to control for the amount and type of vocal training.

It is well known that most of human behaviour depends on strategies which are acquired by learning and training. In voice training and therapy much attention is spent on teaching breathing techniques (cfr. "breath support"). Sundberg et al.[101-102], however, express their scepticism regarding the benefit of this strategy from a physiological point of view. In fact, Griffin et al.[103] even stated that "because breathing patterns among the subjects were so variable, analysis of averaged data is not meaningful".

In an article on 25 years of progress in research of the singing voice production, Cleveland[104] points to the discovery that the modes of vocal fold vibration represent extremes of a continuum from pressed over flow to breathy. In classical singing the subglottal pressure and the adductor forces are moderate, but in a more "Broadway type" voice production, the subglottal pressure and the adductor forces are often greater.[104]

Regarding pitch, intensity and quality shifts differing strategies are legion. It is also generally accepted that trained singers acquire specific phonatory behaviours. Supraglottic constriction, however, is often apparent at the pitch extremes in trained singers, a condition which has been described in vocal pathology as well.[105-107].

According to Miller[108], "new to the recent history of solo singing is a category of performer known as "the *untrained professional*". In most voice studies, however, trained persons (only) had singing training. Other types of voice training seem to be largely neglected. For instance, there is a lack of information on the many different voice training techniques used in the education of actors and on the training of the speaking voice of students in speech and voice pathology, aiming at a clear voice with carrying-power, using an eutonic posture and diaphragmatic breathing.[109-113] Vocal coaches, however, stress the effectiveness of breathing exercises that use both singing and speaking, moving from one to the other.[114-117]

The fact that performers often must speak or sing and move or even dance at the same time is largely neglected in voice studies. This is exactly the type of vocal performers the author of this manual has been confronted with for many years. Moreover, the fact that everybody speaks more often than he sings is often forgotten as well as the interaction of the speaking voice on the singing voice. According to Sataloff[118], dissociation of one's speaking and singing voice is probably the most common cause of voice problems in singers. Misuse of the speaking voice is recognized as resulting in damage that affects singing.[118-121]

5. By assigning beforehand different people to different categories there is always a possibility that the same person may belong to more than one category.

In the Appendix, a compilation is given of 364 descriptions of subjects, as found in the literature by the author!

According to Harvey[122], the "professional voice user" is, regardless of age, a designation describing countless variations of phonatory abilities and demands (e.g., teachers, attorneys, secretaries, singers, actors). In some studies, however, some groups of singers were excluded. Hollien et al.[123], for instance, made a study on the intelligibility of vowels sung at extremely high fundamental frequencies in "singers", but "no pop or rock singers" were accepted.

Singers who had many years of singing lessons and enjoying a brilliant professional career, can, at a particular moment, be regarded as voice patients who are developing or already have developed a (functional) voice disorder. Teachey et al.[124], for instance, conducted a study on singers with less than 2 years formal vocal training, which the authors called "untrained singers", and found that nearly 70% of their subjects characterized their voices as being "hoarse, rough, or raspy". Twenty percent also described some associated breathiness. Sixty percent of these "untrained singers" presented with vocal fold lesions, almost all of which were vocal nodules. Sapir[125] too, found nearly one-half of the voice students having sought medical help for voice problems.

Wuyts et al.[126] draw our attention to the problem of interpreting conflicting effects in voice diagnosis and therapy. They acknowledge that in some cases, the pathology was still present after therapy, even though the voice function was better according to E.N.T. specialist and patient. In other cases, therapy ameliorated just one variable of the voice while the other variables got worse.[126]

In vocal pathology, mild adduction disorders are neither organic nor functional disorders; rather there is a *continuum* of organic alterations with different laryngeal vocal disturbances[127-129], or, as expressed during the 'Jahrestagung der Deutschen Gesellschaft für Sprach- und Stimmheilkunde,' Bad Segeberg 1978:" All functional voice disorders are situated between both poles of hyper- and hypofunction".[130]

Airainer and Klingholz[131] examined patients to whom the diagnosis "hypo- or hyperfunctional dysphonia" or "hyperfunctional dysphonia with a secondary organic lesion" applied. However, they felt that their subjects had to be *a priori* divided into four groups: male non-singers, male singers, female non-singers, and female singers. To be classified as singers, their subjects had to be singing in choirs for several years.

Overlapping of categories also happens when one tries to divide people into non-singers, amateur singers, singing students and professional singers. Schutte and Miller[132] too, admit that the line between professional and dilettante is indistinct.

But what to do with the bulk of the subjects in our own study? Some of them are "classical" singers, who changed their techniques hoping to get a role in a musical. Others had years of dancing training but just took a few singing lessons before auditioning for a musical production; the same with many actors. Meanwhile, some of them had developed a functional voice disorder. They had no idea about their voice classification or even had forced their voice to simulate a voice type which was not their true natural vocal type.

During many auditions we also encountered "pop" and "rock" singers, without any form of vocal training, but who also wanted to become a "musical star". During the rehearsals it became clear that their "years of professional experience" as "singers" were not at all useful to meet the high demands of acting, singing, and dancing in a modern musical performance. A lot of them could easily be classified as "voice patients".

The self-reported voice problems in a questionnaire administered by the author to professional singers of opera, musical theatre, and contemporary music, aged 18 to 69 years (Chapter 8), revealed high rates of vocal disability (69%) and diagnosed bad vocal conditions (44%). Besides, singers can present with hoarseness in their speaking voice or with problems specifically related to their singing voice.[133-135]

Singers also differ greatly not only in the technical aspects of their singing technique, but also in their repertoire. Nobody will deny the differences between, for instance, a highly trained Wagnerian opera singer, a Peking opera singer, a Spanish falsetto singer, an American crooner, a well-loaded Irish folksinger, a hoarse jazz singer, a yodelling singer from Tyrol, a heavy metal or rock singer, a double-voice Touvinian singer,[136-138] and an operetta-soubrette, and so on. Miller[139] even points to the recent category of performer known as "the *untrained professional*". Moreover, as Titze et al.[140] reported, only 15% of the estimated professional singers in the United States are classical singers; the other singers fit into multiple categories. However, all those "singers" have in common that they use their singing voice in one way or another.

Nonetheless, the *loudness* factor seems to be all important to performers engaged in vocally demanding professions and hobbies. As mentioned before, physiological inefficient SPL control strategies are since long acknowledged as potentially injurious to vocal fold tissues[141], but the fact that "a comparable acoustic product can be generated using different physiological strategies"[142] is widely ignored in the voice research paradigms.[143] Phyland et al.[144] too, point to the "wide variability among singers as one of the major confounders in the estimation of the incidence or prevalence of voice disorders among singers". Variables such as the amount and nature of singing training and experience, the amount and nature of singing demands and the performance environments and the singing style, are of influence on the occurrence of voice problems.

Finally, Peppard et al.[145] advise that, in studies of voice disorders, "voice production in the populations examined should be viewed on a *continuum* with normal singers at one end and non-singers with nodules at the other". This also means that "further research should look at *larger samples* of normal populations of singers and non-singers and should consider *other sources of variation* to delineate more clearly normal production and deviations occurring with voice disorders".[145]

We are convinced that a basic elementary source of variation is *voice category.* That's why the author of this book spent a lifetime of testing all kinds of voices, trying to classify them in an objective, scientifically based way.

Chapter 2

The influence of singing education on voice characteristics

Today's life is immersed in music: willing or not, in almost every situation, day or night, music is in the air. Especially young people have a leaning to listen to contemporary music, songs based on all kinds of regularly changing hit lists, and promoted by the market and mass media. Successful voices of the moment - good or bad ones - are imitated by young people, often without concern of the quality of the sound produced by their idols or by themselves.

The influence of voice training on vocal capabilities is well known from clinical experience and the relationship between the singing teacher and the singing student is particularly interesting in this regard. The singing student often chooses a singing teacher with a particular voice type, which he or she likes and wants to imitate, while the singing teacher in his turn may be inclined to reinforce that attitude. On the other hand, frequently changing from one singing teacher to another during one's singing education and one's professional singing career is common practice. This means that the singer is flooded with different advice over the years, including many comments on his "real" voice type. At the same time, during the singing education the singer becomes aware of the changing features of his or her voice, for the better or worse.

Tarneaud[146] already explained, many years ago, that pitch and timbre not only depend on constitutional and physiological factors but also on educational mimesis, acquired in various surroundings, family, school, and profession. Each singer has not only one characteristic timbre, but a set of timbres, or a timbre transformation. Voice quality depends highly on vocal techniques, thus on voice education. Many singers have developed a functional adaptation of their vocal organs, which is not always in correspondence with their anatomical and physiological abilities.

Nowadays a lot of singing students are often in turmoil: by choosing a kind of education programme - be it classic or commercial - they enter a protected environment in which they are directed for many years in a particular direction: choosing a repertoire, taking singing lessons which direct them to make restraint choices in connection with their assumed voice type. As the singing teacher is not sure about the exact voice classification at the beginning of the study, very often a cautious repertoire is chosen. Singing teachers then claim the voice of the young singer is supposed to ripen, to mature and so on. However, singing exercises try to expand the singing range in one or another direction and this also influences the singing teacher and the singing students in their perception of their vocal evolution. If the singing teacher is not sure about the right voice type of his/her pupil, there is a great chance that the voice of the young singer is forced in a direction which can damage his future career.

Lycke and Siupsinskiene[147] recently made a study on the *effects of training duration and institution on basic Voice Range Profile parameters.* VRP recordings were made of 162 females, taking individual singing lessons *during 5 consecutive years (1st - 5th level*) in Dutch, Belgian, English, and French public or private training facilities. Sixty-seven non-singing female students served as controls.

RESULTS

- Vocal capabilities of singing students measured by Voice Range Profile are significantly extended in both frequency and intensity parameters in comparison to non-singing students.
- Training years have a significant effect; conservatory singing students in more advanced singing classes demonstrated a significantly greater frequency range, particularly at high frequencies, than did first-year students.
- Musical theatre training has more positive effects on both frequency and intensity related parameters than does classical training.
- Private and musical theatre training have more positive effects on voice characteristics than do public or classical training.
- Private training has more positive effects on voice dynamics than does public training.
- When compared to non-singers, all singing student subgroups showed significant increases in all basic VRP parameters. However, *the register transition parameter was not influenced by training duration*. This important observation is analysed in a further study.

- We concluded that VRP recording provides both qualitative and quantitative information about vocal capabilities and could serve as a useful tool for voice teachers, offering a way to assess vocal training and training progress.

CHAPTER 3

CONTEMPORARY SINGING EDUCATION AND VOICE CLASSIFICATION

At present, music education and performance can be divided into two broad categories: Classical Music and Commercial Music.

Classical Music represents various genres such as Opera, Lied, and Oratorio.

Traditionally, in Classical Music voices are classified into three principal categories: for the female voice: alto, mezzo, and soprano, and for the male voice: bass, baritone, and tenor. There are, however, many subtypes, according to different roles and based on the characteristics of the voice, such as loudness, timbre, mobility, vibrato, temperament, expression, and personality. In classical singing education great emphasis is put upon voice classification, but little is known how the relatively new music institutions and individual singing teachers deal with voice classification.

Commercial Music represents genres including Pop, Rock, Jazz, Country, Rhythm, and Blues, Hip-Hop, Rap, Gospel, and Musical Theatre.

According to Gilman et al.[148,] contemporary Commercial Music is the largest, and possibly the most popular genre of music in the Unites States. It may be assumed that the same trend occurs in European and other countries, probably due to the emergence of the commercial industry reality TV shows such as 'The Voice', 'Star Academy', 'X-Factor' and so on.

In his master's thesis in Leisure Studies, "An agogic approach and a government-directed approach of the phenomenon Musical Theatre in Flanders", Lycke[149] analyzed the decision of the Flemish government to create a specific Musical Theatre Company within the structure of the Royal Ballet of Flanders. The growing popularity of the Musical, compared to the Opera performances, played a major role in this political decision. The results of the questionnaires by the author, analyzed in

Chapter 4, also show the great difference between the preference of contemporary singing teachers for Musical Theatre (66,7%) in comparison to Opera (13%) and all other musical styles.

As mentioned in Chapter 2, the conclusions expressed in the study of Lycke and Siupsinskiene[147] clearly demonstrate the many effects of individual singing lessons on the voice of singing students, *depending on the type of singing education and institute.*

In their study on Commercial Music, Radionoff et al.[150] concluded that "along with nomenclature disparity, a tremendous lack of consistency exists among curriculums of commercial music degrees." Many singing students are taking private singing lessons which are not curriculum-bound. Contemporary commercial music singers often complain that their singing teachers do not understand the vocal styles and demands of a Contemporary Commercial Music singer.

Classifying a voice means, in the first place, to determine the frequency and intensity voice range in which a subject can work without harming or fatiguing his voice and to which repertoire he should be assigned.[151-154] Correct classification of the singer's voice is indispensable to achieve optimum performance. Coleman[155] already stated the consensus that singing and speaking outside a given physiological pitch or intensity range is a potential hazard. The biographies of famous and less famous singers frequently mention examples of the pernicious outcomes for their voice and for their career caused by incorrect voice classification.

CHAPTER 4

VOICE CLASSIFICATION IN PRACTICE: CRITERIA IN CONTEMPORARY SINGING EDUCATION

With the intention to explore how contemporary singing teachers deal with voice classification and which criteria they use, **a first questionnaire** was sent to 200 private singing teachers, who were registered on the commercial Dutch Internet site www.vocalisten.nl and who mentioned their e-mail address. The singing teachers who cooperated in this explorative study returned their answers via e-mail. These private singing teachers recommended themselves for *a total of 134 specialties and styles of singing*! Many of them had a classical singing education, but each of them proclaimed to master a great variety of singing styles like Belting, Blues, Classic, Close Harmony, Country, Disco, Easy Listening, Evergreens, Funk, Fusion, Gypsy, Hard Rock, Jazz, Latin, Opera, Pop, Rhythm and Blues, Salsa, Soft Rock, and World Music. *The private singing teachers were asked if voice classification was important to them and why. They were also asked which criteria for voice classification they applied*.

Aiming to compare the results of the **first questionnaire**, sent to private singing teachers, we also wanted to know the attitude towards voice classification by singing teachers in officially subsidized national music conservatories, submitted to the inspection by the Government. At three conservatories: one Belgian classical conservatory specialized in Opera, Lied, and Oratorio, and one Dutch and one British conservatory specialized in Musical Theatre, **a second questionnaire** was distributed among singing teachers via the Head of the Department. The answers to the questionnaires were collected by one of the singing teachers. The 22 singing teachers from the three conservatories who cooperated in this study classified a total of 165 singing students: 81 singing students (58 females and 23 males) at the Belgian classical conservatory, 63 singing students (55 females and 8 males) at the Dutch conservatory (Musical Theatre), and 21 singing students (9 females and 12 males) at the British conservatory (Musical Theatre). The singing students were aged between 18 and 28 years, mean age 21 years. The singing teachers were asked to classify their own singing students and to indicate on what criteria their voice classification was based.

A third questionnaire was distributed among the singing students of all levels of the above indicated three conservatories. A total of 165 singing students, 122 female students and 43 male students, aged between 18 and 28 years, mean age 21 years, filled in the questionnaire about their voice classification. The students were asked if they knew their voice classification, who had determined their voice classification and how, and if they thought their voice classification was correct.

During this investigation, spread over one year, 75.3% of the classical singing students and 88.3% of the Musical Theatre students were classified by their singing teacher. The students who cooperated in this study got enough time to read and to sign an informed consent. The students filled in the questionnaire and handed it over to the investigator. There was also an opportunity to ask more information about the aim of the study. Seventy-three female first year students in the Masters' degree program in speech-language pathology at a Belgian university (aged between 18 and 20 years, mean age 18 years) were used as a control group.

Descriptive statistics were performed by SPSS 16.00

RESULTS

Questionnaire 1

From the 200 singing teachers 72 answers were received from 58 female (80.6%) and 14 male (19.4%) singing teachers. Consequently, the response rate is 36.0%. Although most of these singing teachers had a classical singing training, each of them recommended him/herself on the website for many specialties and musical styles (up to 24 in one teacher). Most popular styles were Musical Theatre (66.7%), Classic (50.0%), Pop and Jazz (each 43.8%), Dutch Pop (19.0%), a Capella (17.0%), Close Harmony (16.0%), Lied (15.0%) and Opera (13.0%).

Most respondents mentioned their own voice classification, while 10,50% of the singing teachers didn't seem to know their own voice type. Almost one quarter of the respondents (24,3%) mentioned to belong to 2 voice types (e.g., baritone, tenor), while 7,3% of the singing teachers even claimed to possess 3 voice types (e.g., alto, mezzo, soprano). Subtypes (for instance, dramatic, lyrical, coloratura…) were mentioned by 21,9% of the respondents.

Forty-four singing teachers (61.1%) found voice classification important for at least one reason, while twenty-eight singing teachers (38.9%) stated that voice classification was not an important issue for their teaching.

Most singing teachers (n= 66, 91.7%) provided information about their criteria for voice classification, despite their controversial ideas about the importance of voice classification. These criteria for voice classification can be sorted into physical features, acoustical features, specific methods, miscellaneous, and "other factors". Six respondents (8.3%) did not mention any criteria for voice classification.

Most frequently used acoustical parameters for voice classification were frequency range/tessitura (56%), voice quality/timbre (56%) and *register transition (9%*). Some singing teachers (13,6%) proposed a careful testing over time or starting in the midrange (6,9%). Others (13,6%) preferred a specific methodology (e.g.: Estill Voice Training, Lichtenberger, Sadolin, …). Anatomical (12%) or psychological (6%) characteristics were less appreciated. One singing teacher evoked a purely commercial approach: voice classification on demand.

Arguments pro voice classification were prevention of voice problems (37,2%), need for the choice of repertoire (37,2%), usefulness for choirs (32,6%), importance for classical music, opera, and Musical Theatre (23,2%), knowledge of one's vocal capacities (18,6%), and need for a well-adapted singing education (18,6%).

Arguments against voice classification were: too restrictive (44,9%), not important for commercial music (34,7%), voice classification is no priority (32,7%), voice classification can change (28,6%), voice classification is not significant (12,2%), each voice is unique (12,2%) and voice classification is too broad/too vague (8,2%).

We couldn't compare the results of our study to those of other authors because of lack of studies on this subject. Studies on different genres of singing styles are still scarce. Older studies only focused on classical singing, emphasizing the importance of voice classification.

Our results show the tremendous change in attitude towards voice classification by many singing teachers today. Voice classification, at least for classical singing, has always been forwarded as a basic principle in singing education. Today, however, lots of singing teachers do not care any longer about a correct voice classification, to avoid possible voice problems. Anatomical characteristics are no longer considered as important. Even register location, traditionally considered as an important parameter of voice classification, is used by only 9% of the respondents. Even if the singing teacher him/herself had a classical singing education, based on voice classification, less or no attention is given to this, formerly very important, aspect of voice education.

Almost 40% of the internet singing teachers stated that voice classification was no important issue for their teaching. Additionally, not all the reported arguments contra voice classification seems to be valid. After all, if voice category could change anyway, classification is still important to watch the instant physiological limits of the voice, just if the voice is unique. Therefore, voice classification is important in all types of singing.

These findings indicate a worrisome trend of altered attitude towards voice classification by many private singing teachers today. Of course, one can argue that a lot of singing teachers try to attract as many singing students as possible by an extensive offer of singing genres. But how can be explained that in this enquiry 91,7% of the respondents still gave information about their criteria for voice classification, while 38,9% of them didn't find voice classification an important issue for their teaching?

The fact that almost one quarter of the respondents (24,3%) mention to belong to 2 voice types (e.g., baritone, tenor), and 7,3% of the singing teachers even claim to possess 3 voice types (e.g., alto, mezzo, soprano), while 10,50% of the singing teachers don't even seem to know their own voice type sounds very peculiar.

Popular magazines regularly mention the cancelled concerts by Commercial Music because of "some persistent voice problems", while the statistics about surgical interventions for organic voice disorders remain rather discrete…

In my own private practice, singers, and actors with functional or even organic voice disorders frequently told me they had taken singing lessons for several years with up to ten singing teachers, who had classified them in all imaginable voice categories.

Interested by this curious phenomenon, the author compared the multiple data found on the Internet about voice classification of famous female commercial singers with *voice classification based on an algorithm* *deduced from the limits of frequency range/tessitura as found in the literature, according to 38 authors with different backgrounds* (see Chapter 5).

Tables 1 to 4 give some idea about the *huge diversity and many contradictions between the (self?) declared voice classification of the singers and their (unofficially) reported lowest and highest frequencies.*

Lowest frequencies:

TONE	**Hz**	***FEMALE***	***VOICE***	***TYPES***			
g	**196**	**Contralto**	**Mezzo**	**Soprano**			
f	**175**	**Contralto**	**Mezzo**	**Soprano**	**Maria Callas**	**Julie Andrews**	
e	**165**	**Contralto**	**Mezzo**	**Soprano**	**Kate Perry**	**Janis Joplin**	**Sarah Brightman**
		Contralto	**Mezzo**	**Soprano**	**Shakira**		
d	**147**	**Contralto**	**Mezzo**	**Soprano**	**Barbara Streisand**	**Amy Winehouse**	**Lara Fabian**
		Contralto	**Mezzo**	**Soprano**	**Kylie Minogue**	**Nina Hagen**	**Patti Labelle**
		Contralto	**Mezzo**	**Soprano**	**Sade**		
c	**131**	**Contralto**	**Mezzo**	**Soprano**	**Cher**	**Christina Aguilera**	**Adele**
		Contralto	**Mezzo**	**Soprano**	**Avril Lavigne**	**Beverly Knight**	**Charice Pempengco**
		Contralto	**Mezzo**	**Soprano**	**Diana Ross**	**Donna Summer**	**Lady Gaga**
B	123	Contralto	Mezzo		**Céline Dion**	**Anastacia**	**Beyonce**
		Contralto	Mezzo		**Alicia Keys**	**Alanis Morisette**	**Lana Del Rey**
		Contralto	Mezzo		**Rihanna**	**Yma Sumac**	
A	110	Contralto			**Whitney Houston**		
G	98	Contralto			**Madonna**	**Kate Bush**	**Aretha Franklin**
F	87	Contralto			**Tina Turner**		
E	82	Contralto			**Mariah Carey**		

Table 1: Lowest frequencies of famous female commercial singers.

Highest frequencies:

TONE	Hz	FEMALE	VOICE	TYPES	SOPRANO	MEZZO	CONTRALTO
g4	3136				**Mariah Carey**		
f4	2799						
e4	2637						
d4	2349						
c4	2093			Soprano	**Christina Aguillera**	**Yma Sumac**	
b3	1976			Soprano			
a3	1780			Soprano			
g3	1568			Soprano	**Kate Bush**		
f3	1397			Soprano	**Cher**	**Donna Summer**	**Nina Hagen**
e3	**1319**	**Contralto**	**Mezzo**	**Soprano**	**Maria Callas**	**Aretha Franklin**	**Beverly Knight**
		Contralto	**Mezzo**	**Soprano**	**Charice Pempengco**	**Patty Labelle**	**Sarah Brightman**
d3	**1175**	**Contralto**	**Mezzo**	**Soprano**	**Barbara Streisand**	**Alanis Morisette**	**Rihanna**
		Contralto	**Mezzo**	**Soprano**	**Shakira**		
c3	**1047**	**Contralto**	**Mezzo**	**Soprano**	**Kate Perry**	**Lara Fabian**	**Beyonce**
		Contralto	**Mezzo**	**Soprano**	**Diana Ross**	**Kylie Minogue**	**Lana Del Rey**
		Contralto	**Mezzo**	**Soprano**	**Tina Turner**	**Whitney Houston**	
b2	**988**	**Contralto**	**Mezzo**	**Soprano**	**Madonna**	**Alicia Keys**	**Avril Lavigne**
		Contralto	**Mezzo**	**Soprano**	**Lady Gaga**		
a2	**880**	**Contralto**	**Mezzo**	**Soprano**	**Anastacia**		
g2	**784**	**Contralto**	**Mezzo**	**Soprano**	**Sade**		
f2	698	Contralto	Mezzo				
e2	659	Contralto			**Adele**		

Table 2: Highest frequencies of famous female commercial singers.

In the literature, 110 Hz is mentioned as the lowest female frequency. However, in our explorative study, based on 3 questionnaires, 3 of our female subjects produced 98 Hz, and 1 subject produced even 87 Hz. Moreover, 2093 Hz is mentioned as the highest female frequency. In our study, 7 of our female singing students produced 1568 Hz as the highest frequency:

g4	3136	Mariah Carey			
f4	2799				
e4	2637				
d4	2349				
c4	2093	Christina Aguillera	Yma Sumac		
b3	1976				
a3	1780				
g3	1568	Kate Bush			7/86 singing students
A	110	Whitney Houston			
G	98	Madonna	Kate Bush	Aretha Franklin	3/86 singing students
F	87	Tina Turner			1/86 singing students
E	82	Mariah Carey			

Table 3: Extreme low and high female frequencies of famous female commercial singers.

We also made a **synthesis of the voice ranges** of those famous female commercial singers:

	E	F	G	A	B	c	d	e	f	g	b	c1	d1	e1	f1	g1	a1	b1	c2	d2	e2	f2	g2	a2	b2	c3	d3	e3	f3	g3	a3	b3	c4	d4	e4	f4	g4
Adele						c															e2																
Alicia Keys					B																				b2												
Amy Winehouse							d																					e3									
Anastacia					B																			a2													
Cher						c																							f3								
Kate Perry								e																		c3											
Rihanna					B																						d3										
Sade							d																g2														
Shakira								e																			d3										
Tina Turner		F																								c3											
Alanis Morisette					B																						d3										
Aretha Franklin			G																									e3									
Avril Lavigne						c																			b2												
Barbara Streisand							d																				d3										
Beverly Knight						c																						e3									
Beyonce					B																					c3											
Charice Pemgengco						c																						e3									
Christina Aguillera						c																											c4				
Dona Summer						c																							f3								
Janis Joplin								e																						g3							
Lady Gaga						c																			b2												
Lana Del rey					B																					c3											
Madonna			G																						b2												
Whitney Houston				A																						c3											
Céline Dion					B																					c3											
Diana Ross						c																				c3											
Julie Andrews									f																b2												
Kate Bush			G																											g3							
Kylie Minogue							d																			c3											
Lara Fabian							d																			c3											
Maria Callas									f																			e3									
Mariah Carey	E	F	G	A	B	c	d	e	f	g	b	c1	d1	e1	f1	g1	a1	b1	c2	d2	e2	f2	g2	a2	b2	c3	d3	e3	f3	g3	a3	b3	c4	d4	e4	f4	g4
Nina Hagen							d																						f3								
Patti Labelle							d																					e3									
Sarah Brightman								e																				e3									
Yma Sumac					B																												c4				
	E	F	G	A	B	c	d	e	f	g	b	c1	d1	e1	f1	g1	a1	b1	c2	d2	e2	f2	g2	a2	b2	c3	d3	e3	f3	g3	a3	b3	c4	d4	e4	f4	g4

Table 4: Voice range of famous female commercial singers.

Mariah Carey clearly is the absolute winner, but it is also confusing to read on the Internet that the famous ethereal voice of Kate Bush is defined as having a dramatic soprano vocal range! The results of the 195 female singing students in our explorative study will be analysed further on. Moreover, we will discover that the results of our own subjects are not so bad either!

As Radionoff et al.[150] pointed to the tremendous lack of consistency among curriculums of commercial music degrees, less care about vocal hygiene and ergonomics can be expected. These findings must have obvious consequences for the prevention and care of voice disorders. It has been assumed that professional singers are at risk for voice problems, resulting in vocal pathologies or voice disorders. Moreover, some *studies showed the great prevalence of voice disorders among singing students, singers and singing teachers*.[125]

Gilman et. al.[148] investigated the perceptions and barriers to seeking voice care among contemporary commercial music performers. Although most subjects reported that their voice was a critical part of their profession, the lack of available and affordable voice care and education about the importance of voice care proved to be an important barrier to seeking appropriate help for voice problems. *The apparent trend of altered attitude towards voice classification as a basic principle of voice education may be seen as a result of the changed music scene today*. Therefore, a decrease of care of vocal hygiene and ergonomics may be expected. These findings must have consequences for the prevention and care of voice disorders.

Questionnaire 2

Access to conservatories for scientific research is not easy. One classical conservatory and two conservatories specialized in Musical Theatre agreed to cooperate in this study. However, various other departments of these conservatories, which are also involved in singing education, were not willing to cooperate. In the three conservatories, singing voices were still systematically classified. Moreover, during this investigation, spread over one year, only 75.3% of the classical singing students and 88.3% of the Musical Theatre students had been classified.

Giving more than 100 conferences and workshops in 15 countries, often confronted me with the many prejudices and difficulties to get access to music conservatories for scientific research, and this, up to now.

A friend of mine, a well-known phoniatrician recently wrote:” in my opinion X is not the ideal country to look for cooperation in scientific research projects about voice in conservatories, because there is the (false) belief that art must be independent from science and that science could create a sort of damage to creative intuition. Does it sound ridiculous? I know... It is hard also for me and my colleagues.”

Moreover, some indications of concurrence between conservatory singing teachers could be observed, with singing students often changing classes as a result.

Frequency range/tessitura and voice quality/timbre were used by all conservatory singing teachers as voice classification criteria, except for one classical singing teacher who used no voice classification criteria at all. Singing teachers of the three conservatories used a different set of voice classification criteria per singing student, while voice classification criteria also appeared to be dependent on the type of conservatory.

Singing teachers of the Belgian classical conservatory used 2 to 7 different criteria. Except for three singing teachers, using only frequency range/tessitura, timbre, and register transition as voice classification criteria, all other singing teachers used quite different sets of criteria, while one classical singing teacher used no classification criteria at all. In classical singing teachers, vocal development and frequency range of belt were not used as voice classification parameters.

Singing teachers of the Dutch and the British Musical Theatre conservatories used 2 to 11 different criteria. They all used frequency range /tessitura and voice quality/timbre as voice classification criteria. The frequency range of belt was specifically mentioned by 5 of the 10 singing teachers of Musical Theatre.

The results of the questionnaires among conservatory singing teachers indicated that, at least in some classical and Musical Theatre conservatories, voice classification is still an important issue in singing education. However, *each singing teacher of each type of conservatory used a varying individual set of voice classification criteria, depending on the singing student and on the specialty of the department*. One singing teacher wrote: “I trust my own judgment”, without mentioning which criteria she used and another one claimed: “The voice type is what the singer tells you what he/she is”. Still another conservatory singing teacher reported her skepticism about the need for voice classification, fiercely claiming: “in my class I make them all sopranos”!

Singing students were classified by a combination of 2 to 11 different criteria. The criteria enumerated by the singing teachers were not always the same for each of their students. The criteria could be sorted into 11 major groups. Frequency range/tessitura, voice timbre, quality, colour and character were most frequently used as voice classification criteria, followed by register transition and volume. These criteria are also well known as basic voice parameters. Only few singing teachers mentioned the exact dimensions of the frequency range/ tessitura or situated the register transition on the frequency scale.

The use of belting techniques in Musical Theatre makes the frequency range of belt an important issue, which is absent in classical singing education.

In some cases, descriptions were given about the nature of the student’s voice, its actual development (which could make a classification premature or uncertain), and the ease and comfort of tone production.

While in classical and in Musical Theatre conservatories voices are still classified according to well-known traditional criteria, this is much less the case in private singing education: frequency range/tessitura (100.0% vs. 56.0%), quality/timbre (100.0% vs. 56.0%), register transition (57.1% vs. 9.0%), and volume (52.4% vs. 12.1%). Private singing teachers also prefer a more careful testing over time (13.6%) and specific methodologies (12.0%). It is also quite possible that private singing teachers do not feel the need to classify, nor do their singing students feel the need to be classified.

The results of this study cannot be compared to those of other authors because of a lack of studies on this subject and must be cautiously interpreted as they only provide an insight into the responses of 22 singing teachers at 3 conservatories in 3 European countries.

Next to the traditionally classically oriented music conservatoires many new music education institutions emerged in recent years. In the ever-changing world of music genres and styles, music institutions and singing teachers need to adapt to the new demands of their students. Many formerly classically trained singing teachers are confronted with the demands for new or mixed singing techniques and singing styles. Formally, voice specialists stressed the importance of an exact voice classification before voice education starts. Incorrect voice classification could induce functional and eventually, organic voice disorders. The results of our study indicate a marked difference in attitude towards voice classification and different criteria used for voice classification in various types of singing teachers today. A highly subjective approach to voice classification by many singing teachers apparently demonstrates common feelings of uncertainty. The results of this study indicate the hazard of neglecting careful watch on the physiological limits of the voice. The need for quick success has also induced a tendency to an attitude of less concern for vocal hygiene. Further research is needed to understand the actual trends in the singing world which will have, no doubt, important implications for clinical practice.

Questionnaire 3

In the group of singing students at the classical conservatory 19 (23.4%) indicated not to know their voice category. This number was 10 (11.9%) in the Musical Theatre singing students, while 61 (83.6%) first year students in the Masters' degree programs in speech-language pathology of the control group reported not to know their voice category. Of the classical singing students 29 (50.0%) reported to be classified as sopranos, 9 (15.6%) as mezzos, 6 (10.3%) as altos, 8 (34.8%) as tenors and 10 (43.5%) as baritones. In the Musical Theatre group 11 (17.2%) of the singing students reported to be classified as sopranos, 25 (39.1%) as mezzos, 18 (28.1%) as altos, 11 (55.0%) as tenors and 9 (45.0%) as baritones. Of the 73 female university speech-pathology students in the control group 12 (16.4%) students who were singing in a university choir were classified by the conductor of the choir. In this control group 4 (5.5%) of the female students were classified as sopranos, 2 (2.7%) as mezzos and 6 (8.2%) as altos. A clinician was consulted for voice classification in 8 (3.4 %) of all 238 subjects (singing students and controls). A total of 28 (34.6%) of classical singing students and 5 (5.9%) of Musical Theatre students classified their own voice. One control, singing in a choir, classified her own voice.

All singing students answered to be subjectively classified by their singing teacher or choir conductor by doing some exercises (e.g.: vocalises) during lessons or rehearsals. Concerning the question: "Do you think your voice classification is correct?", 19 (23.5%) of the classical singing students, 5 (6.0%) of the Musical Theatre singing students and 6 (8.2%) of the controls believed their voice classification was not correct. Doubts about a correct voice classification was reported by 9 (11.1%) of the classical singing students, 7 (8.3%) of the Musical Theatre singing students and 6 (8.2%) of the controls.

CONCLUSIONS

Studies on different categories of singing are scarce and were mainly focused on classical singing, which emphasizes the importance of voice classification. During the last decennia the scientific world noticed the changing world of singing education and practice and some studies appeared on different singing genres and techniques.

While many singing teachers in the internet enquiry (questionnaire 1) had a classical singing education themselves, they paid few or no attention to voice classification, which was formerly very important in classic voice education. Almost 40% of the internet singing teachers stated that voice classification was no important issue for their teaching.

While in classical and in Musical Theatre conservatories voices are still classified according to well-known traditional criteria, this is much less the case in private singing education: frequency range/tessitura (100.0% vs. 56.0%), quality/timbre (100.0% vs. 56.0%), register transition (57.1% vs. 9.0%), and volume (52.4% vs. 12.1%). Private singing teachers also prefer a more careful testing over time (13.6%) and specific methodologies (12.0%). It is also quite possible that private singing teachers do not feel the need to classify, nor do their singing students feel the need to be classified. Obviously, in our internet study there is no consensus about the criteria for voice classification.

Musical Theatre students were most frequently classified in the middle and lower voice categories. Quite the opposite was seen in the classical singing conservatory, where the highest categories dominated. An explanation may be that middle voices are more preferred in Musical Theatre, while higher voices are most favoured in classical conservatories, each attracting in a way its own clientele of singing students. There is also the possibility that each type of conservatory tries to train its own preferred vocal types by specifically adapted singing techniques and gives less thought to a correct voice classification.

The results of our study showed that of all voice classification criteria, which were mentioned by singing teachers, *frequency range constituted the only parameter that could be measured objectively*. However, although frequency range was considered as the most important parameter for voice classification, *only few singing teachers mentioned the exact dimensions of the frequency range / tessitura of their students.*

Lycke et al. (Chapter 4) compared the results of voice classification by singing teachers with the results of *voice classification based on an algorithm deduced from the limits of frequency range/tessitura as found in the literature***.** The algorithm was elaborated, based on the limits of the female frequency range, according to 38 authors with different backgrounds. *The voice classification by the singing teachers did not fit in the algorithm. Frequency range alone proved to be not suitable as the parameter for voice classification.*

Singing teachers tended to classify their students in the highest (sopranos) and middle (mezzos) voice categories (75.6%) while, according to the algorithm, 82,6% of the same students were classified in the middle and lower voice categories (mezzos and altos).

Singing teachers had 14.0% doubts about voice classification of their students versus 4.7% according to the algorithm. Singing teachers classified 29.0% of their singing students as sopranos vs. 12.8% according to the algorithm. They classified 46.5% as mezzos vs. 67,4% according to the algorithm, and 10.5% altos vs. 15.1% according to the algorithm. None of the sopranos assigned by the algorithm were classified as sopranos by the singing teachers. Only 27 of the 58 mezzos and only three of the 13 altos according to the algorithm were classified as such by the singing teachers.

There was even no consensus about extreme voice types: sopranos according to the algorithm were classified as altos by the singing teachers and vice versa. This huge discrepancy between classification by singing teachers and classification according to the algorithm could be explained by the fact that in this study every singing teacher used his/her own criteria for frequency range, even depending on each individual singing student.

Between the two methods of voice classification there was *most disagreement concerning the labels sopranos and mezzos.* According to McKinney[156], misclassification can be a major cause of dysfunction in the young adult voice. As “every aspiring young singer knows that the larger incomes are in the high notes, so regardless of statistical evidence that most of them are baritones and mezzos, they push for the higher voice classifications quite early.”[156] These observations are corroborated by a study on mechanical stress in phonation by Titze[157], who found that the largest mechanical stresses in vocal fold vibration are the tensile stresses required for pitch increase.

Klingholz[158] states that male singers have less problems with their singing voice than female singers because female vocal folds vibrate two times more than male vocal folds. Moreover, he stated that female voices very often are classified as a voice type which is too high. In a study on "vocal attrition" (vocal pathology and reduced vocal functions associated with behavioural, biogenic, and psychological factors), 62 of the 74 of the university female voice students (84%) said to be sopranos, 11 (15.0%) were mezzos and only one student declared to be a contralto. Only 10 (13%) of these singing students proved to be free of symptoms, 19 (25%) had few and 45 (61%) had multiple symptoms.[158]

Miller[159] testified: "young singers press for louder and louder and higher and higher sounds, no matter what their bodies can do comfortably and efficiently", and Sataloff[160] stated: "singers are habitually unhappy with the limitations of their voices. In many situations, voice teachers are to blame. Both singer and teacher must resist the impulse to show off the voice in works that are either too difficult for the singer's level of training or simply not suited to the singer's voice". The results of our study confirm these statements.

Although voice classification based on frequency range is still very popular among contemporary singing teachers, the results of this study demonstrate that frequency range proved not to be suitable as a voice classification parameter, if used as a single parameter. *While frequency range is an objective parameter, the combination with other, but subjective criteria, makes voice classification an even more subjective issue.*

The percentage of singing students who could not be classified according to the six basic voice categories (alto-mezzo-soprano for female voices and bass-baritone-tenor for male voices) is remarkably high: 12.0% female and 26.0% male students in the classical conservatory and 26.6% female and 30.0% male students in the Musical Theatre conservatories.

The singing students answered to be subjectively classified by their singing teacher or choir conductor by doing some exercises (e.g., vocalises) during lessons or rehearsals. This indicates that *there is no generally accepted protocol for voice classification*. Furthermore, *many singing students expressed their doubts about voice classification*: 17.6%

of the singing students did not know their voice category, 9.7% had doubts and 14.5% found that their voice classification was wrong. These high percentages demand serious consideration because voice specialists have always stressed the importance of an exact voice classification before voice education starts. Incorrect voice classification may induce functional and eventually, organic voice disorders.

Most of the first-year students in speech-language pathology did not know their voice category. This could indicate that young people in general are not aware of their own voice classification. Voices seem to be classified only when there is a need to (for instance, when presenting as a member of a choir or in preparation for a (classical) singing career).

CHAPTER 5

VOICE CLASSIFICATION IN VOICE RESEARCH

One must consider that voice classification has known many variations according to the period and the musical styles. In the13th century, for instance, neither the high nor the low region of the human voice were exploited. In France, at the end of the 16th to the end of the 18th century, voices were divided in soprano, mezzo, contralto, tenor, baritone, first bass, second bass, each voice utterly within the limit of one octave and a quarter.[161-163]

Writings[164-168] – even from a psychoanalytical viewpoint[169-170] – describe the many different roles in religious and profane performances attributed to specific voice types in different cultural settings.

During many centuries professional singing was usually restraint to church music and opera. And so was the singing education. Singing students were mostly educated in a very private environment. Before conservatoires showed up, singing students lived for many years in the closed family setting of the singing teacher. They not only got their daily singing lessons but were also involved in the daily life of the singing teacher and his family.

On the opera scene, female and male voices are divided in six principal types: bass, baritone, tenor, contralto, mezzo, soprano. There are, however, many subdivisions (voice types), according to different roles, and based on the structure of the voice, i.e., the loudness, timbre, mobility, vibrato, temper, expression, personality, and so on. For instance: Soprano leggiero, Soprano Lirico, Soprano lirico spinto, Soprano drammatico, Soubrette, Jugendlich-dramatische Sopran, Dramatic coloratura soprano, Mezzo, Dramatic Alt, Spielalt, Tenore Lirico, Tenore lirico spinto, Tenore drammatico, Tenore buffo, Jugendliche Heldentenor, Lyric baritone, Dramatic baritone, Character baritone, Heldenbariton, Bass-baritone, Basso noble, Basso buffo, Character bass…

There also exist intermediate voices, like the light lyric soprano ("dugazon"), the baritone-Martin and so on for corresponding roles.

Secondary classifications are made according to:

- the maximal voice intensity, distinguishing e.g. the lyric opera tenor, the tenor of the comic opera (“demi-caractère”) and the operetta tenor, or the tenor lirico spinto and so on.
- the used vocal techniques e.g.: “coloratura”, specialty in quick vocalises, mostly with the light soprano, but also with the dramatic soprano, the “basse chantante” and so on.
- the age of the artist: young lyric sopranos are often used as “soubrettes” in specific Mozart operas, in operettas, while young dramatic sopranos are called “jugendlich dramatisch”. At the end of her career, a mezzo becomes “desclausas”.
- the vocal possibilities; in cases of reduced possibilities adjectives are added: “second”, “third”, or, worse, “coryphe”, “comprimaria” or “comprimario”.
- the artistic possibilities to play a certain role: a second tenor for instance, could be brilliant as “tenor buffo” (which asks for a penetrating timbre) or a “trial “.
- in the concert hall a concise classification is used: sopranos, altos, tenors, and basses, on the understanding that the sopranos are most of the time light or lyric sopranos, the altos are mezzos, the tenors are very light, and the basses are baritones. In the lyric theatre they often would be attributed to second roles or less. Concert performances frequently appeal to male falsetto voices.[171-173]

Specific songs suitable to specific voice types were scrupulously elaborated by opera composers. In some cases, composers even adapted (and still adapt) the musical score to the vocal possibilities and limitations of the singer. This could explain why some singing teachers of commercial music don’t bother about voice classification: songs are adapted or even rewritten to suit the assumed possibilities of the chosen singer or singing student.

One thus could easily argue so many singers, so many voices. Voice categories are artificial creations, bound to the historical development of the schools and the singing theatre, to the evolution of the aesthetic taste and to the particularities of the writing of some composers (Verdi for instance).

Voice specialists, however, stressed the importance of a correct voice classification before voice education starts.[174-181] Incorrect voice classification can enhance functional and organic voice disorders.[175-176,182-186] The biographies of famous and less famous singers very frequently mention examples of the pernicious outcomes for their voice and for their career caused by incorrect voice classification.[187-190]

The Recommendation by the Union of European Phoniatricians (UEP) for Standardizing Voice Area Measurement/Phonetography (1982) provided a lot of technical instructions regarding the registration of the "laryngeal possibilities with respect to fundamental frequency and sound intensity". Typical applications are:

- the assessment of the normal voice.
- testing singing voice potentialities.
- diagnostic aid in cases of vocal disturbances.
- the assessment of the results of therapeutic treatment.

Studies on voice usually provide exact information on the *number of subjects*, their *gender* and *age*. All other descriptions of subjects' qualities are missing or less accurate. We scrutinized our bibliography to find out which characteristics were mentioned. Less than 5% of the studies give subject information on:

- the average/mean age,
- height,
- weight,
- home,
- health condition,
- cold or sinus problems at the time of participation,
- use of medication,
- smoking habits,
- pure tone hearing screening,
- speech or hearing problems,
- phoniatric examination,
- judgment by a speech pathologist

Information on certain aspects of *health condition*, *screening* and *examination procedures* are merely intended as eliminating criteria in composing a study group.

Regarding the *training of the subjects*, we could distinguish copious information on:

- vocal training
- singing training
- years of training
- profession
- professional status
- years of professional experience areas of professional experience.

To try to classify these items, we made *a compilation of 364 different descriptions* in our Appendix.

Although a lot of authors make great efforts to give a description of their subjects' development of vocal proficiency, the distinction between *vocal training* and *singing training* is seldom clear. Most used are the rather neutral terms of "untrained subjects", "non-singers", "untrained singers" and "trained singers". Exceptionally, a definition is given of the subjects' status, e.g.: *trained singers*: "individuals who, actively and formally for professional reasons, study vocal music and train their voice according to the common principles and practices currently suggested by professional vocal teachers"[191] In a study by Teachey et al.[192] on vocal mechanics in "untrained professional singers", singers with less than 2 years formal training were classified as "untrained". Miller[193] even mentions a category of performer known as "the untrained professional".

The *years of training* and/or *professional experience* are seldom mentioned. Information on the *profession* of the subjects, their *professional status* and their *areas of professional experience* is very limited.

Despite this lack of uniformity in describing the subjects' vocal and/or singing training, a lot of authors do insist on the observed differences between "**trained**" and "**untrained**" subjects:

- because the laryngeal capacity is altered by voice training, the standard voice profiles obtained from trained children are not representative for the profiles of untrained children's voices.[194]
- individuals with vocal training are more accurate in their prephonatory adjustments than are individuals with no vocal training.[195]
- for the singer, laryngeal controls must be much more precise than for the speaker.[196]

- singers take just as long to initiate a tone as do non-singers, but they are more accurate in their targeting of a given frequency once phonation is initiated.[197]
- the ability to sing on key might be considered the feature that distinguishes singers from non-singers.[198]
- singers and non-singers vary the position of their larynx over quite a distance as they sustain frequencies throughout their full vocal range.[199,200] Generally, a shortening of the vocal tract is observed in non-singers as they position their larynx upward with vocal pitch, while the vocal tract lengthening is observed in singers as they lower their larynx below the rest position, hence lengthening their vocal tract for singing throughout their vocal range.[201]
- whereas untrained persons appear to make little distinction in their production behaviour between speaking and singing, trained singers organize their production in a different manner for singing than for speaking.[202,203]
- voice quality differences occur as the voice source signal passes through the supraglottic vocal tract.[204]
- during singing tasks, the trained singers' respiratory movements were very well-organized with respect to abdominal-thoracic coordination, and to respiratory-vocal coordination. They showed little variation in pattern during repetitive tasks. Untrained subjects' respiratory patterns during singing were characterized by markedly poorer coordination and by greater variability of movement pattern within a given task.[205]
- breathing strategy plays an important role in voice production during singing.[206,207]
- trained singers sing with a less pressed phonation than do untrained singers.[208]
- the most outstanding single difference between this group of choral singing females and the voice of a professional singer was the almost total absence of the vocal vibrato.[209]
- vocal training does appear to develop differences in the utilization of the sound producing mechanism for singing that are not present in the average or untrained voice.[210]
- a trained singer can be considered as an athlete who needs exercises for strength, endurance, timing, and agility.[211-215]
- separate normative data are needed for evaluation of the vocal athlete, i.e., the classically trained singer.[216]
- whereas untrained persons appear to make little or no differential use of their speech mechanism for singing and speaking, trained

singers in fact do. Herein then, lies the point of perceptual dominance of the trained singer. However, we are still unable to precisely describe the physiological manipulation of the singer, nor have we explored the problem of inter-singer variability.[217,218]

- as for the "singer's formant", it appeared from our preliminary acoustic records (real-time spectral analysis) that the trained singers produced this formant more consistently than the untrained singers during the singing of the arpeggios.[219]
- one of the goals in the training of the professional singing voice is the development of a frequency region of energy at about 2.8 K HZ. The presence of a significant amount of energy in this frequency region of the vocal spectrum tends to enhance the voice quality by producing an effect described by some as the vocal "ring". The vocal ring phenomenon is also referred to as the Singer's Formant.[220]
- since the singer strives to reduce or eliminate vocal roughness through training techniques, it might be hypothesized that there is less perturbation in vowels sustained by singers than in vowels sustained by subjects without vocal training.[221]
- in addition to respiratory differences, differences in laryngeal dynamics between trained and untrained subjects have been noted. Trained singers have been observed to utilize various modes of phonation not observed in untrained subjects, such as the use of "damped" folds, increased ability to control airflow, and isometric contraction.[222]
- skilled singers become adept at reproducing specific combinations of pitch, vowel, and intensity with what they consider a proper placement and desired colour.[223]
- in our work we have studied the development of the vibrato in students undergoing training, and find that, as this development progresses, vibrato is introduced to a greater extent, the movement is intensified, and the frequency raised. Most student's readings fell between 5 and 6 per second.[224]
- with years of training and performance, the mature vocal performer experiences fewer vocal changes with aging than does his or her age peer who is not a performer.[225]
- perceptual analysis indicated that singers could be correctly identified with greater frequency than by chance alone from their singing, but not their speaking utterances.[226]
- overall, the trained vocalists have the capability to produce greater F° ranges and greater maximum, minimum, and comfortable

intensity levels within the total F° range than do untrained vocalists, regardless of gender.[227]
- singers tend to produce greater SPL than non-singers, although this usually occurred only at a few intensity conditions.[228]

Other researchers, however, reported that:

- studies have demonstrated that trained subjects are less susceptible to vocal damage, although, once again, few statistically significant changes have been reported. In general, few conclusive findings have come from the laboratory.[229]
- there was no significant difference between artistic level singers and student singers or between either of the "singer" groups and the control groups.[230]
- the results of this study suggest a comparable constitution of the voice source in trained and untrained subjects, while the extended phonatory capabilities in trained subjects are probably based on an improved voluntary control over the voicing mechanisms.[231]
- the vocal apparatus basically does not differ between the untrained and trained male and female subjects, which might be explained by the relatively low level of training in the "trained" group.[232]
- it is not necessary to understand the mechanics of respiration (or the mechanics of singing in general) to have a successful singing career.[233]
- as with any other measure of speech and voice, there was a good deal of variability in the way in which the professional singers positioned their larynx during the production of the various tasks.[234,235]
- the habitual pitch level of professional singers is like that of untrained speakers.[236]
- singers with or without symptoms of vocal pathology do not show differences in vocal range.[237]
- with a few exceptions, the typical speaking behaviour of trained singers is not differentiated from that of untrained speakers.[238-240]
- the mean differences between the mean phonational range of a group of professional singers of all ages and the mean phonational range of an untrained group were not statistically significant.[241]
- in this study, however, singers and non-singers exhibited very similar phonational ranges.[242]
- interestingly, there is little or no significant difference in maximum vocal intensity between a trained and untrained singer.[243]

- male singers do not produce any higher SPL values at maximum vocal loudness than male non-singers.[244,245]; the same is true for the lower part of female singers' pitch range.[246]
- interestingly, the spectrum of the voice source is about the same in ordinary speakers as it is in singers and trained speakers.[247]
- it appears that the greatest evidence for a singer's formant can be found in the vocal performance of artistic level singers. The presence of energy in the frequency region of interest also can be found in the vocal productions of some of the student singers, and, in some cases, even for non-singer musicians.[248]
- these findings suggest that certain attribute variables such as musical training may influence performance on speech and voice production tasks. In establishing normative data for voice performance tests, it may be desirable for speech and voice scientists to consider such variables more carefully. Additional research is needed, however, to specify the degree to which musical training transfers to non-musical speech/voice tasks.[249]
- the upper modal and lower falsetto register boundaries exhibit little variability between singers and non-singers.[250]
- it is very confusing to singers and actors to think that they have two voices when they really have two vocal folds that will speak or sing or yell or laugh.[251]
- when different singers are asked to sing the same vowel, marked differences in vowel quality are frequently noticeable.[252]
- the outstanding difference between the better and the bad singers is the lack of vibrato frequency spread which characterizes the poor voices. Regarding harmonic distribution, there is no pattern which may be selected as indicative of a good singer.[252]
- except for the fact that the singer who produced his voice badly gives a lower intensity than the others, there is no consistently outstanding characteristic.[252]
- respiratory behaviour of professional country singers during singing resembled that of speaking.[253]
- no significant differences were found between the trained and the untrained groups in their ability to discriminate and/or control breath pressure.[254]
- professional operatic singing does not request a uniform breathing strategy for all singers.[255]
- the results of these investigations have shown a wide variability in the respiratory strategies employed by different singers.[256]

- in reading a paragraph at normal loudness and reading the same paragraph at twice normal loudness, the respiratory kinematics obtained by female classical singers are, for the most part, like those obtained from untrained women, untrained men, trained male classical singers, and trained male and female classical actors. [257]
- we also showed how an artist could have a certain measure of success with limited vocal equipment. While this statement was not intended to depreciate the vital importance of voice, it did indicate the equally great importance of artistry. While many phases of artistry are a matter of temperament and can, therefore, hardly be measured in scientific terms, certain other phases involve mechanical skill.[258]
- the results revealed great variability among singers with respect to the use of the jaw opening. For example, one singer produced the vowel /u/ with a jaw opening of about 25 mm, whereas most other singers had an opening of about 5 mm. These differences may reflect different singing techniques, possibly in response to different vocal tract lengths or morphology.[259]
- our own study focused on singing according to the Western operatic style. In this style, the singers are required to produce loud singing, as sound amplification systems are mostly not used. It seems particularly important for these singers to produce loud singing without excessively high subglottal pressures, as that may strain the vocal fold mechanism. In many other styles of singing, such as musical theatre, belting, and country-and-western singing, sound amplifying systems are normally used. This may imply that singers in these styles use different strategies. This needs to be studied in future research.[260-264].
- the results suggest that these country singers used basically the same type of phonation when they sang and when they spoke.[265]
- one discrete factor that may be particularly relevant to loudness production is training. Superior speakers have been found to exhibit greater variability. Indeed, not only training in speech, but also training in vocal or instrumental music may affect vocal variability.[266]
- the large ranges in fundamental frequency, jitter, shimmer, and signal-to-noise ratio are perhaps explained by the different ages and sizes of the subjects. However, recall that statistical analyses of these data determined no significant age, or sex effects for any of the acoustic measures.[267]

- as might be expected, both the male and female singers exhibited less jitter during their singing utterances in comparison to the non-singers, although these differences were nonsignificant. No clear trend emerged for the sung utterances for shimmer. For noise-to-harmonic ratio, the male singing group showed a significantly larger noise-to-harmonic ratio in comparison to the male non-singers.[268]
- the most outstanding single difference between this group of choral singing females and the voice of a professional singer was the almost total absence of the vocal vibrato.[269-270]
- the most consistent differences were the presence or absence of the singer's vibrato and formant in the singers versus the non-singers, respectively.[271]
- there appears to be no direct relationship between vocal training and its influence on the speech parameters measured for these professional singers.[272]
- except for more frequently observed complete closure and lateral phase differences of vocal cord excursions in trained subjects, no further differences were established between untrained and trained subjects.[273]
- the prospective assignment of subjects to the voice performance classes (i.e., stage singers, students of singers, amateur singers, and phoniatric patients) on the results of the F°-SPL-measurement alone remains somewhat problematic.[274]
- it often seems that voice profiles only are not enough to differentiate between trained and untrained voices; in case of voice disorders, mostly with hyperfunctional voice disorders, it is not easy to distinguish between physiological voice and disorders of the voice, or to correctly describe success or failure of therapy.[275]
- even the boundaries in pathological voices proved to be very large, as demonstrated in acoustical, aerodynamic and phonetographic studies.[276]
- the differences between non-singers and singers do not concern those aspects of voice function that are reflected in a phonetogram.[277]
- in the case of male singers, no clear difference in maximum SPL can be observed between singers and non-singers. The same is true for the lower part of female singers' pitch range.[278]
- the excellent singer is not physiological endowed and/or "gifted" but rather has benefited from technical voice training.[279]
- even among the normal groups examined herein, there were individuals who exhibited extensive variation, a factor that warrant

consideration when large subject groups are sampled or when sampling is done across voice disorders and diseases.[280]
- teachers of singing and control subjects acknowledged a similar rate of current voice problems.[281]

According to Sihvo and Sala[282], "great intra- and interindividual as well as intra- and inter-investigator variations are typical in all measurements of psychophysiological phenomena in humans". The search for objectivity in voice diagnostics too is hampered by the huge interindividual and intraindividual variability of the human voice.[283-286]

One can, without any doubt, conclude that *subject classification* remains a weak point in voice research. Our review of a great variety of studies show that the same difficulties arise when trying to classify not only the *subject,* but also the *vocal instrument* and the *voice.* An extensive list of the most used descriptions of the subjects' *voice condition* can be found in the Appendix, cited above. Here again, the most common descriptions are general ones: '*healthy voices'* or '*normal voices',* and '*patients'* or '*pathological voices'.*

While acknowledging classification to be one of the major objectives of scientific endeavour, it was established in the preceding chapters, that *subject classification* and *voice classification* remain hotly debated items in voice research. Especially regarding *voice classification,* voice scientists exhibit an ambiguous attitude: on the one hand, a subject's voice category is uncritically accepted without any manner of control, and on the other hand, voice classification is regarded as an indispensable tool for assuring a person's vocal health. *Voice classification*, then, is said to be very complicated, requiring a whole battery of complex tests and instruments.

We hypothesize, however, that F°-SPL measurement can provide a simple, but invaluable tool for voice classification. To that end, we will review in Chapter 6 the different acoustical parameters of voice, traditionally explored in voice research.

Information on certain aspects of *health condition*, *screening* and *examination procedures* are merely intended as eliminating criteria in composing a study group.

Regarding the *training of the subjects*, we could distinguish copious information on:

- vocal training
- singing training
- years of training
- profession
- professional status
- years of professional experience areas of professional experience.

Classifying a voice means, in the first place, to determine the voice range in which a subject can work without the risk of fatiguing his larynx and to which repertoire he should be assigned by the singing teacher. Garde[287], a French phoniatrician wrote, many years ago: "Voice classification is as important as the determination of the blood group and can be seen as a biological constant".

Strangely enough, in voice research, *voice classification* - if ever mentioned - is uncritically accepted by ALL investigators as an uncontested fact. But *who* devised voice classification, and *how*, remains unclear, except from some studies, referring to self-identification[288-290] or to singers, "representing a variety of voice types, according to the report of the choir director".[291]

According to Welch et al.[292], voice classification is an integral feature of our singing culture and individuals are seen and see themselves as belonging to a particular voice category, according to the conventional nomenclature for that category.

Some authors give a subjective appraisal of voice range in connection with voice type: "individuals with a restricted/wider range"[293] and "high voice register strongly pulled down, counteracting the evolution of a midvoice"[294], while other studies make mention of "singers of all voice categories"[295], or "singers of the four major voice categories"[296] or "higher/lower voice positions"[297] or even "good voices of lower tessitura" (contralto and baritone).[298]

The uncertainty about the *exact* voice category is also expressed in terms like bass/baritones[299-301], older/younger bass/baritones[302], tenor-baritones[303], mezzo-alto[304] or 'singing students in alto field.[305] Considering the many subtle differentiations, traditionally made in opera and concert, it is amazing that only one voice study deals with a "Spinto-tenor"[306], and another with a "lyric and dramatic soprano"[307]. Other studies refer to countertenors.[308,309] An extensive list of terms used in voice research can be found in the Appendix.

Tarneaud[310] states that the *tessitura* - the number of tones that is best suited to a voice - varies not only according to the *voice category*, but also according to each individual person. However, different authors have assigned different limits to the tessiture of every voice type. According to Garde[311] one should even classify not the voices, but the individual. This brings us back to the preceding chapter on s*ubject classification*. According to Welch et al., [312] however, the physiological and acoustic base for subcategories of broader classes is unclear.

As explained above, female, and male voices are commonly divided into six principal types: bass, baritone, tenor, contralto, mezzo, soprano. *But how can voices be classified*?

Although voice classification is of utmost importance for the career of the (student) singer, in assigning a specific singing role or in choosing the appropriate songs, most manuals on singing techniques remain silent on how to classify a voice. Of course, it is recognized that basses and altos should be able to produce the lowest pitches, and tenors and sopranos the highest pitches, and, consequently, baritones and mezzos, something in between. Sometimes approximate voice ranges are proposed, but cautiously pointing to the many possible exceptions.

Bonet and Casan[313] state that voice classification is necessary for all children who sing but propose a classification method only based on locating the lowest and highest (unforced) frequency tone. They found the same mean lowest frequency (a = 220 Hz) as well in non-dysphonic boys and girls as in dysphonic girls, and b (247 Hz) in dysphonic boys. The mean highest frequency was +/- cis2 (547 Hz) in dysphonic boys and girls, and +/- gis2 (830 Hz) in non-dysphonic boys and girls. They measured, however, extreme pitches going from e (165 Hz) to dis3 (1244 Hz), but omit to explain how the children were classified and only mention that their method "requires a musically and vocally well-trained examiner".[314]

In order to classify a voice one can refer to the situation of the different registers and to the pitch of the speaking voice.[315] Nevertheless, the voice range also plays an important role while at least as much importance is attached to the timbre (a real mezzo or alto distinguishes herself from a soprano on whatever note by a much warmer timbre or by a much darker voice).[316-318]

According to some authors[319], however, timbre could determine the voice category: a dark mezzo could sing higher than a real soprano.[320]. Other authors[321] agree that criteria such as timbre and tessitura can be deceptive.

It is remarkable that in a report by Cleveland[322], intended to give "a Clearer View of Singing Voice Production: 25 Years of Progress", only a few lines are devoted to "voice classification". Vocal tract resonance patterns are considered as being different for various voice categories (basses, tenors, altos, and sopranos).[322] This means that the most frequently occurring voice categories (baritones and mezzos) are ignored!

Publications on voice classification are scarce.[323] Voice scientists even seem to demonstrate a distinct discrete attitude towards assigning their subjects to specific voice categories. Reviewing several decennia of voice research leads us to the consideration that not much has changed ever since. Through the years, even information about voice range / tessitura remains scarce and diverse.

We synthesized the *(extreme) limits of voice ranges / tessitura*, as suggested by a lot of authors with different backgrounds[324-350] in the following table:

Classification	**Lowest tone**	**Lowest frequency**	**Highest tone**	**Highest frequency**
Bass	C1-------E	33 Hz - 82 Hz	a-------fis3	220 Hz - 1483 Hz
Baritone	B1-------B	62 Hz - 123 Hz	f1--------b1	349 Hz - 494 Hz
Tenor	C---------c	65 Hz - 131 Hz	g1-------d2	392 Hz - 587 Hz
Contralto	A---------g	110 Hz - 196 Hz	d2-------e3	587 Hz - 1319 Hz
Mezzo	B---------a	123 Hz - 220 Hz	f2--------e3	698 Hz - 1319 Hz
Soprano	c--------c1	131 Hz - 262 Hz	g2-------c4	784 Hz – 2093 Hz

Table 5: Limits of voice range / tessitura of basic vocal types, according to different authors.

One must consider, however, that some authors[351] accept a difference of more than one octave between their data of voice range and tessitura of the same voice categories, just to play safe, as we presume:

- alto: range: 131 – 784 Hz; tessitura: 262 – 494 Hz
- mezzo: range: 165 – 880 Hz; tessitura: 294 – 523 Hz
- soprano: range: 196 – 1175 Hz ; tessitura: 392 – 698 Hz

Correct classification of the singer's voice is indispensable to obtain its optimum output.[352,353]

Most singing teachers judge their students' voices by only listening to two parameters of voice: voice quality and voice range. Tarneaud[354], however, explains that pitch and timbre depend not only on hereditary and physiological factors but also on educational mimesis, acquired in different surroundings, family, school, profession. Besides, voice quality is highly dependent on vocal techniques, thus on the received education. This means that many (if not all?) singers have developed a functional adaptation of their vocal organs, which is not always in correspondence with their anatomical and physiological possibilities. Besides, each singer has not one characteristic timbre, but a set of timbres, or a timbre transformation.[355,356]

Erickson[357]explains that, given the possible changes in timbre across the singing range, it is possible that any two voices may be perceived as having similar timbre on one pitch-loudness-vowel combination and dissimilar timbre on another. She concludes that "categories must be elastic and may not be reducible to one unchanging acoustic metric".[357]

According to Tarneaud[358], classification of the singing voice and of the speaking voice is based on the anatomical and physiological evaluation of the vocal apparatus. The difficulties of voice classification are those of every biological classification, based on the existence of many factors, more or less concordant in the same individual. According to the same author, voice classification is based on 1. anatomical and bio-typological factors, such as: height, the dimensions of the vocal cords, the shape and the volume of the resonating cavities, the general and vocal muscular constitution, and a lot of bio-typological traits.

2. acoustical factors, such as: tessitura, speaking fundamental frequency, the passages and voice timbre; 3. the accordance or discordance of the above-mentioned factors.

Factors of voice classification, according to Garde[359] are:

- the length of the vocal cords.
- the resonators and the timbre.

- accessory aspects: the body length, the habitual pitch of the speaking voice, the morphology, endocrine and sexual aspects, and neuro-psychic condition.

Marunick and Menaldi[360] found that no single measurement of the maxillary dental arch form could be seen as a predictor for voice classification. Their data, however, suggest that sopranos have a shallow palate, mezzos a medium palate, and altos a deep palate. These results are agreement with earlier studies[361,362], declaring that there is a general rule that big resonators are found in low-pitched and dramatic voices, and small resonators in high-pitched and lyric voices. Gutzmann[362], however, stated that the absolute assessment of the voice category should be made, based on the larynx (length of the vocal folds) and, secondary, the relative assessment should be made, based on the shape of the palate, "colouring" the voice. He also cautions against all imaginable variations.

The above mentioned anatomical and biotypological factors aspects usually require a lot of complex instruments, and most of all, highly experienced specialists. Voice range, timbre and register transitions are usually considered to be important classification criteria.[363] However, the assessment of tessitura, speaking fundamental frequency, passagio's, and voice quality require an experienced ear.

Concerning phonetography, Behrman et al.[364] cite a conclusion of the International Voice Committee, considering the VRP as more useful as a within-subject measure than as a between-group measure. The possibility that phonetographic analysis could discern between voice types was overlooked. Nevertheless, the Committee recommended that the voice range profile be studied further to achieve a classificatory scheme for the different kinds of upper and lower contour patterns observed.

For many years we experienced with phonetography as an appropriate aid for voice classification. From time to time, some authors, praising the wide possibilities of phonetographic analysis, give some hints in this direction.[365-371] However, a specific study on voice classification by phonetography could not be found. Although other authors[372-377] assume that phonetography provides a lot of useful information in classifying a voice, no specific interpretation of phonetographic results regarding voice classification could be found in the scientific literature. No specific curves are presented regarding specific voice categories. This has not only to do with some difficulties in interpreting the phonetographic curves, but also with the general conviction that voice classification belongs to the domain of the professional singing voice. At this point, voice classification seems to be a prerogative of the singing teacher, who seems to possess an exceptional trained ear for assessing voice categories. Acknowledging, however, that this methodology cannot be accepted any longer as the only sure way of classification, we will try to demonstrate with our examples that voice classification by ear alone often fails. Moreover, we will indicate why this method must fail in many cases and especially at which locations in the frequency spectrum most classification errors occur.

CHAPTER 6

PARAMETERS OF VOICE REVEALED BY F°-SPL PROFILES

6.1. Vocal range (= pitch range)

The complex sounds, produced by human beings, are composed of the fundamental (the lowest frequency, correlating with the frequency of the glottal opening and closing) and harmonics (partials, overtones), which are multiples of the fundamental[378,379], for instance:

- fundamental: c = 128 vibrations
- 1st harmonic: c1 = 256 vibrations or 128 x 2
- 2nd harmonic: g1 = 384 vibrations or128 x 3
- 3rd harmonic: c2 = 512 vibrations or 128 x 4

The distances between some of the overtones and the fundamental are called *intervals*, for instance:

- second: distance of 2 tones
- third: distance of 3 tones
- fourth: distance of 4 tones
- fifth: distance of 5 tones
- sixth: distance of 6 tones
- seventh: distance of 7 tones
- octave: distance of 8 tones

When these tones are performed consecutively, we get a *scale*[380]. The frequency of 440 cps (cycles per second) or Hz (Hertz) corresponds to the 'concert a', produced when the tines of the tuning fork vibrate back and forth 440 times each second. Doubling the frequency raises the pitch by an *octave.*

The pure mathematical relationship of fundamental and harmonics is an important fact to remember, when discussing the methodology of phonetography later.

For the moment, let's consider only the important aspect of *tonality*, which refers to the intimacy of the octave in musical scales, but generally applies to any two tones when the frequency of one tone is the double of another. The most prominent harmonic always has a frequency which is the double that of the fundamental (stimulus tone). This suggests, according to Gulick[381], that the *octave* may have a kind of physiological intimacy.

Furthermore, electrophysiological studies of single units in the auditory nerve indicate that a neuron that shows itself tuned to a best frequency also shows itself tuned to simple multiples of that frequency. Accordingly, auditory neurons with secondary and tertiary response areas could easily account for *tonality* and the difficulty of discriminating the *octave interval*. Still according to Gulick[381], physiological intimacy of the octave does not require that this interval be divided into eight smaller intervals, as in the *tempered diatonic musical scale* to which we have grown accustomed. Neither does it mean that a scale could not extend beyond the octave for its termination. Although most Western music is written either in the Ionian (*major*) or Aeolian (*minor*) mode, even the less popular modes (Dorian, Phrygian, Lydian, and Mixolydian), *all contain the octave.*[381]

Even in pathological cases (e.g., a report on a rare case of an 18-year-old girl who suffered a perverse mutation towards the end of her pregnancy), phoniatric examination showed that the voice of the girl was that of a baritone. Her vocal range, register changes, and habitual pitch descended one octave.[382]

Hanley and Thurman[383] remind us of a few fundamental facts about the *E.T.M. (Equally Tempered Musical) scale*: the basis unit comprising the full scale is the *octave*, which constitutes a difference in frequency between tones in a ratio of 2:1. There are six whole tones in an octave and twelve semitones. The "do-re-mi" octave and the white keys of the piano include five whole-tone and two half-tone or semi-tone intervals. The units in this scale do not have absolute value in cycles per second, but only have relative or ratio value above or below any selected point. For example, "re" has no fixed value in cps, but rather is obtained by multiplying "do" by a specific numerical factor.[383]

It is the *fundamenta*l, i.e., the lowest frequency, which can be analysed in a complex sound, that gives the sensation of *pitch.* Pitch is thus the *perceptual correlative of fundamental frequency.*[383]

Pitch depends on frequency of cord vibrations which depend on:

a). length, thickness, breadth, and stiffness of the vibrating parts of the cords.
b). muscle force tending to close the glottis (oppose the cords).
c). breath pressure.
d). time relationships of opening, closing and shut phases of vocal cord movements.[384]

Pitch is also dependent on gender, the laryngeal structure, the tension of the larynx musculature and the *voice category.*[384] Loud voicing at high pitches in speaking and in singing is known to be very demanding.

Sulter et al.[385] remark that "only little knowledge is available concerning the mean range and standard deviation of the frequency range in large, specified groups of men and women".

The measurement of pitch and intensity, as expressed in the phonetogram, clearly indicates the complex relationship between these two most important parameters of voice.

In singers, pressure is adapted not only to phonatory loudness but also to fundamental frequency. Vocal loudness and voice fundamental frequency are normally interdependent; on the average, speakers and singers raise their average speaking pitch by about 0.4 semitones per dB increase in equivalent sound level.[386,387]

Every human being can produce a variety of tones which is called the *vocal range*. The possibilities of the singing voice vary along a musical scale, going from C (65 Hz) for some basses to g3 (1566 Hz) or even c4.[326] The range of sounds most convenient to a voice is called *tessitura*, which is not only different for each *voice category* but also for everyone.[388]

According to Habermann[389], basses possess the largest vocal range and tenors the smallest, while sopranos have a large vocal range, and the mezzos have a small range. He makes a distinction between ordinary voices with highest tones situated one third to a sixth lower than the highest tones of artistic singers, the lowest tones being the same.

Brown et al.,[390] however, found no statistically significant differences in mean phonational range between a group of professional singers of all age groups and an untrained group, while Wirth[391] maintain that baritones have the smallest vocal range.

Children between 7 – 14 years can be divided into voice categories too.[392-394]

- soprano: a – g2.
- mezzo: g – e2.
- alto: f – c2.

In an amusing old Dutch study from 1912, Schuyten[395] narrates the extreme difficulties he experienced in trying to classify the voices of 3 – 15 years old school children. At the end, he found the workload not enough rewarding! He advised, however, that the songs the children learned must be situated within their individual vocal ranges.

In children too, it proved of value to establish a correct distinction between the physiological and the musical frequency range. Even in very young children the physiological frequency range of the voice has a broad, almost "adult" range.[396]

Frank and Sparber[397] deny that the vocal range of common people could attain two octaves, like mostly thought. They do not mention by which method they classified their subjects, but they found only one tone difference between alto, mezzo, and soprano voices! Moreover, they concluded that the highest pitches of normal voices are one third to one sixth *lower* than formerly mentioned in the literature.

Böhme and Hecker[398] corroborate the continuous shrinking of the vocal range in people over 60 years.

Many authors stress the fact that people's interest in frequency is limited to a range with a lower value around 16 to 20 Hz and an upper one between 16.000 and 20.000 Hz. This range encompasses normal human hearing. The sounds of speech are even more limited in range: fundamental vocal cord vibration very rarely extends below about 70 Hz and above 1000 Hz.[399]

Zack et al.[400] found no effect of task (discrete steps and glissando) on determination of maximum phonational frequency (MPFR) in a group of 30 normal adult females.

In a study on the expression of emotion in voice and music, Scherer[401] found that "of all variables studied, F° range had the most powerful effect on judgments."

Abithol[402] remarks that, on the theatrical scene, linguistic differences are observable: in Russian, almost two octaves are used, in English one and a halve octave, and hardly one octave in French.

We explained already the difference between vocal range (as noted in phonetographic procedures) and the tessitura. Singing teachers usually evaluate the combination of pitch and vocal quality by ear, thereby excluding some pitches they cannot accept from an aesthetic point of view, whereas scientists generously accept every pitch which the subject's larynx can produce at a given moment, regardless of its quality. This controversy easily explains why the few manuals which provide information on the lowest and highest pitches of the human voice differ so greatly, and why there still exists so much confusion between artists, conductors, directors, singing teachers, and even voice scientists, regarding *voice classification*. As almost everybody feels entitled to make a highly subjective statement on the classification of a given voice, by the sole grace of one's own perfect, well-trained, musically tuned two ears, one can easily understand the many misunderstandings on this subject. The use of phonetography as an objective aid in *voice classification* can be of great help, as we will prove later.

Exceptionally, even in some phonetographic studies researchers prefer not to consider the utmost performances of the voice, fearing that some damage to the voice organ could be done.[403-408] Strangely enough, some studies, e.g. Kötter and Klingholz[409], accept voice categories as they are communicated to them by others. The obtained Voice Range Profiles are then interpreted according to the voice categories of their subjects!?

6.1.1. Overlapping of voice categories

We synthesized the data, expressing the large limits of *voice range / tessitura of the* six *basic human voice types*[410], found in the literature, to demonstrate the many **overlaps** between not only two adjacent but even between *all* voice categories. (Table 6):

TONE	Hz	*MALE*	*VOICE*	*TYPES*	*FEMALE*	*VOICE*	*TYPES*
c4	2093						Soprano
b3	1976						Soprano
a3	1780						Soprano
g3	1568	Bass					Soprano
f3	1397	Bass					Soprano
e3	**1319**	Bass			**Contralto**	**Mezzo**	**Soprano**
d3	**1175**	Bass			**Contralto**	**Mezzo**	**Soprano**
c3	**1047**	Bass			**Contralto**	**Mezzo**	**Soprano**
b2	**988**	Bass			**Contralto**	**Mezzo**	**Soprano**
a2	**880**	Bass			**Contralto**	**Mezzo**	**Soprano**
g2	**784**	Bass			**Contralto**	**Mezzo**	**Soprano**
f2	698	Bass			Contralto	Mezzo	
e2	659	Bass			Contralto		
d2	587	Bass		Tenor	Contralto		
c2	523	Bass		Tenor			
b1	**494**	**Bass**	**Baritone**	**Tenor**			
a1	**440**	**Bass**	**Baritone**	**Tenor**			
g1	**392**	**Bass**	**Baritone**	**Tenor**			
f1	349	Bass	Baritone				
e1	330	Bass					
d1	294	Bass					
c1	262	Bass					Soprano
b	247	Bass					Soprano

a	220	Bass				Mezzo	Soprano
g	**196**				**Contralto**	**Mezzo**	**Soprano**
f	**175**				**Contralto**	**Mezzo**	**Soprano**
e	**165**				**Contralto**	**Mezzo**	**Soprano**
d	**147**				**Contralto**	**Mezzo**	**Soprano**
c	**131**			Tenor	**Contralto**	**Mezzo**	**Soprano**
B	123		Baritone	Tenor	Contralto	Mezzo	
A	110		Baritone	Tenor	Contralto		
G	98		Baritone	Tenor			
F	87		Baritone	Tenor			
E	**82**	**Bass**	**Baritone**	**Tenor**			
D	**73**	**Bass**	**Baritone**	**Tenor**			
C	**65**	**Bass**	**Baritone**	**Tenor**			
B1	62	Bass	Baritone				
A1	55	Bass					
G1	49	Bass					
F1	44	Bass					
E1	41	Bass					
D1	37	Bass					
C1	33	Bass					

Table 6: Synthesis of the limits of voice range / tessitura of the six basic voice categories.

6.1.2. Classification problems around specific frequencies

If someone would try to classify a voice by ear, based on the limits of voice range / tessitura alone, some problems will occur around specific frequencies.

- Considering the lowest tones:

Male voices.

TONE	*FREQUENCY*	*CLASSIFICATION PROBLEM*
B1	62 Hz	Bass - Baritone
C	**65 Hz**	**Bass - Baritone - Tenor**
D	**73 Hz**	**Bass - Baritone - Tenor**
E	**82 Hz**	**Bass - Baritone - Tenor**
F	87 Hz	Baritone - Tenor
G	98 Hz	Baritone - Tenor
A	110 Hz	Baritone - Tenor
B	123 Hz	Baritone - Tenor

Table 7: Classification problems situated at the **lowest** tones of male voices.

One can easily observe that the lowest tones of a male voice produced around C, D or E, could be attributed to a bass, or a baritone or a tenor.

Female voices.

TONE	*FREQUENCY*	*CLASSIFICATION PROBLEM*
B	123 Hz	Contralto - Mezzo
c	**131 Hz**	**Contralto - Mezzo - Soprano**
d	**147 Hz**	**Contralto - Mezzo - Soprano**
e	**165 Hz**	**Contralto - Mezzo - Soprano**
f	**175 Hz**	**Contralto - Mezzo - Soprano**
g	**196 Hz**	**Contralto - Mezzo - Soprano**
a	220 Hz	Mezzo - Soprano

Table 8: Classification problems situated at the **lowest** tones of female voices.

For a female voice, the lowest tones around c, d, e, f and g could be attributed to a contralto, or a mezzo or a soprano.

Considering the highest tones:

Male voices.

TONE	*FREQUENCY*	*CLASSIFICATION PROBLEM*
f1	349 Hz	Bass - Baritone
g1	**392 Hz**	**Bass - Baritone - Tenor**
a1	**440 Hz**	**Bass - Baritone - Tenor**
b1	**494 Hz**	**Bass - Baritone - Tenor**
c2	523 Hz	Bass - Tenor
d2	587 Hz	Bass - Tenor

Table 9: Classification problems situated at the **highest** tones of male voices.

One can easily observe that the highest tones of a male voice produced around g1, a1 or b1 could be attributed to a bass, or a baritone or a tenor.

Female voices.

TONE	*FREQUENCY*	*CLASSIFICATION PROBLEM*
f2	698 Hz	Contralto - Mezzo
g2	**784 Hz**	**Contralto - Mezzo - Soprano**
a2	**880 Hz**	**Contralto - Mezzo - Soprano**
b2	**988 Hz**	**Contralto - Mezzo - Soprano**
c3	**1047 Hz**	**Contralto - Mezzo - Soprano**
d3	**1175 Hz**	**Contralto - Mezzo - Soprano**
e3	**1319 Hz**	**Contralto - Mezzo - Soprano**

Table 10: Classification problems situated at the **highest** tones of female voices

For a female voice, the highest tones around g2, a2, b2, c3, d3 and e3 could be attributed to a contralto, or a mezzo or a soprano.

As an amusing note we can also point to the special situation where, at specific frequencies, the bottom tones of some female voices could be confused with those of some male voices, and the highest tones of some male voices could be mistaken for those of some female voices!

TONE	*FREQUENCY*	*CLASSIFICATION PROBLEM*
A	**110 Hz**	**Baritone - Tenor - Contralto**
B	**123 Hz**	**Baritone - Tenor - Alto - Mezzo**
c	**131 Hz**	**Tenor - Alto - Mezzo - Soprano**

Table 11: Overlapping of male and female **lowest** tones.

TONE	*FREQUENCY*	*CLASSIFICATION PROBLEM*
d2	**587 Hz**	**Bass - Tenor - Contralto**
e2	**659 Hz**	**Bass - Contralto**
f2	**698 Hz**	**Bass - Contralto - Mezzo**
g2	**784 Hz**	**Bass - Alto - Mezzo - Soprano**
a2	**880 Hz**	**Bass - Alto - Mezzo - Soprano**
b2	**988 Hz**	**Bass - Alto - Mezzo - Soprano**
c3	**1047 Hz**	**Bass - Alto - Mezzo - Soprano**
d3	**1175 Hz**	**Bass - Alto - Mezzo - Soprano**
e3	**1319 Hz**	**Bass - Alto - Mezzo - Soprano**
f3	**1397 Hz**	**Bass - Soprano**

Table 12: Overlapping of male and female **highest** tones.

Frequency range, however, is frequently used as a basic voice classification parameter.

Lycke et aL.[411] made an explorative study: "*Frequency Range as a Parameter for Female Voice Classification"*, by means of an algorithm, based on the limits of the female frequency range, according to 38 authors of different backgrounds. The results of the voice classification by the singing teachers were compared to the results of voice classification by the algorithm. The results of the study demonstrated that frequency range alone proved to be not suitable as a parameter for voice classification.

Of course, one could argue that, during the classification procedure by ear alone, one considers a kind of balance between the quality of the lowest and the highest tones which can be attributed to some type of voice, but in our opinion, this remains a mere guess in most cases. One thus may have serious doubts about the credibility of voice classification based on voice range / tessitura alone. In fact, the discussion on *acceptation of a tone* as being inherent of the specific vocal make-up of a subject, or the fear that some tones may be dangerous for someone's voice, clearly indicates that frequency alone is not sufficient to make a distinction between the voice categories. In fact, we believe that in this matter*, **voice intensity** provides an answer to this age-old discussion*.

6.2. Voice intensity

In the preceding pages we explored the meaning of the determination of the range of pitches in every subject and its complicated relationship with voice categories. As we know, the voice source can be varied continuously along the phonatory dimensions of *pitch* and *vocal loudness.*[412]

To understand what voice intensity really means, we must refer to some basic thoughts about this most important parameter of voice.

"**EXPLOSION**", - that word, according to Hanley and Thurman[412], most completely sums up how sounds begin. "It is a spreading outward in all directions of a change in the space and pressure relations among the particles that make up the medium, the material, or substance in which sound is born"

Intensity, as the measure of subjective *vocal loudness*, is expressed by a logarithmic scale and is proportional to the square of amplitude and frequency. Intensity is also proportional to the square of the pressure and the square of particle velocity. According to the same authors, sound intensity involves consideration of the rate of flow of energy through a unit area of the medium, a quantity difficult to measure. This is so because the audible range in the basic physical energy units appropriate to this sound attribute is several billion units in extent. Hence it has become a convention to report not *sound intensity*, but *sound level*; the latter being expressed in ratio units, **decibels (db.),** rather than the absolute units which appropriately express sound intensity.[412]

The decibel works to a *logarithmic scale* (exactly as our ears do):

INTENSITY RATIO	DECIBEL EQUIVALENT
1	0 dB
10	10 dB
100	20 dB
1.000	30 dB
10.000	40 dB
100.000	50 dB
1.000.000	60 dB

REMINDER: *a doubling of intensity = 3 dB(A*). Inverse square law: *SPL dies away by 6 dB(A) every time the distance from the source is doubled.*

When one realizes that a doubling of intensity = 3dB(A), one can understand the excitement of opera lovers for a beautiful tenor's very loud high c2, or for the highest pitches of an exceptional soprano voice in Mozart's "Queen of the Night". For the same reason one can explain the huge success of the best-selling soundtracks of some pop-singers like Whitney Houston! In my opinion, it is a real wonder that our vocal apparatus with its tiny vocal cords (between 1,5 cm and 2,5 cm in length in males and between 1,25 cm and 1,75 cm in females) can produce such extreme frequencies and intensities, during almost a whole life!

In exploring phonetographic results we always must bear in mind that logarithmic scales must be used because of the vastness of these ratios. It is a remarkable fact that the intensity of very loud speech is roughly a million times that of softly whispered speech.[413] *There is a range of approximately 140 dB from the threshold of sound detectability to the threshold of pain in the frequency region where hearing is most acute, while the average level of human vocal sounds is about 65 dB above an arbitrarily chosen zero level of 0,0002 dynes per centimetre squared, when the sound measuring instrument is held 1 m. from the speaker's lips.*[412]

Although the human ear is an excellent instrument to quickly detect the nuances of voice quality that still escape the laboratory analyses[414], detecting exact loudness differences by ear happens to be far more difficult. This is also the case in the control of dynamic intensity range. Coleman[415], for instance, found that, in his study on dynamic intensity variations of individual choral singers, 15 of the 20 choral singers produced mezzo forte song levels closer to their fortissimo level than to their pianissimo level.

In comparison to the parameters pitch and timbre, loudness differences of more than 10 dB are necessary to be detected.

The ear proves to be less susceptible for loudness differences.[416] As Punt[417] denotes, a person with normal hearing perceives notes of certain pitch ranges as *louder*, than those of other pitch ranges, their intensity being equal. In general, voices sound louder as they range from bass, baritone, tenor, contralto, mezzo to soprano, partly because of this phenomenon, and partly because the lowest notes can only be sung comparatively softly for physiological reasons. The bass and the lower ranges of the baritone sound especially soft and the higher soprano notes especially loud, but the effect of harmonic partials as well as the fundamental pitch note must be considered.[417]

SPL is an important variable to be considered, although clinicians may not be able to detect the small differences across complex speech tasks.[417] The loudness difference that we perceive between singers and non-singers does not consistently correspond to a SPL difference. So, according to Sundberg[418], *SPL is a poor indicator of vocal loudness*.

Ternström[419] explains how the dynamic range of a choir is determined by the skill of the singers, their number, and the room acoustics. Extending the dynamic range of a choir happens to be difficult, as *doubling the number of choir singers only increases the sound level by 3 dB, while a doubling of subglottal pressure of an individual singer raises the sound level by +/- 9 dB*.

Belting is perceived as loud phonation, somewhat like yelling, but this vocal technique would have less success in large concert halls without extra amplification support.[420,421] Sundberg et al.[422], however, in an experiment with a female professional singer, trained in both the operatic and belting styles and in an intermediate vocal technique ("mixed"), found that SPL was quite similar in operatic and mixed styles, while it was at least 10 dB louder in belting.

Jo Estill's paper on "Observations About the Quality Called "Belting" at the 1980 Symposium "Care of the Professional Voice" (Voice Foundation, N.Y.), was called "the most provocative of the presentations". She made some interesting first-order observations on belting, having implications for research, e.g. 1. "it is loud" and 2. "the tone sounds higher than it is". Miles and Hollien[420], affirm that "loudness" was the most frequently referenced perceptual description of belting.

Lycke (see Chapter 4) investigated in a more objective way if singers, using belting techniques, can indeed sing higher and louder in comparison to classically trained singers. Phonetograms (Voice Range Profiles) were carried out with the lingWaves VDC (v.2.5), according to the directives of the U.E.P., on 61 students (53 females and 8 males) of a 4-year educational programme in Musical-Theatre. The age of the subjects ranged from 18 to 25 years. All students assumed to have learned different belting techniques by different voice teachers and extensively demonstrated this during the investigation. They previously filled in an extensive questionnaire about the status of their voice at the moment of the test.

RESULTS: Regarding questions on the ease to perform fortissimo and pianissimo tones and mezza di voce, answers on the Likert-scale ranged from 2 to 10, with an average of 5.34 to 7.02 (STD between 1.76 and 1.9). Regarding subjective impressions on attainable high pitches and their quality, the answers were also very divergent, with a mean of 4.76 to 6.97 (STD of 1.57 to 1.79).

In a former study, addressing to young adult people of the same age category, who had a more classical training, c3 (1047 Hz) was noted as highest pitch in males and a3 (1760 Hz) as highest pitch in females. In the study on belting, dis3 (1225 Hz) was noted as highest male pitch and c4 (2021 Hz) as highest female pitch. Only maximum intensities of 115 dB(A) in belting were obtained in young male students and 117 dB(A) in young female student singers, while in the study of classically trained male and female student singers of the same age-group obtained 120 dB(A), resp.125 dB(A).

CONCLUSION: Referring to Estill's observation, it appears that in belting the tone not only sounds higher than it is, but that indeed very extreme high tones can be reached. However, the subjective impression of loudness in belting does not mean that this singing technique also provides the highest obtainable maximum intensity values.

According to Murry and Rosen[423], a cry produced as a shrieking or screaming sound is the result of increased muscular activity, lengthening of the vocal folds, and increased subglottic pressure. Phono trauma, in casu vocal fold haemorrhage, is often the result. Lower SPLs, however, are associated with reduced overall tension in the musculature body of the vocal folds.[424] A study on the speaker's formant in male voices[425] showed that shouting increases the spectral energy of the adjacent critical bands but not the speaker's formant itself. Changes in vocal intensity appear to be directly related to air flow.[426]

According to Hirano et al.[427], the regulatory mechanism of the intensity is rather complicated. In general, contribution of the adductors, especially the vocalis and lateral cricoarytenoid muscles, is dominant for low pitches in heavier register, whereas the air flow is more significant for high pitches in lighter register.[426,427]

Subglottal pressure is known to be the main physiological parameter for regulating vocal loudness[428-437] but several other factors affect SPL.[438-444] Sundberg et al.[444] made a study on phonatory control in male singing. They concluded that "overall, their intensity-pressure relation approached linearity in most cases, although considerable variety between pitches, and within and between subjects, was found".

Plant and Younger[445] came to the same conclusion: "In general, intensity increases with higher subglottic air pressures, but there are also considerable variations both between individuals and within different portions of the frequency-intensity range for a given subject". Wilson and Leeper[446] and Stathopoulos and Sapienza[447] too found large amounts of variability regarding changes in laryngeal airway resistance as a function of vocal sound pressure in both male and female subjects. Keilmann et al.[448] came to the same conclusion for children.

The same remarks can be made regarding prephonatory chest wall posturing. Hixon et al.[449] found a wide range of relative volume contributions of the rib cage and abdomen both within and among subjects.

Sundberg [450] found that singers do not sing more loudly than non-singers, but *singers can be heard even when they are accompanied by a big orchestra if they make use of the "singer's formant", a prominent spectrum envelope peak appearing in the vicinity of 3 kHz in all vowel spectra.* *Formant tuning* (adjusting the centre of frequency of a formant to coincide with that of a harmonic) and *resonance tuning* (an adjustment of the vocal tract to obtain the desired resonance) have a considerable effect on the singing voice, not only on the quality of the sound but also on the sound pressure level.[451-455] As Sundberg[456] expressed it: "the strongest partial determines SPL almost completely; it may be either the fundamental or an overtone, and the amplitude of these partials are varied by different phonatory mechanisms. This appears to be another limitation of the perceptual relevance of the SPL measure". Moreover, tuning F1 to the vicinity of F° at high pitches is an example of supplementing vocal effort by resonance, as it yields a great gain of sound level at no expense in terms of vocal effort.[457] Thus, the relationship between the intensity of the voice source and the radiated SPL is complicated by vocal tract factors[458]; besides, mode of phonation (from breathy to pressed) also can affect SPL.[459,460]

To produce more intensity a higher subglottal pressure is needed, and, in spite of this high subglottal pressure, there must be a good glottis closure.[460] According to Schutte[461], trying to relate subglottal pressure and mean flow rate to the magnitude of the radiated sound power, may provide an index of vocal efficiency. While efficiency increases with increasing sound pressure level, this does not mean that an increase in vocal efficiency will necessarily mean an increase in healthy phonating.[462]

Titze[463] explains that selecting a single output of interest for efficiency calculations (e.g., vocal output) automatically limits the efficiency of a multipurpose machine, namely the human body. The human body appears to be very inefficient as a phonation machine, and glottal efficiency calculations usually do not include a cost/benefit ratio for vocal health and longevity.

The modes of vocal fold vibration represent extremes of a *continuum* running from pressed on the one hand to breathy on the other, with flow in between. There are many ways to elicit the sound of flow phonation from the singer, while this mode of phonation is more efficient and less physically taxing to the singer.[464] In flow phonation the flow nearly, but not completely, reaches a true zero flow value.[465] As Sundberg[465] stated, “differences in glottal adduction force are relevant to the relationship between subglottal pressure and SPL. If glottal adduction is increased and vibration amplitude thus reduced, more pressure is needed for maintaining the same SPL”. The various levels of adduction, often described in extremes of “breathy” and “pressed”, are of great importance from a clinical point of view.[466,467] The phonatory dimensions pitch, vocal loudness and mode of phonation (fluctuating between the extremes of hyper functional and hypo functional phonation) are relevant from the point of view of phonatory hygiene as well as from the point of view of vocal pedagogy.[468] While a not appropriate habitual pitch or vocal loudness can be harmful to vocal health, so does the use of an inappropriate mode of phonation.[468]

Respiratory activity is highly variable in classically trained singers, but no significant differences in breathing activity were found in the so-called “supported singing voice”.[469]

Vocal intensity increases as interspeaker distance increases, but Healy et al.[470] demonstrated gender differences associated with increases in vocal intensity: women showed larger increases than men. Other authors[471,472], however, observed that males use significantly greater intensity levels in speech.

According to Buekers et al.[473], 60-65 dB(A) is necessary for a normal conversation. Statistical analysis, however, revealed that for all speech tasks, men spoke at significantly higher levels than women did. The mean vocal intensity across three speaking conditions, “at a comfortable effort level”, for both men and women ranged from 63 to 75 dB, with most standard deviations falling within the 2.0-3.0 dB range[474]. The conversational intensity level is 70,42 dB for males and 68,15 dB for females.[475] It is acknowledged, however, that variability will fluctuate in association with the type of speaking, i.e., sustained vowel productions are more variable within as well as across sessions in comparison to reading or speaking.[474,476]

According to Sulter et al.[477], intensities above 80 dB(A) and below 60 dB(A) normally will not be used during speech, but they stress the necessity of “the ability to raise one’s voice for adapting to these special occasions that demand high intensities”.

Schmidt et al.[478] defined as “available intensity range” (16.9 – 18.9 dB): that range of intensities that an individual can use in connected speech. They consider maximum intensity range of little utilitarian value, because the intensity range typically used by average speakers is rather restricted (approximately 6 dB in their study; +/- 20dB in trained speaker).

According to Mc Henry and Reich[479], the *relationship between vocal SPL control and dysphonia* has received relatively little research attention. They noted cheering loudness levels, associated with SPLs which were close to their maximal SPLs. This finding must have obvious vocal abuse implications.

Referring to the extensive literature on vocal nodules, Lacina[480] concluded that, without doubt, vocal nodules in singers develop by vocal strain, forcing, singing in the wrong vocal range, and by vocalizing too loud. Heinemann[481] is of the same opinion regarding the causes of hyper functional voice disorders. Vocal attrition is associated with the use of increased loudness levels for extended periods of time.[482,484]

According to Sapienza et al.[482], greater tissue damage is possible is if increased subglottal pressure is maintained for long durations. In addition to acoustic and perceptual changes, laryngoscopic changes are most likely to be revealed in untrained subjects after 15 minutes to 2 hours of prolonged loud reading.[483] Continued use of a high loudness level can lead to further tissue changes such as vocal nodules.[482]

In a class-room experiment, experimenters succeeded in reducing the teachers’ overall SPL with an average of 2.42 dB, with the use of sound-field FM amplification. They prefer this method to continually training teachers to increase their loudness from 3 to 5 dB.[482]

Jonsdottir et al.[485] too, investigated the changes in teachers' voice quality during a working day. With electric sound amplification they reported considerably less tiredness of the vocal mechanism and their voices were perceived by trained listeners as less strained, asthenic, rough, and having fewer breaks.

Brunner and Frank[486] found no specific changes of voice quality in 20 Wiener Sängerknaben (ages 10-13 years) after 2 hours of intensive choir rehearsals. Sonographic analyses even showed marked part-tone shifts, interpreted by the authors as the reason for the change in the typical "spherical and ethereal range" of this famous choir. Note that the authors characterized the voice timbre of this young boys as "covered".

As voice problems in professional voice users result from work-related *vocal load*[487], studies appeared on the effects of vocal loading (prolonged voice use, typically at higher loudness and pitch levels than those used in ordinary speech).[488-497] However, clear criteria on vocal load in different professional voice users are still missing.

Brown and Holbrook[498] used a Vocal Intensity Controller (VIC), developed in the early nineteen seventies, to measure total phonation time and loud phonation time as the talker carries out his or her daily activities. They found that "a major etiological factor of vocal abuse is simply too much talking, but vocal intensity appears to be more damaging to the voice". Individuals who talk a lot and exhibit significant percentages of loud phonation time during their total talking time (say over 30 to 35%), are more likely candidates to experience vocal fatigue than those who exhibit lower levels of loud phonation (say 25% and under). They concluded that "those who talk a lot, talk loudly, and are professional users of the voice, increase the likelihood of developing a vocal pathology or early vocal decline".

Noise is likely to induce vocal fatigue because of its reflexive effects on loudness and pitch. Ohlssson et al.[499], for instance, found that welders experienced hoarseness and vocal fatigue to a greater extent than clerks. The clerks exhibited a more frequent use of the voice at work, but the welders must use their voices under more harmful conditions, having to shout to be heard at work. The judgments also indicated too high a vocal pitch in the hyper functional voices, being exposed to a mean noise level above 85 dB. All welders had a slight hearing loss.

Reimers and Yairi[500] investigated the effects of speaking in noise on vocal fatigue and vocal recovery. Their data, however, failed to show a definite trend. The concluded that "vocal fatigue, and perhaps functional voice disorders may develop more readily in individuals whose laryngeal musculature and mucous membrane are unusually sensitive that only a small departure from optimal voice range results in deviations from normal."[500]

Again, the large and statistically significant variations among subjects reflect a wide range of normal responses to the speaking conditions and thus, "larger groups of "normal" subjects who better represent the average population" would be required.[500]

Gotaas and Starr[501] came to analogue conclusions in a study on vocal fatigue among teachers, but they also stressed the importance of looking at vocally demanding and stressful situations. Loudness levels and talking time may interact with other variables to cause vocal fatigue.[502-504]

Winckel[505-507] extensively described the important influence of room acoustics on the voice, while Sataloff[508] stressed the many problems of singers performing in large halls, with large orchestras, with lack of auditory feedback during outdoor concerts or accompanied by extremely loud background music.

Pahn et al.[509] stress the fact that penetrating the noise is an important goal in voice therapy. Coping, for instance, with an average of 70 to 80 dB (A), measured in kindergartens, is already a difficult task for "little" voices. Heightening the habitual vocal pitch is considered as harmful. Therefore, they train their patients with special kinds of masking noise, which enables a conditioning effect.[509]

Vocal capacity testing is not easy because it remains difficult to mimic the real professional situation.[510] Vocal fold activity was measured through electroglottography (EEG) before and after the Voice Interval Test (VIT): the subjects read a stage play text made up of different vocal instructions. Both patients and normal subjects had the same complaints after the VIT, but patients had more complaints after the VIT than after a working day.[510]

According to Buekers et al.[511,512], the assessment of vocal capabilities must be completed by knowledge about the *vocal load*. They developed a portable voice accumulator registering the duration and intensities of phonation during 4 - 12 h, which reveals accurate quantification of vocal demands. In our opinion, however, to assess the real vocal load during a day long, a voice accumulator should be completed with measurements of all phonated frequencies and produced voice qualities.

Long Time Average Spectrum (LTAS) analysis, providing a mean of spectra from all the sounds of a lengthy speech sample, has been reported to be useful in clinical practice since the seventies.[513-515] Novak et al.[516] evaluated voice fatigue by means of LTAS measurements in actors after theatre performance. The objective changes they found in the spectrum are caused either by the high vocal effort and physical effort of the performance or by the forcing of their voices and by mental stress.

De Bruyne[517] explains the pathophysiology of vocal fatigue by various forms of vocal misuse: an appropriate pitch and loudness disturbs the balanced functioning of the phonatory muscles as well as the mucosal function.

The reduction of intensity is also one of the major symptoms of vocal fatigue.[518]

Gelfer and Young[519] postulate that vocal abusers might speak at higher levels within their available intensity range, resulting in more stress on the phonatory mechanism. In an earlier study by Gelfer et al.[520] it was concluded that a one-hour loud reading task was not sufficient to induce noticeable alterations. Linville[521], however, found that laryngeal adjustments in individual young female speakers varied considerably in their response to 15 minutes of loud reading.

Gramming[522] emphasizes the relevance of spectrum factors to phonetogram measurement. In normal and loud phonation, the strongest partial in a vowel spectrum is mostly that lying closest to the first formant. This partial is very influential on the overall SPL. For soft phonation at low and moderately high fundamental frequencies, this effect would be less clear or missing, as the fundamental is generally the strongest spectrum partial in this case. According to the same author the two phonetogram contours, representing soft and loud phonation, may inform about the different aspects of the glottal voice source. For the lower contour, the SPL is mainly dependent on the amplitude of the fundamental which is related to the peak amplitude of the flow glottogram. For the upper contour, the SPL is mainly determined by the overtones of the voice source spectrum, using a flat frequency curve rather than an A-weighted curve.[522]

When taking phonetograms, Klingholz[523] cautions against the difficulty for trained singers to phonate softly. Moreover, he *cautions against averaged phonetograms because they equalize the characteristics of voice categories*.

According to Bennett[524], when a singer makes a crescendo, he changes not only the loudness of the note sung, but also its timbre. In particular, the amplitude of the upper formants increases more rapidly than that of the fundamental note as the note gets louder. The singers in his study sang more loudly in the upper part of their range than in the lower, but for each of them the SPL increased amplitude at a different rate and reached its maximum at a different point of the range. He concluded that "not the specific values for any one pitch, but rather *the behaviour of the SPL over the entire range was characteristic and individual for each singer*".

According to Gramming[525], the lower contour of the phonetogram, from the lowest fundamental frequency up to 60% and 80% of the fundamental frequency range for females and males, respectively, is about 60 dB. Higher up, the lower contour is 75 dB and 65 dB for females and males, respectively. For both sexes, the upper contour is 80-90 dB for the lower half of the fundamental frequency range, except for the lowest frequency, and about 90 dB in the upper half of the fundamental frequency range.

Comparing patients with non-organic dysphonia with healthy subjects, Gramming[525] found gender differences: *female patients had a significantly lower upper phonetogram contour as compared to the female healthy subjects*. *Male patients had a significantly higher lower phonetogram contour as compared to the male healthy subjects*. The average phonetogram area was expanded in both genders after therapy, but after therapy, the upper contour was found to increase only in female patients. The averaged phonetograms of the male patients showed no clear changes after therapy, neither for the upper contour, nor for the lower contour. She explains this apparent discrepancy by arguing that the male patients significantly expanded their fundamental frequency range after therapy. Because of the normalization regarding the pitch range, this expansion affects the phonetogram area but not the averaged phonetogram! Gramming's results about maximum and minimum SPL differ from those from other studies. She argues that "patients do not necessarily need to reach normal SPL values after therapy"?!

Hoffman-Rudy et al.[526] studied three categories of professional voice users/vocal performers: musical theatre, choral ensembles, and street theatre. These "*high-risk vocal performers" produce their singing or theatre voice at their maximum vocal effort level*. In our own study, all our subjects undoubtedly belong to the group of "high-risk performers".

So, voice intensity happens to be a very important parameter of voice, and its exact measurement by phonetography is essential in voice research.

6.3. Voice quality

Moore[527] considers "quality" or "timbre" or "character" of the voice as "the auditory impression created by the complexity of the sound wave", resulting from the number and relative intensities of the component elements of the sound wave. An almost unlimited range of different sound qualities is produced by adding overtones to the fundamental note (glottis note). These "formants", shaped by the vocal tract, give the voice sound its typical resonance colour[528-530]. The vibratory characteristics of the vocal folds, in combination with the shape and configuration of the vocal tract, are determining factors for the quality of a given voice[531] or, as Sundberg[532] formulated:" *vocal tract morphology, as reflected by formant frequencies, is relevant to voice quality*".

According to Winckel[533,534], ten to twelve overtones in the voice of professionals and laymen provide a pleasant feeling in listeners. With more overtones the voice sounds shrill and harsh; with less than six overtones, the voice gives a thin, asthenic impression, suggesting already a pathological or ageing voice.

While a good musical ear is considered of great importance for a good singer, an experiment showed that singers subjects sang more out of tune with anaesthesia than without, probably as an effect of a deteriorated proprioception in the glottal region[535].

Murphy[536] prefers to make a distinction between differentiations in *timbre* (objectively based, measurable by frequency and intensity spectral analyses) and *quality* differentiations, which may be seen as the psychological correlate of resonance and timbre suggested the usefulness of patterns.

To avoid confusion, Delattre[537] uses "*colour*" for vowels and "*quality*" for voice. As a linguist and experimental phonetician, he considers the acoustic features that characterize vowel colour to be very clear, which cannot be said about the acoustic features that characterize voice quality, either in speaking or in singing.

Michel[538] considers *voice quality as an amalgamation of phonation, articulation, and resonance*. The way in which these three entities are used is described by the term "*prosody*", which includes inflection, rate, dynamics, stress, etc.

In the literature voice quality disorders have been descriptively labelled in many ways, for instance, as breathy, whispered, aspirate, asthenic, dead, dull, toneless, hoarse, husky, harsh, throaty, raucous, rasping, thin, feeble, hollow, metallic, raspy, rough, coarse, glottal fry, vocal fry, pulse register, crackly, diplophonic, dull, strained, strangled, guttural, shrill, strident, piercing, pinched, thick, tired, weak, unpleasant, muffled, hypernasal, denasal, aphonic, monotonous, vocal tremor and so on.[539-550] "Normal voices" are labelled too: white, pleasant, warm, round, full, rich, bright, clear, resonant, ringing and so on.[551,552]

Regarding singing, Miller[553] states: "Quality takes on meaning far beyond the harmonic composition of a complex tone and refers to the total impression created by sung tones". Moreover, distinct vocal qualities, as expressed in different vocal styles, such as classical singing, Lied, blues, rock, pop, country & western, crooning, belting, mix, legit, hip hop, and so on, require specific, cultural dependent and time-bound, vocal adaptations.[554-563] Besides, as Austin[564] stated: "there is a wide variety of taste involved in declaring what is good and bad singing, even within the rather narrow definition of "classical singing in the Western tradition of art song and opera".

The individual features of voice timbre depend on the individual anatomic variations but also on the speaker's or singer's technique, thus "colouring" the voice.[565,566]

According to Wickel[567,568] and Sundberg[569], formant frequencies, i.e., articulation, are of paramount importance to the voice sounds. They totally determine vowel quality, and they give major contributions to the personal voice timbre Moreover, they can be used by singers to reduce the timbre differences which result from a shift between registers.[569]

For many decennia research has been done on the "singer's formant(s)", the *"ring"*[570-602], a *clustering of the third, fourth, and fifth formants in the acoustic spectrum.* The exact location of region(s) with a maximum amplification[603], the width of the formant regions of the singing voice and of the speaking voice[604-607], the gender-factor, and the classification-factor[608] are still questioned. However, general agreement exists on the importance of the singer's formant as typical for what Rzhevkin[608] called "that particular brightness of timbre in good singing voices which is often characterized by the word 'metallic' and therefore should be considered fundamental and most important as a sign of a correctly trained singing voice ".[609-612]

Pershall and Boone[613] found that the settings to produce the "ring" were quite similar to those used in the "*cover*".

Sundberg[614-622] did major investigations on the singing voice. Regarding female singing, however, he acknowledged the difficulty of explaining the acoustic data. ("one can seldom be sure if a difference between two vowel spectra is due to a difference in the phonation (glottal sound source) or in the articulation (vocal-tract sound transfer characteristics) or both"). This eventually led to questioning the existing of a singer's formant for the soprano voice.[623-634] Sonninen et al.[635], however, found a clear singer's formant in the forte covered examples of a dramatic soprano (- or was it a mezzo?). Weiss et al.[636] prefer the term "extended frequency reinforcement" (EFR) for the broadband high harmonic reinforcement phenomenon typical of strongly projecting soprano voices. Morsomme et al.[637] found a singing formant as frequently in sopranos as in altos.

Important aspects such as the increasing lip- and jaw openings with increasing fundamental frequency[638-640], formant tuning[641-645], widening of the pharynx and vertical laryngeal height lowering as inducing factors for obtaining a more resonant and far carrying sound[646-674] even over big orchestras, associated with the well-known problem of intelligibility of high pitches (especially for female voices)[675-677] are thoroughly studied.

Detweiler[678] questioned Sundberg's hypothesis of the resonance source of the singer's formant (two-tube resonating system). *Voice classification* seems to play a major role in the way the singer adopts a specific laryngeal posture.

Miller et al.[679] stress the importance of the two lowest formants, carrying a major part of the sound pressure of a sung tone, next to the singer's formant.

With the aid of modern instrumentation, vocal quality has been dissected in tiny black lines, which can learn a lot to the voice researcher, but, as

Miller[680] proclaims: “Yet, no spectral analysis will ever tell all of the facts regarding quality in the singing voice”.

Studies on *jitter* (cycle-to-cycle perturbations in fundamental frequency) and *shimmer* (perturbations in amplitude) and degree of spectral noise (*S/N ratio*) demonstrate the many difficulties in discerning adequately between “normal” and “pathological” voices.[681-698] Some authors even concluded that “jitter and shimmer measures in extended phonation were not adequate as index for the detection of laryngeal pathology. “[691-701]

Many perceptual and acoustic studies on voice disorders are based on the analysis of sustained vowels (mostly ‘a’). This method can be regarded as atypical in comparison to a functional instruction such as fluent speech or a F°-SPL measurement.[702] In a study on sentence/vowel correlation in the evaluation of dysphonia, Wolfe et al[703], for instance, found that normal speakers frequently produce sustained vowels that are more dysphonic than continuous speech. They concluded that “sustained vowel sounds may not be an adequate clinical index to the dysphonic severity of continuous speech”. Longer vowel duration is necessary, according to Schneider[701] but at a cost of increased processing time. Moreover, in most of their cases, “there was variability from day to day”.[704-705]

According to Ludlow et al.[706] a screening procedure must be applicable to individuals for determining whether an obtained value is within the normal expected range, given a subject’s particular characteristics.

Pabon and Plomp[707] and Pabon[708-710] described a method of automatic phonetogram registration in a silent booth, including acoustic voice quality parameters such as jitter, shimmer, and the crest factor.

In everyday practice, however, both therapist and patient are in desperate need of a more accessible aid to catch the actual quality of a given voice. Of course, it would be quite interesting to include a simple indication of voice quality within the traditional F° SPL measurement. Seidner et al.[711,712] proposed a numerical evaluation of the spectral voice areas, with a strong accent on the importance of the measurement of the *singer’s formant* in the phonetogram (“spektrales Stimmfeld”). The absolute intensity value of the singer’s formant characterizes the *carrying power* (“Trag- und Durchdringungsfähigkeit” der Stimme) and the quality of a given voice.[713-723] According to Schultz-Coulon[724], the concept of the carrying power provides a definite indication for quality and efficiency of the voice.

Titze[725] made a study on the acoustic interpretation of *resonant voice*, by most clinicians considered as "a target vocal production in terms of vocal health". Resonant voice seems to contain the ideal mix of laryngeal adduction (somewhere between breathy and pressed) and ample reinforcement of vocal fold vibration by the vocal tract. He calls vocal "ring" a by-product, a clustering of higher formant frequencies to raise the spectral content in the 3000 Hz region.

The intensity of the singing formant is dependent on voice intensity, pitch and *voice classification*.[726-728] The singing formant of basses and baritones is situated between 2,5 and 3,0 kHz, and higher than 3,5 Hz in sopranos.[729] Sundberg [730] too, acknowledges that the relation between the centre frequency of the singer's formant is relevant to *voice classification.*

These strong partials around 3,0 kHz are clearly decreased in functional voice disorders.[731] Sundberg [732-734] maintains that the centre frequency of the singer's formant varies, *depending on the voice category*, but on slightly different frequencies: in bass singers, it centres around 2,2 kHz; in baritones, around 2,7 Hz; in tenors, around 3,2 Hz.; and in altos, around 2,8 Hz.

Wirth[735] situates the singing formants at still other frequency regions: 2100 – 2400 Hz in basses and baritones; 2500 – 3000 Hz in tenors; 3000 – 4000 Hz in sopranos and mezzos. The measured peak between 2000 and 5000 Hz is therefore not to be confused with the singing formant, which is the result of an extended and widened hypopharynx by a year-long practiced lowering of the larynx.

Sataloff[736] acknowledges that the singer's formant significantly contributes to the *difference in timbre among voice categories*, occurring in basses at +/- 2300 Hz, baritones at 2600 Hz, tenors at 2800 Hz, mezzos at 2900 Hz, and sopranos at 3200 Hz. It is frequently absent in high soprano singing.

The improvement of the carrying power of the singing and/or speaking voice is one of the major objectives of voice training and voice.[737-738] Efforts were made to objectify the singer's formant.

Because there seems to be no uniform agreement of the definition of the singer's formant, Omori et al[739,740] introduced the *Singing Power Ratio (SPR)* - defined as the ratio between the highest intensity peak between 2 and 4 kHz and the highest intensity between 0 and 2 kHz. -, as a quantitative measure of the resonant (ringing) quality of the singing voice.

Rossiter and Howard[741] developed a "Real-Time Visual Feedback Computer Tool for Professional Vocal Development" with emphasis on the clustering of the third, fourth, and fifth formant, the peak of which is called the singer's formant. They acknowledge that the display of this *single parameter* is likely to be of more benefit as feedback to professional voice users, than the display of the entire acoustic spectra.

Since 1992 we could freely experiment with the Fonetometer FRS –1, developed by J.H. van Dijk and put at our disposal by Prof. Dr. H.K. Schutte, head of the Voice Research Laboratory, Department of Medical Physiology of the University of Groningen. This device allows measuring the "singer's formant" and can readily be interpreted in comparison with the maximum intensity curve of the phonetogram. (Chapter 8)

Anno 1940, Bartholomew[742] wrote: "when voices are used which by accepted artistic standards are satisfactory, these high frequencies will be found rather narrowly limited to range for men between roughly 2400 and 3200, and frequently averaging at 2800 or 2900, and for women a trifle higher ". Many other authors will follow, describing what has been called later: the *singer's formant*. Sundberg[743], for instance, wrote about the singer's formant as "a typical characteristic of voiced sounds sung by male opera and concert singers". Other researchers detected analogue characteristics in student singers', in choir singers, in non-singers' and actor's voices, in Jewish cantors, but not in country singers' voices.[744-755] In fact, a good voice with carrying power also exhibits strong spectrum partials in the region of 3,0 kHz.[756,757]

Doskov et al[758] measured the energy concentration in the range of the SHF (Singer's High Formant): 23% in opera singers, 16% in folk singers, 7% in pop-singers, and less than 4% in the (non-singing) controls.

The slight peak between 3 and 4 KHz in normal voices has been called the "*speakers formant*" or the "*speaker's ring*".[759-761] Rothman et al.[762], however, could not detect a singer's formant in the speech output of professional singers, while Detweiler[763] detected the presence of a robust and singer's formant in both modal and pulse register and expressed the need to further explore the impact of vocal technique on the resonance source of the singer's formant.

We will discuss our own experiments and interpretations of this important parameter in phonetographic measurements further on.

Voice quality is assumed to be the most difficult parameter of the voice to evaluate, and the **ear** is considered to be the best instrument for that purpose by a lot of authors.[764-784]

According to Debruyne[785], evaluation by the human ear is global, considering the purpose of the voice. *The human ear is also unable to hear the individual singers in a choir.*[786]

Sundberg et al[787] do not deny the important role of a good musical ear for a successful singer, but also point to the importance of proprioception in the glottal region.

To date, computer analysis of the voice only provides additional information. Wedin et al.[788] suggest combining auditory perception with an objective qualitative as well as quantitative instrumental analysis.

Perceptual evaluation of voice quality proved to be highly subjective[789-791] *and remains controversial because of poor correlation among raters.*[792-795]

According to Buekers[796], even speech therapists attach to much value to subjective perception and must learn reporting voice changes in an objective and quantitative way. Moreover, auditive stimuli are rapidly passed away.[797]

During a German congress on functional therapy of the disorders of the singing voice, the participants (phoniatricians, speech therapists, and voice and singing teachers) agreed that objective evaluations of the voice are "more objective" than the ear of the singing teacher, but the acoustical and subjective impressions should be related to the objective measurements.[798]

According to Wapnick and Ekholm[799], "it is common lore that vocal experts often disagree with each other in their evaluation of vocal performance". In their study on expert consensus in solo voce performance evaluation, they found that intrajudge reliability was much higher than interjudge reliability. Experts thus have difficulty in evaluating vocal quality but appeared to be more reliable for very good performances than they were for average performances.[799]

As Sundberg[800] stated:" the sound of a voice consists of a number of harmonic partials, i.e., a chord of sine tones of different frequencies. Such sets of tones are generally lumped together by our perceptual system and are heard as units. It is in fact quite difficult for us to hear any of these partials as an autonomous tone, even in cases when a particular partial is much stronger than all other partials". When fundamental frequency is high, it is difficult to identify the spectrum peaks caused by the formants.[800]

Nevertheless, up to now, many evaluating lists have been proposed, e.g. *The Voice Profile, The Buffalo Voice Profile, The Voice Assessment Sheet, The GRBAS Scale, The RBH scale, The Dysphonia Severity Index, The Voice Related Quality of Life-instrument,* and so on.[801-812]

Laver et al[813], for instance, proposed a *Vocal Profile Analysis Protocol* and discussed the necessary characteristics for schemes describing vocal quality, admitting that the auditory clues to the presence of a given "setting" i.e., "any habitual tendency underlying the articulatory performance of the chain of consonant and vowel segments towards maintaining a particular configuration of the vocal apparatus" are often intermittent, depending on the segmental make-up of the text being uttered at the time.

Evaluation of a perceptive voice scale revealed that a lot of parameters, e.g., vocal pitch, are nor reliable enough. Caution should be exercised against trying to capture perceptive impressions in numbers, or even relate these parameters to objective measurements.[814]

The GRBAS scale evaluates hoarseness on a four-point scale, describing five parameters (grade, roughness, breathiness, asthenia, and strain) and is accompanied by a standardized tape of typical voice samples. Evaluation is, of course, subjective, and requires training and experience. The reliability has been tested in a few studies[812-820], questioning the accuracy and precision of the scale. Test-retest reliability of the GRBAS scale proved to be moderate.[821]

Remarkably enough, those researchers who are in favour of a subjective perceptual evaluation of voice, conclude that the measurement of the voice range, dynamic range, the highest and lowest pitches, and the loudest and softest intensities, considerably correlate with the perceptual "G" or Grade factor in the GRBAS Scale. Those restricted measurements, not to be confounded with phonetography, are considered as an objective complement of their subjective perceptual appreciation.[822]

Another study on the reliability and relevance of perceptual evaluation of dysphonia revealed that precisely the parameters *loudness and pitch* proved to be unreliable when perceptually evaluated, even by trained professionals. As the GRBAS scale only considers the *timbre* of the voice, the authors, however, concluded that "fortunately, both pitch and loudness, are easy to measure in an objective way".[823]

To Nawka et al.[824], R (roughness), B (breathiness), and H (hoarseness) are sufficient for the auditive evaluation of the hoarse speaking voice. They acknowledge, however, that the degree of hoarseness can vary along continuous speech and thus must be interpreted by integration of all perceived impressions.

Because of the strongly varying quality of the voice in time, Dejonckere et al.[825] added a sixth parameter I (*Instability*) to the GRBAS scale and call it the *GIRBAS scale*.

Since this evaluation procedure is subjective, the examiner must possess a trained ear[826-828] and, as Michel[829] already remarked: " the addition of artistic merit to the evaluation of voice quality makes the process more subjective and vulnerable to individual differences among evaluators".

A study on performance effects showed that many of the singer subjects showed deterioration after performance. Perceptual ratings, however, did not reflect the acoustic analysis results[830], while Augsten and Gall[831] found that two different pathological voices could be well differentiated by subjective perception but looked quite similar by frequency analysis.

Dejonckere et al.[832] agree that the GRBAS-scale is still scarcely used in a systematic way and Sala et al[833] state that there is no standardized questionnaire on vocal symptoms that could be used in order to get results comparable with other results, while Yu et al.[834] also concluded that "despite extensive research in this domain, there is currently no single widely accepted, standardized technique of objective voice evaluation".

Perceptual evaluation thus remains a very controversial method. Pabon[835] even finds the use of perceptive scales an impossible choice.

Nevertheless, there is a need for a global method of measurement of the vocal quality, reflecting the multidimensional character of the voice.[836,837] The *Dysphonia Severity Index*, for instance, claims to be multidimensional, incorporating perceptual, acoustical, aerodynamic and phonetographic characteristics. The phonetographic variables are lowest pitch, highest pitch, voice range, semi tone range, lowest intensity, highest intensity, and dynamic range. The authors found that the highest frequency and the lowest intensity are highly relevant in voice patients.[837]

Siupsinskiene and Lycke[838] suggest that the *quantitative assessment of the singing voice quality,* measured by Spectral and Voice Range Profiles, could be recommended for phoniatricians and speech-language pathologists in their clinical practice.

Other clinicians point out that often determination of *quality of life* is missing in multiparametric clinical research. A short and very easy to score testing instrument, the "*Voice Related Quality of Life-instrument*" is proposed, together with perceptual voice evaluation and acoustic voice analysis.[839]

This brings us to the special relationship between Psyche and Voice. Back in the fifties, Trojan[840,841] proved the relationship between "Stimme" and "Stimmung". Other authors[842-876] stressed the importance on the voice product of factors such as personality, character, typology, constitution, emotions, genetic aspects and so on. Mutational voice disorders as a problem of identification are well known in clinical practice.[877]

Performance anxiety and its influence on the voice, is another of the many indications for the close relationship between the psyche and the vocal instrument. Listeners too, seem to have idiosyncratic expectations about the nature of the emotion that is required of the role or in the specific scene performed by the vocalist.[878]

The psychosomatic aspects of diagnosis and therapy of functional dysphonia are still under study[879,880], underlying the need of multidisciplinary research and questioning the concept of functional dysphonia.[880-883]

In an editorial on the importance of the psychosocial interview in the diagnosis and treatment of "functional" voice disorders, Aronson[884] explains "our allegiance to the word "functional" and our failure to acknowledge emotional stress as responsible for many of these voice disorders." Some studies even accept that functional dysphonia usually occurs in people who are emotionally unstable[885,886]

Considering the huge difficulties to adequately describe voice quality, let us conclude with the remark of Michel[887]: "Language is simply inadequate and not up to the task.

6.4. Vocal registers

Definitions and descriptions of vocal registers

Anyone who is interested in voice will sooner or later be confronted with the term “register”. Although most people have some idea of what is meant by “register”, an exact definition of register seems to be almost impossible (Seidner et al.).[888]

Authors like Large[889] and Hollien and[890] still keep referring to the well-known register definition of Garcia (anno 1840): ”a series of succeeding sounds of equal quality on a scale from low to high, produced by the application of the same mechanical principle, the nature of which differs basically from another series of succeeding sounds of equal quality, produced by another mechanical principle”, or to the more extended definition of Nadoleczny (anno 1923), who assumed that the internally similar tones of one register were dependent upon a definite, invariable behaviour of the harmonics.

Tarneaud[891] emphasized the fact that untrained voices present a disproportion between the laryngeal sound and the resonance in the pharynx of untrained voices, which results in clearly perceptible registers and passagios. With a well-established muscular training, these registers and passagios disappear. In other words, the singer has learned to tune his pharynx to the sound produced by the larynx.

Hirano et al.[892] stressed that register, pitch, and intensity are not independent parameters in the human voice. Register is primarily regulated by the vocalis muscle, especially in the chest register. The lateral cricoarytenoid, interarytenoid and cricothyroid muscles also cooperate.

A complete understanding of the physiology of register function is still lacking.[893]

A voice register is usually seen as a *totally* laryngeal event.[894-897] Spencer and Titze,[898] however, nuance this statement and define registration as a *primarily* laryngeal event. “Acoustic and myoelastic influences on register transition may exist along a *continuum* of blended interactions.”

A register change means a change in vibrating mode[899] or an actual change in source function.[900]

Modern scientists agree that voice registers must be *operationally* defined: perceptually, acoustically, physiologically, and aerodynamically.[901] Titze[902] even expressed the need to describe registers also on the neuromuscular, biomechanical, and kinematic level! For obvious reasons some researchers prefer to limit their endeavour to only one aspect of the problem, e.g., the physiological description, admitting that "no single investigation can hope to address all the elements previously cited".[900,903]

Voice registers can be seen as voice quality phenomena, but labels, such as falsetto, normal male, etc., could bias the observer's judgments.[904]

To complicate things, some authors[905] also consider the "*covering of the voice*" as a kind of register. This mechanism consists of the forward clapping of the thyroid cartilage and the stretching of the vocal folds. Pershall and Boone[906] speculate that "to produce a high C from a male larynx would require a very high breath pressure against a maximally tensed vocal fold with supraglottic laryngeal constriction. The larynx is kept in a low position, the epiglottis is erected, the supraglottal space is enlarged, the laryngeal ventricles are expanded, the first formant frequency is lowered, and the second formant frequency is increased.[907-910] This happens on a fixed point, in contrast to the transition from chest register to falsetto register, which can be shifted. This fixed point is situated at c1/d1 for the bass, d1/e1 for the baritone and e1/f1 for the tenor. For female voices (alto – mezzo – soprano) this fixed point lies one octave higher. *The finding of this fixed point is considered as important for voice classification.*[911]

The purpose of covered singing (mainly used by males), is said to smooth the register transition near the so-called passagio (250-400 Hz, depending on voice category).[912-916]

Vilkman et al.[917] consider the covering of the voice as a "mixed register in which falsetto and chest register qualities coexist and thus the voice source is richer in harmonics even at high pitches."

The colour of the voice becomes darker above the passage.[918-921] The covered voice (voix couverte, voix sombrée, gedeckte Stimme, gedeckte Tongebung, voce coperta) is considered the only way to safely sing the highest tones, thus achieving equalization of register.[922-927] This technique of covering the voice can be applied to the whole vocal range.[928]

Many singers (mostly untrained) try to continue to sing the tones above the passage in an *open voice* (voix ouverte, voix blanche, offene Stimme, offene Tongebung, voce aperta, chest register) as high as possible.[929-934] The open voice is produced with tensions in the neck and with a high larynx position. With ascending pitch, all vowels sound the same and become reedy. Prolonged open singing provokes tremolo.[935,936]

Untrained voices show a "vocal break", i.e., "a sudden transition from one voice register to another".[937] The trained male singer, however, changes the position of the first formant (F1) to fall below the second harmonic (H2) in the transition from *chest register* to *head register.*[938]

The bridging of chest register to falsetto register (c1 – f1 for male voices and c2 – f2 for female voices) is also called "*voix mixte".*[939-942]

The controversy is at its highest level when the number of existing voice registers is discussed. The exact number of registers remain unknown but varies between one and 107![944,945] Schutte and al[946] and Miller and Schutte[947] cite the historic Italian school, identifying several categories of registration timbres such as: (1) voce di petto (chest voice), (2) voce mixta (mixed voice), (3) voce finta (feigned voice), (4) voce di testa or voce piena in testa (head voice) and (5) falsetto. The feigned voice and male belt are considered as the mild and strenuous forms of the "register violation. Voix mixte, voce finta and belt are different expressions of the robust "head" register.[947]

Hollien[948], however, postulates that only three major registers exist; they are the pulse, modal, and loft registers, but in the literature, we still can find studies on the so-called whistle register (flute register, flageolet register, Pfeifregister)[949-954] and the Strohbasregister (pulse, vocal fry).[955,956]

To many researchers "the riddle of the middle register" still exists[957-962], while Miller et al.[962] proposed the name of *mezza voce* as a distinct register of the male singing voice.

Miller and Schutte[963] also discussed the question whether the female middle voice is a combination or balance of the primary registers, chest and falsetto.

In Chapter 8 on our own procedure of F°-SPL measurement some indications of the middle register, visible in the phonetogram, will be given. In the same Chapter 8 on case studies, an example will be given of different ways of register transition used in an experiment, and quite visible in the phonetogram.

Titze[964] discerns two types of transitions: a periodicity transition from a continuous tone (chest) to a series of pulses (vocal fry) and a timbre transition corresponding to the primary and secondary passages, based on changes in the closure conditions of the glottis.

Although a vocal register is considered as a "totally laryngeal event"[965,966], certain authors feel to make a distinction between singers and non-singers[965,967-969] and between speaking vs. singing registers.[967] The singer seems to have the continued potential to use the voice registers if necessary or desirable.[965,967-969] So, trained singing voices could (or should ?) exhibit only a single register, while retaining their original set of registers.[965,967-968] Equalization of registers may be related to the laryngeal mechanism of medial compression. [970]

Comparing the findings within and between studies remains very difficult, primarily because of the discrepancies in the register systems used.[971] No one can deny that further research on vocal registers is necessary.

Properties of the registers, based on physiological mechanisms

According to Klingholz et al.[972-973], the larynx can't produce all pitches of the voice range with the same mechanism and many adjustments of muscular and aerodynamic forces may occur in phonation.[974-984]

Each voice register is characterized by specific properties and dependent on specific physiological mechanisms, which we will briefly summarize:

- **Pulse register or Vocal Fry.**
- best described as a phonational register occurring at frequencies below those of the modal register.[985,986]
- formerly considered as a voice disorder: harsh phonation.[987,988]
- long closing phase (more than 50% of the duration of the vibration). [987,988]
- ventricular space is smaller than in modal register, indicating ventricular fold impingement.[987]
- subglottal air pressure appears to be greater for modal phonations (during connected discourse) when compared to vocal fry phonation.[989]
- increased mass and reduced stretch account for the very low fundamental frequencies.[990]
- fundamental frequencies < 70 Hz are judged as vocal fry.[991]

- **Chest or Modal register.**
- relatively short or sometimes non-existent closed time.[992-994]
- flat spectral slope.[995]
- low jitter.[995]
- low relative noise level.[995]
- exhibits energy in a greater number of partials.[996]
- exhibits more energy in the higher numbered partials.[996-998]
- in head/chest, harmonics in singing formant range were markedly strong.[999]
- the vocalis activity is dominant over the cricothyroid activity.[1000-1002]
- SPL and F° depend on the tension of the m. vocalis.[1003]
- length of the vocal folds increases with F°.[1004]

- **Falsetto / Loft register.**
- not the usual mode of phonation used in speech.[1005]
- can be seen as a male voice with feminine quality.[1006]
- inefficient, ineffective, and generally unpleasant, even dangerous.[1007-1009]
- restricted SPL range.[1010-1012]
- vocal intensity is clearly associated with air flow change.[1013]
- sine like waveform, but still very powerful and penetrating up to high frequencies.[1014]
- in the higher pitch-area the falsetto can be very loud with a less breathy quality.[1015]
- the opinion that the loft register is weak and small and therefore inept as a singing voice can be questioned.[1016,1017]
- steep spectral slope.[1018]
- high jitter.[1018])
- high relative noise level.[1018]
- instabilities in the phonation.[1018]
- vocal folds close smoothly.[1018]
- there is no major collision between the vocal folds in falsetto mode.[1018]
- closure is often incomplete.[1018]
- closed phase of the glottis is short or absent.[1019,1020]
- the entire vocal fold is strongly stretched.[1021,1022]
- only the thin glottal edges vibrate, resulting in a stiffening of the vibratory mechanism with decreased mucosal wave pattern and amplitude.[1023]

- few harmonics and substantial amount of noise in the acoustic signal.[1024]
- falsetto phonations exhibit higher energy in the fundamental, whereas modal phonations show greater energy in the 3-5 partials.[1025]
- higher harmonics increase with F°.[1024]
- higher harmonics including those in the singing formant range and the high-frequency range were weak.[1026]
- the characteristic voice is of thin quality, weak volume, and restricted pitch range.[1027]
- collapse of the m. vocalis activity.[1028,1029]
- cricothyroid activity is dominant over the vocal activity.[1030-1032]
- can be seen as the piano expression of the **head register.**[1033,1034]
- countertenor voice is a modified or refined falsetto, which is neither weak nor breathy but has a rich and sonorous quality, probably because the vocal fold vibrations are characterized by complete glottal closure and a mucosal wave.[1035]
- correct identification of falsetto voice quality, in comparison to “normal”, “female” and “child”, amounts to 70%.[1036]

- **Middle register (voix mixte, mezza voce).**
- properties of the middle register are mostly presented as a transition from modal (chest) to loft (head) register[1037-1044] or as appearing primarily in the voices of student or developing singers and thus regarded as a problem to the aspiring singer.[1045]
- the airflow rate in middle voice is certainly larger than that of chest voice.[1046,1047]
- the laryngeal wave pulse shifts from a sharply peaked shape in chest register to a lower and broader shape in middle register.[1047]
- major adjustment of the laryngeal musculature when middle register is shifted to from chest register and vice versa.[1047]
- vocal folds are thinner and longer than in chest register.[1048]
- “amphotere” sounds, i.e., sounds which can be sung in chest register and in head register, making the existence of a middle register questionable. [1049-1051]
- misuse of the “voix mixte” is one of the possible causes of the origin of vocal noduli.[1051]

- **Whistle register (flageolet register, Pfeifregister**).

Keilmann and Michek[1052] made an extensive study on the physiology of the female whistle register as a separate register on top of the head register. This "flageolet register" exhibits more jitter and less higher harmonics than the head register. The amplitude of the vocal folds is small, the glottis is continuously open. In high frequency yelling, however, the glottis was very narrow. The maximum phonation time is shorter than in modal register but is typically dependent on training. Uncontrolled use of the whistle register at the beginning of a singing training could induce a hyperkinetic dysody. If the singer, however, can avoid the necessary high tensions of the vocal folds, then the whistle register appears to be less strenuous and harmless. Vibrato and alternation of intensity is possible, but the voice quality is poor.

The extreme high pitches of the whistle register, sung by coloratura sopranos, are mostly sung in staccato, seldom in legato.[1053,1054]

Miller and Schutte[1055] situate the flageolet register "at a point where it is no longer expedient to adjust the vocal tract for further raising of the first formant." This point is situated between g2 (788 Hz) and d3 (1175 Hz). According to these authors, only a minority of sopranos have the capacity to employ this register effectively. However, according to our findings, also mezzo's and contraltos can produce these extreme high pitches. We noted a3 (1760 Hz) as the highest female pitch! (See Chapter 8)

Others[1056,1057] deny the existence of a whistle register as a true register.

Location of the registers

Although vocal registers are known to occupy separate portions of the total fundamental frequency range of the human voice[1058], perceptual judgments alone invariably lead to endless discussions and controversies.[1059] One just must bear in mind the still existing practice of trying to locate registers by means of the subjective sensations felt by singers in some parts of their body.[1060-1064]

In addition, the practice of register balance in educated singers interferes with locating the register transitions[1065] and transitions sometimes lay outside the normal ranges on account of a given voice disorder.[1066] Nevertheless, McGlone[1067] prefers a method of self-determination of the shift between the registers, since that is "more reliable than having judges make the decision". However, Neumann et al.[1068] found that "singers themselves are frequently unable to locate their point of transition and to distinguish clearly between registers", while the judgment by musically trained persons is also questioned. “Identification of vocal registers is still a formidable task for the investigator-listener”.

In our own praxis, we still remember an amusing anecdote of a young female singing student, desperately trying to avoid the register break, very visible in our phonetogram registration. The singing teacher, sceptically looking over my shoulder at the computer screen, started giving some examples herself, continuously exhorting the poor student to try a lot of different techniques to avoid the much visible register break on the screen, but without any success… The apparently frustrated singing teacher finally exclaimed: “there must be something wrong with your machine”…

The scientific approach of register location is even more hazardous. The position of the larynx, the waveform of the vocal folds, the aerodynamics of the vocal apparatus, the voice quality and even the subjective feeling of the singer just give a few possible indications, according to Klingholz et al.[1069,1070]

The register transitions, visible in the phonetogram, at certain frequencies illustrate clearly the different mechanisms based on pre-phonatory larynx positions and specific muscle activities. According to Klingholz[1070], 80% tenors, 83% baritones, 71% basses, 86% sopranos, 75% mezzos and 88% altos were correctly identified by his method of ellipse parameters. However, he admits he couldn’t classify the faulty classified subjects because of their little vocal capabilities…

In a study on mutational voice disorders of young men, Hammarberg[1071] affirms that the pitch change during normal mutation is often one octave. However, in contrast to most observations, she thinks that “the voice breaks in the full-grown larynx normally occur one octave above the normally used pitch”.

As frequency location could not be the sole characteristic of a vocal register[1072], we are convinced that more attention should be paid to its vocal intensity characteristics. It is here that, in our opinion, phonetography can open a new era of voice research. Of course, a lot of scientists discovered the sometimes eye casting dip(s) in the phonetogram but interpretation always remained obscure.

According to Klingholz et al[1073] and Airainer and Klingholz[1074], markers of the register ranges are the transitions which are indicated “by minima in the forte contour and maxima in the piano contour, and minima of the dynamics, at specific pitches.”

Pabon[1075] prefers to talk about a region where modal and falsetto register overlap. He acknowledges that, in general, register differences are accentuated by a greater effort (louder voice production, higher pitch).

In earlier publications[1076,1077] automatic phonetogram registration is considered to be helpful to determine voice breaks and to indicate register contours, facilitating voice classification. In a following study, however, the same author thinks that the register transition from modal to loft cannot be located with certainty from the phonetogram or by the ear.[1078] *Glissandos,* for instance, cause a larger "dip" and high pitches can be obtained in the modal register by a singing technique, based on forcing. This also means that the singer has a choice, be it limited to camouflage or to accentuate the register transitions. We will provide examples of this interesting phenomenon in Chapter 9, featuring longitudinal phonetograms.

Frank and Donner[1079] report that register transitions can be shifted in pitch when someone is singing for a long time in a faulty voice classification. Moreover, a tenor, for instance, can perform a register equalization like a baritone and older voices can show shifts in register transitions.

A lot of authors regard the dent in the phonetogram of untrained normal voices as a mark for the transition from chest-voice to falsetto voice. A well-trained voice no longer shows any such dip[1080], or "the condition is apparently ameliorated in the course of training", as Wolf et al.[1081] already remarked many years ago. According to Klingholz[1082], clinicians must be able to recognize registers as only phonations in the modal register must be accounted for in F°-SPL measurement!?

Gramming[1083] thought that the dips in the phonetogram could also depend on the spectrum details. Troughs were associated with spectra in which the level difference between the two strongest spectrum partials were small. So, peaks and troughs in a phonetogram contour cannot always be interpreted as a sign of register shifts.[1084]

Pedersen et al.[1085] too, conceive the register phenomena in the phonetograms as in part related to formants, while Svec and Pesak[1086] noticed "some less apparent discontinuities demonstrating probably the existence of additional voice registers for more gentle regulation of laryngeal position and airflow".

Awan[1087] doesn't pay attention to vocal registers. He simply accepts that "register changes would naturally occur at some point or points within the total F° range". This remark seems amazing, as register dips can be observed as eye-catching markers in every phonetogram!

Although a nearly identical phonatory quality of each register is required, little overlap in fundamental frequency between adjacent registers ("amphotere Klänge") is accepted.[1088-1094] These "amphotere Klänge", overlapping the transition between chest register and head register, can amount to 4-6 semi-tones.[1095]

Pfau[1096] remarks that the register limits depend on whether the subject sings from low to high or vice versa, which means that there exists a transition area including the so-called amphotere tones. Register boundaries are thus movable: higher when singing upwards, lower, when singing downwards.[1097]

Novàk and Vokràl[1098] tried to establish quantitative and qualitative acoustic parameters of a good voice, suitable for future voice professionals. They divided their subjects "according to the timbre of the voice" in the six common voice categories. However, the group of baritones and basses was pooled "because the differences in the voice pitch and register breaks were not marked"?!

Studies on register changes on young children are scarce. Frank[1099] reports audible register changes between c2 and d2 in 6-years old children but were not able to classify their voices.

Roubeau et al.[1100] made a comprehensive study of the change from one type of register to another one (the "shift" between vocal registers) by analysis of the EGG trace. They found significant differences between gender and between the type of glissando at which the register shift occurred. The change from mechanism I (chest and mixed registers) to mechanism II (falsetto register) occurred at a higher frequency range than the change II – I did, a fact well known in vocal pedagogy:

	Glissandos	**Starting frequency**	**S.D.**	**Ending frequency**	**S.D.**
Male	I - II	238	3,8	318	6,3
	II - I	266	8,2	195	6,6
Female	I - II	312	4,5	345	4,5
	II - I	321	6,7	279	4,9

However, these results seem strange: while generally an one-octave difference between male and female registration[1013] is accepted, Roubeau et al.[1100] only found two tones difference between male and female singers, which, in our opinion, means that in women, the shift between chest and middle register was measured! Moreover, their results for the shift between modal and falsetto register in men would indicate that there were no tenors in their subject's group (highest ending frequency is lower than e1 (330 Hz)!

The same remarks can be made about the Sulter et al.[1101] study, situating a local minimum, as a transition from chest to falsetto register, in male subjects at about 392 Hz (g1), (which, in our opinion must give an indication for a tenor voice), and only one note higher, at 440 Hz (a1) for female subjects.

Sundberg[1102] thinks that only the upper boundary of the chest register is useful, while Wirth[1103] assumes that it is not certain if the registers are related to voice categories. Nevertheless, a lot of authors provided some indications for the "passagio".

According to The Marchesi Model for female registration[1104], the highest note in the chest register in all female voices varies between e1 and f1; the highest note in the medium register varies from f2 to fis2.

Sundberg[1105] situates the range of overlap between male modal and falsetto registers in the vicinity of 200 to 350 Hz (g – f1). In the female voice, the ranges of overlap between chest and middle registers are found around 400 Hz (g1), (cfr. Sulter et al.) and around 660 Hz (e2) for the overlap between middle and head registers. He acknowledges that these ranges of register overlap, and the register boundaries vary substantially among individuals but omits to associate these findings with specific voice classification.

Baken[1106] agrees with the Hollien model of three registers, with the following boundaries, but without indication of voice categories:

	MEN	WOMEN
Pulse register	25 - 80 Hz	20 - 45 Hz
Modal register	75 - 450 Hz	130 - 520 Hz
Loft register	275 - 620 Hz	490 - 1130 Hz

Hollien et aL[1107], however, reports quite different register ranges for untrained voices:

	MEN	WOMEN
Pulse register	7 - 78 Hz	2 - 78 Hz
Modal register	71 - 561 Hz	122 - 798 Hz
Loft register	156 - 795 Hz	210 - 1729 Hz

According to Ross, cited by Large[1108], transition frequencies vary with the vowel, which suggests that the configuration of the supraglottal vocal tract must indeed be related in some way to the register problem in singing.[1109]:

VOWEL	SOPRANO	ALTO	TENOR	BASS
/i/	e2	c2	e1	c1
/u/	f2	d2	f1	d1
/e/	g2	dis2	g1	dis1
/o/	gis2	e2	gis1	e1
/a/	a2	f2	a1	f1

Other authors provide more specific information on register transitions related to *voice categories*:

Pahn[1110]:

Bass:above c1.Alt: above c2.
Baritone: above d1.Mezzo: above d2
Tenor:above e1.Sopran: above e2.

van Deynse and Goslings[1111] came to the same delimitations:

Bass: c1 – d1
Baritone: d1 – e1
Tenor:e1 – f1, and for female voices: one octave higher.

Sieber, cited by Gerritz[1112]:

Bass: bes - b. Alt: a1 – b1
Baritone: cis1 - d1.Mezzo: cis2 – d2
Tenor: e1 – f1 Soprano: es2 – e2.

Janev and Gjuleva[1113] also provide information on transition tones for the middle register (but only for female voices):

	Chest - Middle	***Middle-Head***	***Chest -Head***
Bas			ais - c1
Baritone			cis1 - e1
Tenor			e1 - f1 - g1
Alto	e1 - f1	b1 - c2	
Mezzo	e1 - f1	cis2 - d2	
Soprano	e1 - f1	e2 - f2 - fis2	

Hacki[1114] still proposes other frequencies for the transition of middle register – head register in male and female voices:

- Bass: d1- Alto:a1
- Baritone: d1 - dis1- Mezzo:a1 – ais1
- Tenor: dis1 – e1- Soprano:ais1 – b1

Butenschön and Borchgrevink[1115] make no difference between mezzo and soprano and between baritones and tenors:

Mezzo / Soprano: - the low register extends from b to bes1.

- the minor transition: bes-1 – c1.
- the middle register extends from b to e2.
- the transition to head register: dis2 – e2.
- the head register extends from e2 upwards.

Baritone / Tenor: one octave lower.

The ‘dark’ voices, alto and bass, *may* have their transitions a semitone to a whole tone lower.

Register boundaries between chest register – middle register are, according to Wirth[1116]:

- bass: d, d1; transition: c1 – d1.
- baritone: e, e1; transition: d1 – e1.
- tenor: f, f1; transition: e1 – f1.
- alto: d1, d2; transition: c2 – d2.
- mezzo: e1, e2; transition: d2 – e2.
- soprano: f1, f2; transition: e2 – f2.

The author doesn't mention the existence of a loft register.

Hertegard et al.[1117] assume that their 11 professionally trained singers closely follow the pitch of the passagio. However, 290 Hz seems to be the passagio for both a bass and a baritone, 300 Hz for another bass, 350 Hz for both a baritone and a tenor!

Only few authors[118-1120] mention the methodology employed to assess the register transitions. We will explain our new methodology in Chapter 10.

Based on phonetographic measurements and parametrical quantification. Klingholz et al.,[1121] divided the voices of 50 choirboys only into two classes: altos and sopranos. Moreover, the register transition zones they propose are very large and divergent with those mentioned by other authors:

	Chest - Middle	***Middle-Head***
Alto	a – c1	f1 – b1
Soprano	c1 – f1	a1 – d2

Frank and Sparber[1122] report on a case of treatment of a nodule in an opera singer. After voice therapy, the former register transition on b1-c2 rose to d2-e2. The habitual pitch, which was also too low (g), rose to b-c1, while the vocal range changed from A-f2 into a-f3.

In a study by Neumann et al.[1123], the passagio is acknowledged to be carried out over a series of pitches within the upper part of the (male) frequency range. They studied characteristic *spectral patterns in pitch ranges which are determined by the voice category.* Phonetograms clearly show these zones, as will be demonstrated in a lot of our examples in the Chapters 8-9-10 and 11 on our own research.

We'll discuss the interesting topic of register changes more extensively later in the context of our own (longitudinal) phonetographic results (Chapter 10). Moreover, the results of our PhD study clearly have demonstrated the huge importance of the localisation and interpretation of the register change zone for objective voice classification.[1124-1128]

6.5. Habitual pitch (= speaking fundamental frequency) and optimal (optimum) pitch.

In addition to the determination of the pitch range, the determination of the habitual pitch and the optimal pitch is an important issue in clinical practice. Here too, F°-SPL measurement can provide useful information.

The *habitual pitch* (modal frequency level) is the pitch that someone uses most in everyday speech[1129-1135], while the *optimal pitch* is the pitch level at which the voice is produced most efficiently, with the least amount of laryngeal tension, and with the greatest ease of physical effort.[1136-1140]

Atkinson[1141] found a great deal of variability in SFF (speaking fundamental frequency) between different speakers, but also as much variability within a single speaker as there is between several speakers of the same sex.

Various methods for eliciting habitual pitch have been proposed. From the results we can learn that habitual pitch and its patterns of variation prove to be highly idiosyncratic.

According to Brown et al.[1142], even among the "normal" groups, there were individuals who exhibited extensive variation.

In a study by Zraick et al.[1143], no significant effect of the elicitation task was found in males and in children; a statistically significant effect of task was found in female subjects. The authors apparently were not interested in analysing the *range* of the SFF of their subjects, nor the connection with *voice categories*:

- children: 181.56 (fis) – 284.30 (cis1); mean: 214.64 (gis) – 228.45 (ais).
- adult males: 85.61 (F) – 219.44 (a); mean: 120.79 (Ais) – 219.44 (a).
- adult females: 140.61 (cis) – 275.53 (cis1): mean: 186.78 (fis) – 205.47 (gis).

It is worthwhile to dwell a while on the procedure for eliciting the habitual pitch via the seven different tasks, studied by the same authors: "each subject was *seated in a chair* and instructed to speak *at a comfortable pitch and loudness level* for all tasks". The results of this study demonstrate that, even in these easy-going conditions of the test situation, there is a range of the SFF of one octave in males and more than one octave in females; only the children had a range of less than an octave of their speaking fundamental frequency.

One can easily imagine what will happen in more "normal" conditions, when speech is more spontaneous and emotionally directed and the subject is not constrained in a laboratory setting with a microphone kept at a constant distance of approximately 6 inches! Moreover, the means of these results suggest that all subjects would belong to a lower voice category! It is obvious that such averaged results, *without considering the different voice categories,* are misleading and of dubious practical clinical use.

Abithol[1144] notes 180 Hz as mean SFF for the males, 220 Hz for the females, (which means a difference of only 2 notes !?) and 300-450 Hz for the children.

In spontaneous speech the fundamental frequency fluctuates ½ to one octave (i.e., 6 to 12 H.T.) around an average pitch, which is called the *habitual pitch*. In phonetics this modulation of frequency is called "*melodic accent*". Simultaneously there is a fluctuation of +/- 5 dB around an average intensity value ("*dynamic accent*"). The range of frequencies and intensities which must be available for spontaneous speech with normal loudness ("Sprechfeld"), not to be confounded with the real measured ("Sprechstimmfeld"), can easily be traced.[1145,1146]

In Gramming's study[1147] the mean fundamental frequency in normal speech was about 15 to 20% above the lowest pitch in the phonetogram and corresponding to 5 semitones. For loudest possible speech it was raised to 40 to 50%, or about one octave above the lowest pitch. She finds it more pertinent to speak about an *optimal pathway* in the phonetogram than an optimal voice pitch.

Coleman and Markham[1148] prefer to speak of an average SFF and a standard deviation. Nevertheless, they acknowledge that "in spite of the variability of SFF in individuals or in groups, it is common in current research studies to report relatively small frequency differences between or within individuals and groups as statistically significant."

For lack of a well-grounded method of eliciting the habitual pitch, Orr et al.[1149] also choose 5 semitones above the lowest pitch as SFF.

Concerning the relationship between the habitual pitch and the lowest pitches of the vocal range, interesting information is given in an article by van Wijngaarden et al.[1150] After larynx-irradiation, considerable individual differences of the voice parameters, measured by phonetography, were found. The 23 treated male patients with unilateral small carcinoma of the vocal cord showed a reduction of the dynamic and vocal range, with a shift to the bass register. Their average habitual pitch, however, was +/- 104 Hz (Gis), obviously still being in relationship to the average lowest pitch D (73 Hz). Unfortunately, give no information on the voice category of their subjects, which could have given more specific data.

According to Prater and Swift[1151], the range of average fundamental frequencies is approximately 124 Hz for young adult males and around 227 Hz for young adult females.

Schmidt et al[1152] recorded a mean F° for female students (ages 20-29 years) of 224 Hz., while Krook[1153] found a mean SFF of 196 Hz for a group of females on the same age group, 118 Hz for the female group aged 80-89 years and an average of 188 Hz for the entire sample of 467 adult female subjects. She found an average SFF of 116 Hz for the entire sample of 198 adult male subjects, 112 Hz for those aged 20-29, and 124 Hz for the group aged 70-79 years.

Linke[1154] stated that "women in general may be using pitch levels which are lower than advisable for the most effective employment of their voices in speech" (average median frequency level = 201 Hz). His findings coincide with those of Pemberton et al[1155] who recorded a mean SFF of 206 Hz in a group of 28 young women, vs. 229 Hz, found in a similar group of young women, recorded 48 years before. Social and generational social influences must be considered.

A study on healthy middle-aged women revealed a mean F° of 196 Hz, ranging from 170 Hz to 251 Hz (222)[1156], while another study on adult women without voice problems[1157] found a mean F° of 212 Hz. (122 Hz for men).[1157]

Obviously, these averaged measurements must be interpreted as the average of *all voice categories*, which means that, in our opinion, their clinical significance is worthless, without assessing the true vocal type of the subject That is why a lot of researchers determinate the optimal pitch in function of the voice category. Böhme and Hecker[1158], for instance, made an investigation of the range of the singing voice and the "neutral level of the speaking voice" in 632 healthy subjects between 6 to 90 years. *The habitual pitch happens to be directly correlated to the voice category: G (bass), A-B (baritone), cis (tenor) and g (alto), a (mezzo), b (soprano).*

The speaking voice is situated in the lower third of the singing voice range in 91% of the adult subjects.

Perceptual evaluation of the habitual pitch and loudness shows a considerable intrajudge variance, even by trained professionals.[1159]

Some reported data are very peculiar. Brown et al.[1160] reported that "there is a strong trend for the sopranos and tenors to speak at higher SFF levels than either the altos or baritones". In our opinion, this is quite logical! In a following study[1161], however, they found that altos always exhibited the highest habitual pitch levels in comparison to the sopranos and non-singers?!

In our opinion, phonetography can be of great help to assess the voice category and the habitual (and optimal) voice pitch.

Brown et al.[1162-1165] found that the speaking fundamental frequency (SFF) levels varied significantly as a function of age for a non-singer group; those for the group of professional singers did not. Moreover, a group of trained sopranos and tenors exhibited significantly higher SFF levels than did a group of age-matched non-singers, whereas a group of altos and baritones did not differ significantly from a group of untrained controls.

In these studies, the mean SFF for males was approximately 120 Hz. For the females, the mean levels for speaking fundamental frequency were in the age group 25-35 years: 206 Hz (non-singers), 205 Hz (sopranos) and 207 Hz (altos). In the age group 40-55 years: 200 Hz (non-singers), 206 Hz (sopranos) and 197 Hz (altos). In the age group 65-85 years: 190 Hz (non-singers), 201 Hz (sopranos) and 203 Hz (altos). Moreover, the altos always exhibited the *highest* habitual pitch levels in comparison to the sopranos and non-singers?! These results would also indicate that the mean fundamental frequency of every woman is situated around g – gis, which is in contradiction with everyday practice!

Pahn[1166] situates the "Indifferenzlage" in connection with the common voice types:

Bas: F – G	Alt: f - g
Baritone: A – H	Mezzo: a - h
Tenor: c – d	Soprano: c1 – d1

To van Deynse and Goslings[1167], the pitch of the speaking voice lies at G and A for the basses, at B for the baritones and at c and d for the tenors. For women it lies one octave higher.

Wirth[1168] still situates the "Indifferenzlage" at other pitches:

- Bass: G – A
- Baritone: A – c
- Tenor: A – c
- Alto: under gis
- Mezzo: under gis
- Soprano: b – c1

Novàk and Vokràl[1969] evaluate the "centre of gravity of F° at c for tenors and at A for baritones and basses, "because the differences in the voice pitch and register breaks were not marked". The "centre of gravity" in sopranos was c1, b in mezzos, and ais in altos.

Morris et al.[1170] compared the mean speaking fundamental frequency (SFF) for a group of trained male singers, somehow divided into tenors and bass-baritones, and a group of age-matched non-singers in three age ranges: 20 to 35 years old; 40 to 55 years old; and older than 65 years:

	Non singer		**Tenor**	**Bass-baritone**
Young	125,8 Hz		137 Hz	112,9 Hz
Middle-aged	117,2 Hz		146,4 Hz	127,4 Hz
Elderly	130,1 Hz		140,7 Hz	135,7 Hz

These results suggest that ALL males, regardless of their age, would have a mean speaking fundamental frequency (SFF) between A and d. Besides, all non-singers would have a SFF lower than that of the tenor-singers?!

The data for speaking fundamental frequencies in females, provided by Marunick and Menaldi[1171], are situated several tones under the given tessitura (?!):

- Alto: g - a; tessitura: c1- b1
- Mezzo: around a; tessitura: d1 - c2
- Soprano: b – c1 ; tessitura: g1- f2

In children, the speaking and the reading voice is located at an average of 4.3 half-tone intervals from the lowest reachable physiological tone.[1172]

A research note from Wheat and Hudson[1173] reveals that the spontaneous speaking fundamental frequency of 6-year-old black children was situated between 211 Hz (girls) and 219 Hz (boys), while no significant differences were found in mean of voice range values as a function of speaker sex.

Children between 5 and 9 years have a mean fundamental frequency around 270 Hz (cis1)[1174], while Ackermann[1175] found that habitual pitches above c and c1 in boys and in girls indicate a not completed voice breaking.

Wilson[1176] published pitch charts for each age in children, based upon a lot of research studies: for boys (1 -2 years to 18 years): 445 Hz to 125 Hz and for girls (1- 2 years to 18 years): 445 to 205 Hz. As no voice categories are mentioned, it is evident that the "acceptable limits of fundamental frequency", e.g., in 15-year-old boys: c (130 Hz) – g (195 Hz), are supposed to cover all the variations of voice categories and thus are not of great help to the clinician! Nevertheless, the author claims that:" the pitch level used by children with certain pathologies such as vocal nodules may be quite crucial".

Pedersen et al.[1177] studied choir boys aged 8-19 years. Fundamental frequency decreased with age: 273 Hz in 8.7 – 12.9 years, 184 Hz in 13.0 – 15.9 years, and 125 Hz in 16.0 – 19.5 years old boys.

Schultz-Coulon[1178,1179] stresses the importance of a situation related high speaking fundamental frequency instead of a permanently high habitual pitch as causal factor for dysphonia.

Cooper and Cooper[1180] are of the same opinion:" in patients with vocal nodules, normalization of pitch is essential".

Another often cited voice therapist, Boone[1181], stated that "no matter what the basis is of the dysphonia, functional or organic, there is little difference in the kind of voice therapy indicated". He finds that this is best illustrated by a case history of a 41-year-old man who spoke very near at the bottom of his tested voice range. Talking at a slightly higher pitch level produced "a good-sounding, easily produced voice and subsequently eliminated his contact ulcers".

Wedin and Ögren[1182]discuss a voice training program aiming at bringing the pitch to its optimal range in phonasthenic voices. The decrease in intensity because of fatigue lowers the pitch of the voice.

Drew and Sapir[1183], for instance, found that sopranos with symptoms of vocal attrition speak at a lower average SFF than sopranos with normal voices in both spontaneous speaking tasks and reading tasks. Stemple et al.[1184], however, reported significant difficulties in producing low pitches following prolonged voice use, probably related to the involvement of the TA muscle in voice fatigue.

Heylen et al.[1185] found a mean fundamental frequency around 249 Hz (b) in 6-11 year old boys with healthy voices and voices with noduli. The 95% prediction-interval (PI), however, was 205 Hz (gis) – 293 Hz (d1); 6–11-year-old girls have a mean fundamental frequency of 256 Hz (c1) for healthy girls, and 248 Hz (b) for girls with noduli vocales. The 95% prediction interval (PI) was 209 Hz (gis) – 304 Hz (dis1). Again, this 95% large prediction intervals embrace all voice categories!

In our opinion, in the event of voice education or voice therapy, one must investigate first if the habitual or optimum pitch is in conformity with the voice category of the subject. Mean values of the habitual pitch only indicate the ranges of the total investigated population of that specific study.

The habitual pitch can differ from the so-called "*optimal pitch*". Colton et al.[1186] call the concept of optimum pitch a myth. Westerman[1187], however, bears in mind that the human being spends much more time during each day speaking than singing. If the larynx is being forced to try to produce sound at a lower pitch than is possible in that individual, hoarseness is inevitable.

A study by Laguaite and Waldrop[1188] shows that changes in the voice before and after therapy are not due to changes in the fundamental frequency but seem to be related to more regularity in the harmonics and to an extended range in the higher frequencies. They also found that listener's judgments of voice quality and of change in pitch were unreliable. Salimbeni and Alajno[1189], however, claim that changing the pitch in patients with vocal nodules led to a quick recovery of vocal function in 98% of the cases and Jiang and Titze[1190] stress the important aspect of voice therapy "to direct patients to talk with less intensity and less adduction and to use appropriate pitch".

Based on a study of functional problems of the voice after microlaryngoscopic removal of 600 benign vocal cord tumours, Pahn and Kramp[1191], propose postoperative therapeutic measures, including avoiding of a habitual pitch which is too high and speaking too loudly.

In the etiopathogenesis of functional voice disorders much attention is paid by Bauer[1192] to predisposing factors such as exceeding the vocal range and an inadequate habitual pitch.

Schultz-Coulon[1193] too, points out to the danger of a continuous use of a heightened SFF, resulting in a continuous elevated activity of the laryngeal muscles in speaking, while Koufman and Blalock[1194] found that professional voice users, as a group, whether conscious or unconscious, pitch their speaking voices very low. They call it the "Bogart-Bacall Syndrom", pointing at a socio-cultural aspect of contemporary society: "a low voice is considered desirable for both men and women. In men, a low voice is viewed as masculine, authoritative, and confident; in women, it is viewed as dramatic, sensual, and worldly"

Koufman and Blalock[1194] divided their study population into two groups: elite vocal performers (Level I), in whom even slight aberrations of voice were considered serious, e.g., actors, (opera) singers; and professional voice users (Level II), e.g., teachers, clergy. Professional Level I and II men pitched the speaking voice an average of less than 5 Hz above their lowest note; 52% even used a speaking voice that was identical in frequency to their lowest pitch! Professional Level I women had an average habitual pitch of 17 Hz above their lowest note. The authors conclude that the final clue to the diagnosis of TFS (tension-fatigue syndrome), particularly in a professional voice user, should be abnormal pitch of the speaking voice.

According to Burkowsky and Vitali[1195] the concept of optimal pitch is vague and unscientific. They agree, however, that, subjectively, vocal efficiency is best when pitch concentrates in the general area somewhere between one-third and one-fourth of *the total range* above the lowest tone produced.

Burns[1196] pays attention to the problems faced by country and western singers. According to him, problems with the speaking voice have to do with "speaking in an improper pitch, usually too low", while "the pitch the singers use is based not only on their natural range, but also on a need to emulate other successful singers".

Eustace et al.[1197] cite a lot of studies considering abnormal pitch to be a factor of laryngeal fatigue but found themselves no relationship between laryngeal fatigue and abnormal pitch. They failed, however, to take voice classification into consideration.

Milutinovic[1198] describes the "syndrome of inappropriate vocal pitch" and even specifies different clinical outcomes:" In cases of excessively high vocal pitch contact lesions will develop at the predilection sites of the vocal folds, while contact hyperplasia (contact ulcer) will arise in cases of excessively low pitch.

Vocal nodules are often seen as the result of vocal abuse or misuse, in particular the habitual use of too high or too low a pitch.[1199,1200] According to many authors, voice therapy should be initiated if habitual and optimal pitch levels differ by two or more tones.[1201,1202] The habitual pitch is often seen in relationship to the *voice type* and is situated at the lower end (lower third) of the vocal range.[1203,1204]

According to Drew and Sapir[1205], research needs to address not only singer and non-singer differences but also differences between *voice classification.* They report that singers with symptoms of vocal attrition speak and read with a lower mean SFF (Speaking Fundamental Frequency) than singers without symptoms of vocal pathology. *Singers using an inappropriate pitch can be misclassified.*[1206]

To Sapir[1206], habitual use of excessively low pitch is a cause, sometimes the primary cause, of vocal attrition and impaired singing abilities.

Stone and Sharf[1207] found that vocal pitch was a contributing factor in development of dysphonia. Durational effects, however, were inconsistent and depending upon vocal pitch level.

Well-known is the observation that people intend to raise voice pitch when increasing vocal loudness in speech, while singers must be able to vary pitch and loudness independently.[1208]

Schultz-Coulon[1209] realizes that phonating too loud at too high a pitch has become a habit in many patients.

A continuous deviation of the optimum pitch means that more stress is put upon the vocal folds, causing damage to the voice.[1210] This is certainly the case when one considers the emotional context of speech, which also affects the SFF (Speaking Fundamental Frequency) of the voice.[1211] Moreover, one must consider the strong relationship between personality and specific voice disorders, as demonstrated by a *Multitrait-Multidisorder*

Analysis, clearly differentiating between subjects with functional dysphonia and patients with vocal nodules.[1212]

An acoustic analysis of induced vocal stress[1213] demonstrated an increase in the fundamental frequency (F°), considered as a universal indicator of stress.

Orr et al.[1214] situate the SFF° in that part of the phonetogram where the upper steep contour change into a more moderate path. By adopting a much higher SFF° there is a great chance for tissue damage.

According to Hacki[1215], the area of the speaking voice is normally located in the lower third of the phonetogram of the singing voice. The limits of the dynamics of the speaking voice area, however, approach those of the singing voice area or they reach them. Moreover, the area of the shouting voice is found next to the transition of chest and head registers. Sometimes the dynamics of the shouting voice area exceed the area of the singing voice!

Actors, for instance, are very often engaged in extreme phonating situations, which are detrimental to the voice. Raphael[1216] thoroughly describes the many circumstances in which extreme deviations of the optimum pitch are obvious.

Feudo et al.[1217] affirm that actors extend their use of range or spend more time outside of their typical range and increase their mean intensity while performing. Emerich et al.[1218] came to the same conclusion by comparing vocal range and intensity (voice range profiles) in actors in a studio versus on stage.

Concerning the intimate relationship between the speaking and the singing voice, Cooper[1219] considers that the effect of the vocal misuse of the speaking voice – by speaking without knowing what pitch level and range is appropriate - is revealed by the weakness and subsequent trouble of the singing voice (e.g. hoarseness, laryngitis, tired voice, sore throats, voice breaks, pain in the throat, throat clearing, coughing, and many other symptoms), leading to "*vocal suicide in singers*".

Concerning voice therapy, voice exercises usually start with the habitual pitch[1220], but modifying someone's faulty habitual voice pitch isn't always easy because one must consider that "such habitual patterns are developed over a lifetime and are highly resistant to change"[1221-1224]. Moreover, according to Sapir[1225], a lot of psychosomatic mechanisms (e.g., tendency to be worried, depressed, anxious, or having mood swings) may predispose the voice student to develop vocal pathology and /or inhibit recovery from vocal pathology.

CHAPTER 7

THE IMPORTANCE OF VOICE CLASSIFICATION AND ITS IMPACT ON VOICE DIAGNOSIS AND THERAPY

Up to date no single measurement can reproduce all aspects of the voice function. Most authors, however, consider pitch, loudness, and quality as the main parameters of voice. Traditionally, voice classification has been based on these three parameters, but, as Erickson et al.[1226] remarked, "most research studies have focused on the acoustic correlates of one parameter, *timbre.* Yet even this parameter is not well understood ".

Many years ago, Lycke[1227-1229] repeatedly made "some critical remarks on present-day treatment of disorders of the singing voice ", stressing the importance of **voice classification**. However, four decennia later, we could read in an article by Stalmans and De Bodt[1230], that voice classification, although considered to be as most important to a (beginning) singer, still seems to be the prerogative of the singing teacher, based on an interpretation by what the singing pedagogue can hear. We still do not agree with this obsolete viewpoint.

As Frank[1231] already stated: "*the classification of a voice at the beginning of the education of the singing voice by the ear of the singing pedagogue alone, is extremely dangerous*." The same author remarks, thirteen years later, that the whole issue of the assessment of the singing voice mostly has to do with the fact that most voice researchers are not able to distinguish the different kinds of singing voices. **Voice classification** is preponderant."[1232]

According to Sundberg et al.,[1233] "In future investigations it may prove rewarding to select a greater number of singers whose voice sound similar. For instance, common vocal behaviours may exist within subgroups of singers, e.g., lyric tenors or baritones, Wagner tenors, etc.". Kitch et al.[1234] too, choose tenors from one choir singing the same piece of music "to maximize the homogeneity of the singers in terms of voice type and style and to control a far as possible for variability in the performance."

Drew and Sapir[1235] too concluded: "Further research using a larger n is needed to establish normative data for singers by **voice classification** (including subclassification) with consideration given to …", and "research needs to address not only singer and non-singer differences, but also differences between **voice classifications** and subclassifications in women and men in vocal performance studies."

Welch et al[1236] made xeroradiographic-electrolaryngographic analyses of male vocal registers. They found a large amount of the total variance that is attributable to difference between singers, relating to the characteristic timbre of the different voice categories, based on anatomical differences.

Coleman[1237] argues that *one of the essentials of becoming a professional singer or actor is knowing what can be done without risk to the vocal mechanism*. We assume that this statement holds true for every human being. That's why voice classification is of utmost importance for everyone.

The results of our study clearly show that *any voice* can be classified according to the proposed basic voice types. It is interesting to realize that most men are baritones, and most women are mezzos, as our results have shown, according to the Gauss curve. But it is far more important to be sure about the *exact* classification of a given voice because voice classification has *great predictive value: it provides a statement of the overall possibilities and restraints of a given voice.*

Coleman[1238] already stressed the consensus that singing and speaking outside a given pitch or intensity range is potentially risky, but he didn't mention the obvious connection with voice classification!

Holmberg et al.[1239] gave already a hint by stating that "in clinical studies of voice patients, it is often preferable to allow the subjects to use levels of loudness and pitch that are *typical* for them, rather than having them attain prescribed levels." Unfortunately, they omitted to see the relationship between "typical" levels of loudness and pitch and voice type!

Kitch et al.[1240] too, demonstrated "a strong individuality in response to performance" and concluded: " research is needed to compare performers with robust voices to performers whose voices are sensitive to use."

Voice classification, however, offers an excellent guideline to whatever manipulation of the voice: voice improvement, acting and singing instructions, and voice therapy.

Several studies reported characteristic phonetographic profiles for specific vocal groups. However, their conclusions were often contradictory. Our point is that the voice of whatever subject must be classified in the first place, before any other subdivision takes place. A tenor with vocal complaints apparently will show different vocal symptoms at different frequencies, as compared to a baritone or a bass with a similar voice disorder. The habitual and optimal pitch levels, the vocal range, the acoustic spectra featuring the typical voice quality, the location of the register changes and the overall dynamic parameters are totally *voice type dependent*!

Voice classification based on a momentarily acoustic impression of voice range (which is often shifted in one or other direction), on timbre (which is often distorted by training) or by loudness (which is unreliable in comparison to an effective instrumental measurement of intensity), must be replaced by *a step- by- step voice classification procedure by F°-SPL measurement.*

Voice classification by phonetography is not a mere kind of aesthetic operation consisting in classifying special individuals like classical singers. In our opinion, classification of EVERY HUMAN VOICE is a necessity. Voice classification immediately opens new pathways in voice diagnosis, vocal hygiene, and voice education and finally, voice therapy. For instance,

- the assignment of specific roles in the spoken and sung theatre, as mentioned before.
- combining the concept of the phonetogram with automatic pitch extraction of vocal performances and superimposing a contour of the vocal performance demands on the profile of the individual's vocal capabilities.[1241]
- graphic analysis of the frequency of note occurrence within each musical composition (“tessiturogram”) as an aid in objective determination of appropriate repertoire. The tessiturogram can be combined with a phonetogram, permitting a "precise, reproducible, and objective correlation of vocal suitability for the piece to be sung."[1242]

Other applications are:

- indication of the optimum speaking frequencies.
- prevention of voice problems.
- vocal hygiene.
- therapeutic directives.
- carrying power, projection, vocal penetration (Durchdringungsfähigkeit) as a characteristic feature of vocal efficiency[1243-1245], Tragfähigkeit der Singstimme[1246-1248], Durchschlagskraft der Sprechstimme[1249,1250], "Steigerungsfähigkeit der Stimme" [1251,1252].
- Voice Interval Test[1253].
- recording vocal load by a voice accumulator[1254,1255].

In our opinion, voice classification means a lot more than a mere labelling of a (classical) professional singing voice. Decennia of voice specialists[1256-1264] have stressed the importance of an exact voice classification, if possible (?) before any voice training starts. Wrong voice classification could induce functional and eventually, organic voice disorders.[1265-1269] The biographies and manuals of famous and less famous singers bulge with examples of the pernicious outcomes for their voice and for their career caused by faulty voice classification.[1270-1279]

Interestingly, singing teachers (often with voice problems), are incorporated in our subjects' group. In a study by Miller et al.,[1280] using a questionnaire format, it appeared that teachers of singing were considerably more likely to report ever having had a voice problem than controls (64 vs. 33%). It is interesting to look at the symptoms, mentioned by the teachers of singing: 78% of the symptoms was related to loss of high notes vs. 20% of low notes; 22% of the symptoms was related to loss of the loud voice vs. 32% of the quiet voice; 97% were complaining of a tired voice, 73% of hoarseness, 20% of a weak voice and 51% of effortfulness. Sataloff[1281] too, considers that teaching singing may be hazardous to vocal health.

In a study on "vocal attrition" (vocal pathology and reduced vocal functions associated with behavioural, biogenic, and psychological factors) in university female voice students, only 13% proved to be free of symptoms.[1282] All voice students received training in classical singing, but many indicated that they had been engaged in other types of singing e.g., musicals, jazz, folk, and gospel music. Strangely enough, 84% of the female voice students declared to be sopranos, 15% were mezzos and only 1 student declared to be a contralto. Unless almost exclusively "sopranos" took singing lessons in this study, this information proves to be in strong contrast with the Gauss curve! Regarding speech habits, 81% of the students considered themselves “talkative”, 68% said that they usually speak fast, 47% said that they usually speak with a loud voice, 47% found that they usually speak in a voice that is too low a pitch, and 33% confessed that they usually find themselves doing most of the talking in conversations or in social gatherings!

Miller[1283] too, testifies that “young singers press for louder and louder and higher and higher sounds, no matter what their bodies can do comfortably and efficiently”. His remarks strongly resemble those of Dumazet[1284], made many years earlier. Burns[1285] makes the same remarks regarding country and western singers, without (any) musical background and formal training. These observations are corroborated by the study on mechanical stress in phonation by Titze[1286], who found that the largest mechanical stresses in vocal fold vibration are the tensile stresses required for pitch increase. Particularly at the highest pitches the vocal ligament would be at the highest risk.

Many years ago, Ruth[1287] seriously criticized the many shortcomings of the methodologies of singing teachers, often leading to lasting voice disorders in their pupils, while Frank[1288] wonders if research findings on the singing voice can result in directives for exercises for voice disorders.

Sataloff[1289] remarks that “singers are habitually unhappy with the limitations of their voices. In many situations, voice teachers are to blame. Both singer and teacher must resist the impulse to show off the voice in works that are either too difficult for the singer’s level of training or simply not suited to the singer’s voice.”

Regarding elderly voices, Frank[1290] subtly remarks that many older singers must return to the voice classification to which they originally belonged!

To McHenry[1291], misclassification can be a major cause of dysfunction in the young adult voice. As “every aspiring young singer knows that the larger incomes are in the high notes, so regardless of statistical evidence that most of them are baritones and mezzos, they push for the higher voice classifications quite early.” However, he assumes that “once a solid singing technique has been established, a voice almost classifies itself.”

Unfortunately, in our experience, most singing teachers continue giving singing lessons, without being sure of the exact voice classification of their students. In our texts on “Voice classification by phonetography: a step-by-step procedure", our results are always compared with the many divergent interpretations given by other people.

In an article on the dimensions of "*Dysodia* – Historical and Present Aspects", Seidner and Wendler[1292] express their difficulty to find publications on "The Dysodia – functional disorders of the singing voice". Note that this article was written 26 years after the publication of my own thesis as a young speech therapist! In agreement with our own ideas, expressed in our chapter on "Subject Classification in Voice Research", these authors also include non-singers and children in their study on dysodia. They consider therapy for dysodia to be very strenuous and an awkward task!?

Röhrs[1293] analysed long-term results after logopedic therapy in hyperfunctional dysphonia but could not find comparable data in the literature.

As longitudinal studies on therapy for functional voice disorders are extremely scarce,[1293] evidence of voice deterioration, induced by faulty voice classification, and its restoration by voice therapy, illustrated by longitudinal Voice Range Profiles, is still missing too. Several longitudinal phonetograms will be analysed in Chapter 9 to defend our point of view. The relevance of this procedure can be demonstrated by comparing the general data we collected for each tone of the human vocal range, with the specific data per tone of a given voice, provided by phonetography in a lapse of time.

According to Hacki[1294], the normalization procedure of Coleman et.[1295] enables the comparison of phonetograms of different voice types and different vocal ranges. However, voice classification by phonetography enables researchers and clinicians to compare ("norm") phonetograms within each own voice group. Only this way voices can be compared tone by tone. Normalization procedures like those of Coleman, Awan and others only compare 10 tones. Moreover, this limited choice of ten/eleven tones doesn't compare the same tones, because of the often-huge difference in vocal range of the subjects. And last, but not least, this averaging method provides no possibility to clinically demonstrate register transitions and other special features in the smoothed out phonetograms of a whole group.

In his acoustic study on the characteristics of the Voice Range Profile, Titze[1296,1297] too admits that "agreement in the formant ripple cannot be expected, because such ripple would be washed out by averaging over the subjects' different formant frequencies." He noted no ripple at the bottom and a large amount of ripple at the top in his model, based on formant tuning of selective harmonics.[1298,1299] He also made a most interesting conclusion: "Future applications of this model should be directed towards a better understanding of *vocal registers*, *voice classification*, and *voice disorders.*" This happens to be exactly the aim of our own study.

Klingholz et al.[1300] stated that most voice fields, provided in the literature, contain relatively few measuring points, so that register transitions are seldom visible.

Denk[1301] too, supposed that subjects must be grouped according to their voice types to demonstrate the average characteristics of the different voice types, but he doesn't mention the methodology by which his subjects were classified. While his results show averaged vocal ranges, which can be situated within the limits of our generalized Table 5 (except for the baritone range: highest tone = d2 instead of b1), the averaged dynamics show little differences between the voice types: 52/55 dB – 106/113 dB for all female voice types, 55/56 dB – 105/107 dB for all male voice types. Only the piano curves demonstrate the difference of voice types: *the lower the voice, the flatter the rise of the piano curve.*

According to Frank and Donner[1302], voice classification by F°-SPL measurement alone is not possible. They feel there are no characteristics in the voice area in relationship with the different voice categories. (?!)

Although Klingholz[1303] acknowledges the fact that the phonetograms of voice types are clearly to differentiate. His results, unfortunately, have little clinical importance: the F°-SPL Profiles of sopranos and tenors are, of course, shifted to the higher tones. The phonetograms of basses and altos are shifted to the lower regions of the vocal range and exhibit higher sound pressure levels in the lower ranges. F°-SPL Profiles of mezzos and baritones are situated in between. By means of ellipse parameters average voice fields of the six basic voice types were described.[1304-1306] Klingholz[1306] states that male singers have less problems with their singing voice then female singers because female vocal folds vibrate two times more than male vocal folds. Moreover, female voices very often are classified to a voice type which is too high.

By adding the *measurement of the singer's formant* to the combined measurements of pitch and intensity as an aid to voice classification, we think this methodology will give satisfaction to the expectations of Erickson et al.,[1307] who remark that “to date, no research has been conducted that examines the interrelationship of pitch, tessitura, and timbre as predictors of *voice classification.*” Again, in our opinion, it is all in the phonetogram, as we will illustrate in Chapter 8.

CHAPTER 8

OWN PROCEDURE OF F°-SPL MEASUREMENT

8.1. Introduction

From his adolescence on, the author spent many hours with singers, actors, and dancers during their education in music conservatories, in music and dance schools of all kinds, in choirs, in masterclasses, in singing competitions, during auditions, on and around the stage during performances, in private practice and in clinics. During this great lapse of time, many things changed in the world of theatre, music, and dance.

Singers of the "Western operatic style" account for the subjects first studied, followed by actors (in training), wanting to learn to sing, but disliking the "unnatural" opera style. Many potentially beautiful voices of actors in training were detected by phonetography, often featuring better vocal potentialities than the "regular" singing students.

With the successful evolution of Musical Theatre in the eighties, lots of young people were attracted to new mixed singing styles (e.g., classical, natural, rock, belting, jazz …). Music conservatories and "regular" music, acting and dance schools experienced difficult times to adapt to the urgent demands of their students. As Bawntree[1308] stated in his monography on "The New Singing Theatre", there was a need not only for "a sure grap of classical vocal technique", but also for "the ability to extend that technique to cope with today's demands". From a scientific point of view, this evolution opened new perspectives. Acknowledging that most voice research in the past was focused on operatic singing, other vocal techniques were seldom investigated.[1309,1310]

As both loudness and pitch change within wide limits[1311], we were intrigued by the expected differing results in F°-SPL measurement, based on different singing styles. The need for this versatility, expressed by the many *"crossovers" between opera and other kinds of musical theatre* also had his drawbacks. Whereas in earlier times each discipline had its own specific and lasting education, the new musical theatre demanded *an* *immediate amalgam of "actors-singers-dancers*". As a result, a new type of voice problems arose, providing peculiar curves in voice fields, and demanding specific voice rehabilitation techniques. The urge to "explore the full potential of the voice within the limits of its good health"[1312] often came into collision with the demands of the students (and their training institutes) for a rather superficial education, leading to a rapid practice in a forthcoming production. Typical examples of this inward conflict can be found in the longitudinal voice fields analysed in Chapter 8).

The evolution of our own methodology certainly had to do with every kind of vocal performers we had to deal with in the lapse of time. Especially the great variety of controversial vocal techniques - good ones and bad ones - (cfr. the growing success of belting), used by singers and actors of the musical theatre, provided an excellent opportunity to experience the large diagnostic possibilities of F°-SPL measurement. Besides, the recent evolution of a "new singing theatre",[1312] depending on a new kind of performers (singers-actors-dancers) opened challenging possibilities for education and research, but also put at risk many non-educated voices of young people, hoping to get famous and rich in the shortest possible time by imitating other (non-educated) voices which are, for one reason or another, successful at that moment.

So, in our opinion, we had enough evidence to defend the view that there was much more in a phonetogram than usually supposed, and we tried to prove this with a lot of clinical examples.

Moreover, we realized that the whole theory behind this new concept could change the traditional approach to clinical voice treatment and to vocal pedagogy. The interpretation of the *register transitions* and the value of the *singer's formant*, e.g., as being measured during routine F°-SPL-measurement, plays an important role in this context, as we will see later. To demonstrate this, we chose a methodology in which phonetographic interpretation rigorously has been compared to the possibly different personal pronouncements on voice classification by the subjects, and/or by their singing teacher(s), voice teacher(s), conductors, choir leaders, and so on. In other words, we always asked our subjects to what kind of voice category they thought they belonged, what others told them about their voice and what their arguments were.

8.2. Aim of the study

A basic endeavour of all scientific research is classification. In our opinion, every human voice can and should be classified in view of its lasting vocal health.

The three most common parameters of voice are: pitch, vocal intensity, and vocal quality. These features can easily be explored by phonetography. We hypothesize that phonetography provides a striking possibility to classify human voices.

The objectives of this study are:

- to critically analyse the existing literature on phonetography, especially regarding methodology and interpretation of the results.
- to propose a *new concept of methodology and interpretation of phonetographic measurements*, aiming at the *essential classification of every human voice, based on the elaboration of an extensive pattern card of the parameters of the human voice.*

8.3. Own methodology

8 3.1. General aspects

The analysis of the many different methodological aspects of phonetography leads to the conclusion that *subjective factors* are much preponderant.

Taking a much closer look at "S*ubject classification in voice research"* (Chapter 1) and at "V*oice classification in voice research"* (Chapter 5*)* reveals many hidden biases.

In this study we will investigate if ALL subjects - not just classically trained singers - can be classified by phonetography. Voice classification in six basic voice categories (bass-baritone-tenor for male voices, and alto-mezzo for female voices) is since long accepted in the (classical) musical world. However, we state that voices should be classified AFTER the necessary (phonetographic) measurements have been taken, and not *a priori* accepted, as often seems the rule, even in voice research.

In our attempt to investigate whether phonetography might provide a useful tool of classifying ALL subjects, we started our study by treating all subjects of one gender as just one group. We feel that the a priori classification in the so-called "normal or healthy voices", "singers", "non-singers", "student singers", "voice patients" and so on, is too confusing. Too many overlaps in voice status could explain conflicting interpretations of F°-SPL measurements. Even overlaps between the normal distribution (Gauss curve) of "normal" and "pathological" voices is a fact.[1313]

We consider phonetography as a very important part of the classical voice examination procedure. Because most vocal artists received one kind or another of vocal training, which sometimes included elements of voice classification, *we always meticulously involve our subjects in each step of the voice testing procedure.* This means that during the voice examination, not only data from the subject's history, but also specific results of some test items are thoroughly discussed with the subject. At the end of the examination, we already have an idea of a specific diagnosis, which has been confronted with the subject's own view on the matter. F°-SPL measurement, however, is considered as the ultimate functional voice testing procedure, which can strengthen or weaken our preliminary conclusions. It is clear then that, at that moment of the procedure, the subject and the experimenter are eager to know the results of the F°-SPL measurement. The impression of the clinician and the subject, being to a considerable extent subjective, will in the end be confronted with 'what the machine will discover'! And then, of course, during the interpretation of the F°-SPL curve, there is always the possibility that the discussion starts again, to compare our subjective impressions with the objective measurement results. Evidently, this procedure takes a lot of time!

Moreover, let us bear in mind that "interpretation of the phonetogram is still very much an art". [1314]

Coleman[1314] insists on the "careful investigation of both the profile procedures and the variables which potentially affect results." In our study we also wish to give ample proof of the many clinical indications that can be derived from the differing data in every phonetogram.

Spending sufficient time before, during and after the taking and interpreting of the phonetogram offers rewarding possibilities in the event of future *advice*, *training,* or *therapy*.

8.3.2. Methodological aspects

The bulk of research articles on phonetography were written during the coming on the market of new measuring instruments, which we were able to test. [1315,1316]

Ackermann[1317] stresses *the scientific value of consecutive judgments by the same investigator. Intraindividual reliability may be better than interindividual reliability in the evaluation of voice patients*.[1318]

In a study on expert consensus in solo voice performance evaluation, Wapnick and Ekholm[1319] also reported that intrajudge reliability was higher than interjudge reliability.

However, according to Waar and Damsté[1320], considering that the phonetometric measurements of this study were taken by the author in a lapse of almost 60 years, it is hardly surprising that some aspects of our methodology changed over the years. While the investigator was the same person over the years, the instrumental equipment wasn't. So, we used a Sound - Survey Meter, Type 1555-A (General Radio Company, Massachussets, U.S.A); a Realistic Sound Level Meter Cat. No. 33-2050, Radio Shack, U.S.A.; a Real Time Sound Level Analyser, Type NA-23, Rion Co Ltd, Tokyo, Japan; a Fonetometer FRS – 1, Ing. J.H. van Dijk, Oldehove, The Netherlands; a Voice Profiler, Alphatron, Rotterdam, The Netherlands; and a lingWaves Voice Diagnostic Centre, LingCom GmbH, Forchheim, Germany, including: Vospector-DSI (Dysphonia Severity Index), Vocal Loading Test, Long Term Analysis, Speech Sound Spectrography and Real Time Spectrographaphy.

We refer to the in Chapter 6 mentioned psychoacoustical studies and elements of general music theory to argue why our own procedure of F°-SPL measurement uses the well-known *diatonic musical scale*.

Room acoustics happened as diverse as one can imagine, although F°-SPL measurements were never taken in an acoustically treated room.

Feudo et al.[1321] used readily transportable equipment in their objective analysis of actors' voices.

Regarding singers, Kitch et al.[1322] concluded that *the results obtained from research in naturalistic settings may be more valid in singing pedagogy than laboratory studies.* They encourage investigators to explore the possibilities of taking the laboratory to performers and thus have larger groups of subjects available for investigation. In this context, let us not forget the wise remarks of Brodnitz:[1323]" The bigger the machinery, the more the artificiality there is with a patient".

We used an A- weighting network (dB A) and a slow meter damping, while the microphone distance was 100 cm in former days, 30 cm since

1992. Older measurements were converted to the 30 cm. U.E.P. norm. (1983)

Maximum and minimum intensities were measured in a descending scale, starting at pitch c (male voices) or c1 (female voices), first in descending and then in ascending order, first pianissimo and then fortissimo.

All tones of the entire vocal range were measured and since 1992 automatically registered by the software of the F°-SPL equipment. The intensity of the *singing formant* was simultaneously measured and evaluated, which made the methodology still more valuable.[1324]

To obtain useful information from the phonetogram, we determine the *total vocal range*, i.e., we note every pitch the subject can produce, whatever technique he/she may use. We consider phonetography as a specific *functional* voice testing method, exploring the *extreme limits of voice in real time*. Every pitch a subject can produce at a certain moment, exhibits the *functional possibilities* of the vocal apparatus *at that time*.

We stressed the huge importance of the subjective factors in F°-SPL measurement. As mentioned above, all our subjects were strongly involved with the whole phonetographic procedure, as the results of the measurements could affect their (artistic) future, hence the many discussions! This also means that it can be readily assumed that the obtained phonetograms show their best possible results at that moment.

All subjects were in standing position and phonated at least 2 seconds on an ‘a’ with the mouth wide open. All tone qualities were accepted within the physiological limits of their voice production. Because most subjects received one kind or another of voice and/or singing training, special attention went to the specific phonation techniques during the measurements. If some singer was eager to know the difference in dB(A) between different vocal techniques, he was allowed to test this; only the best result was noted in the phonetogram.

We agree with Schutte[1325,1326] that the investigator should have a musically well-trained ear. How else could he seriously judge the subjects’ possibilities, or shortcomings which he might have to deal with, later, in education or therapy sessions?[1327] In voice therapy too, research predicts better prognoses for voice patients with musicality.[1328]

From 1992 on, we were able to measure simultaneously the amplitude of the singer’s formant at maximum sung intensity. We believe this kind of notation of the quality of the voice to be an enrichment of the phonetographic procedure. We were not interested in filtering and averaging methods

The motivated interest by the subjects in the whole phonetographic procedure and the analysis of its results easily explains the long duration of the procedure. (Usually one hour or more) We consider this *time-consuming procedure* worthwhile, as most subjects were very pleased to know *at last* their true vocal type and its depending possibilities. The careful interpretation of the phonetogram, in an animated consultation with the subjects, provides a lot of hints for future training or therapy.

In an article on the "Sources of Variation in Phonetograms", Coleman[1329] describes the wide differences in the way phonetogram data are plotted. In this study we chose, in some cases, for a *vertical positioning* of the phonetogram's data, with the intention to accentuate the interpretation of many meaningful differences in intensity occurring at specific pitches, instead of a mere examining of the overall profile pattern, as most studies do. The use of musical intervals as sampling steps for the phonetogram, in order not "to miss important transitional points on the *frequency continuum*" [1329] is obvious.

A study by Orr et al.[1330] shows that it is possible to use the phonetogram as a discriminating instrument with a limited set of parameters. There is less consensus in the literature regarding the interpretation of shape related parameters, described by arbitrarily projected ellipses in the phonetogram[1331-1333] or by analysing the shape itself by Fourier Descriptors.[1334,1335] Besides, these specialized analyses depend on complicated calculations, not readily available to every clinician in the field. The *shape of the phonetogram*, for instance, is considered as an important feature at first sight [1334-1336] but what constitutes a "normal" enclosed area?

Airainer and Klingholz[1337] propose a quantitative evaluation of phonetograms but admit that the phonetogram area is ambiguous "because the same area not only indicates a large vocal range with little mean dynamics but also a small vocal range with large mean dynamics".

Moreover, locating the transition of chest register to falsetto register in "normal' male voices at about 392 Hz (g1), or at 440 Hz (a1) in women, based on averaged phonetograms measuring only 4 pitches per octave[1338], does not correspond to the common accepted register transitions in the literature. In the study of Orr et al.[1339] the authors even admitted that it was not possible to situate the onset of the falset register because the register transitions were not stated at the time of the phonetogram registration!

Concerning the results of our female subjects, we are aware of a possible influence of *hormonal factors* but are not able to give controllable comments on this matter. Well-documented studies on PMS (Premenstrual Syndrome) and menopause report on about 100 general physical and psychological symptoms, including voice problems related to pitch, intensity, quality, and flexibility.[1340-1353] Moreover, as we learned from the cited article on the use among singers of "alternative medical therapy", many natural therapies have a hormonal effect.[1354]

In this study, 333 individual subjects were studied (214 female subjects and 119 male subjects), which is more than sufficient for statistical analysis[1355] and "assured adequate power (probability of rejecting the null hypothesis when it is false) of the tests".[1356] The elaboration of an *age-related and gender-specific pattern card of the human voice*, based on a step-by-step analysis of the phonetograms of many subjects, has produced a referential database[1357] which enables a *basic voice classification* of any subject. This basic voice classification provides useful information for voice education and voice therapy.

The age of the female subjects ranged from 8 to 88 years. 72,7% of our female subjects were between 17 and 25 years old. The mean age of our female population was 23,8 years.

The age of the male subjects ranged from 10 to 76 years and showed an even distribution: 46,3 % of our subjects were between 17 and 25 years old. The mean age of our male population was 27,8 years.

From 69 subjects (25 males and 44 females) a total of 212 longitudinal measurements were taken.

175 measurements of the singer's formant were taken from 108 subjects (39 male and 69 female subjects).

In this study the importance of measuring *each tone* of the vocal range is stressed many times. When interpreting and analysing our results, one must consider that all pitches that we measured are included in our data, even when, at a given time, not every pitch of the whole vocal range was measured. Also, in some cases, only maximum intensities were measured, so that, in the older data, we hardly can speak of phonetograms. Anyway, in the great lapse of time, we feel that every noted measure has its own meaning in the context of this study on voice classification. More measured pitches provide lots of data points, otherwise neglected as in many other studies, measuring only a few pitches per octave, for instance. Consequently, in this study, we interpret N as every distinct series of measurements within the vocal range of a given subject at a given time.

Young adult people – *with or without voice and/or singing training* – occupied the major portion of the subjects of our study. The conglomerate of these young people, completed by some children, adolescent, mature, adult and even older people, provides a good example of subjects who were, in one way or another, for shorter or for longer time, confronted with their voice production. According to the criteria of Hoffman-Ruddy et al.[1358], the subjects in our study belong to the category of "*high-risk vocal performers.*" However, little literature is available on professional Musical Theatre populations, using a wide variety of vocal qualities that cause variable adjustments in the oral cavity and vocal tract[1359].

We agree with Hoffman-Ruddy et al. that clinicians should be invited to visit the performers' stage, so that there is a better understanding of the detrimental environmental situations they are exposed to.[1358]

Titze et al[1360] presented a study on "populations in the U.S. Workforce who rely on voice as a primary tool of trade". About 15% of the professional singers in the United States were estimated as "classical singers". Further breakdown into country, rock, gospel, jazz, or blues singers seemed to be difficult because many of the latter professional singers fit into multiple categories. However, an attempt to provide a "quantifiable singing standard" has been made by Bunch and Chapman,[1361] based on nine singer categories with comprehensive subcategories under each topic for each type of singer, that is, opera, pop, jazz, etc. The authors expect "to eliminate the problems of enough numbers to form statistically significant conclusions. Second, it will become easy to compare types of singing both within the same general category and those at different levels among the various categories."

Upon the time of writing, we found no single study, employing this "taxonomy of singers used as subjects in scientific research." Our own subjects, however, could fit the following categories, often in a combination of several types:

Types of singers: Opera, Contemporary Music Theatre, Musical Theatre, Concert/Oratorio/Recital, Recording Artist, Pop, Rock, Cabaret and Club, Jazz, Folk, Gospel and Soul, Country and Western, Church and Cathedral, Vocal Groups, Busker/Street Singer.

According to the categories and definition of singers, given by Bunch and Chapman[1361], our subjects fit in one of those following categories:

2. International
3. National/Big City
4. Regional/Touring (often seasonal)
5. Local Community (often semi-professional)
6. Singing Teachers.
7. Full-time Students of Singing (ages 18-25)
8. Amateur
9. Child

As can be seen, the only missing category in our study is that of "1. Superstar", i.e., "a singer of worldwide fame and recognition who commands the highest fees; is supported by powerful marketing and a personal entourage; is never out of the public eye; commands media attention; professional support may include teachers, coaches, repetiteurs, and choreographers ".[1361]

As Sulter et al.[1362] stated, *establishing standard references by averaging or rescaling techniques do not allow for frequency dependent intensity information*.

Behrman et al.[1363] made a preliminary study on the meaningful features of voice range profiles. The criteria used as being potentially meaningful descriptors of the VRP's were *frequency range, dynamic range, minimum intensity level, the smoothness of the upper and lower contours, and the presence of gaps in the contours.*

Our own statistical evaluation is based on 5 parameters, according to the method of Seidner (et al.).[1364,1365]

1. Maximum intensity measurement.
2. Minimum intensity measurement.
3. Difference between maximum and minimum intensity measurement.
4. Intensity of the singing formant.

5. Difference between the maximum intensity and intensity of the singing formant.

We constructed some "*Standard Phonetograms" of male and female voices*. We also experimented with some statistical analysis of the differences between the minimum vales of the maximum and the maximum values of the minimum intensities.

A large zone of one octave in the phonetogram, corresponding to the supposed transition zone between modal and falsetto register was thoroughly analysed.

All data were listed in a *statistically balanced step-by-step procedure of voice classification.*

Our results were compared to the results found in the literature and discussed to provide useful clinical conclusions.

8.4. Voice Range: Results and Discussion

8.4.1. Male voices

8.4.1.1. Lowest tones

Improved vocal range is often the goal when working with voice patients.[1366] However, according to Sulter et al.,[1367] "only limited knowledge is available concerning the mean range and standard deviation of the frequency range in large, specified groups of men and women." In a following study[1368], they reported average frequency ranges at the 10% frequency levels for untrained and trained groups:

- untrained female subjects: 157,3 Hz (dis) – 1.223,7 Hz (dis3).
- trained female subjects:128,4 Hz (c) – 1320,3 Hz (e3).
- untrained male subjects:86,1 Hz (F) – 785,4 Hz (g2).
- trained male subjects: 74,0 Hz (D) - 688,2 Hz (eis2).

These results are based on *averaged phonetograms* with the *rescaling method*. The difference between untrained and trained female subjects is only 0,5 to 1,5 tones. The difference between untrained and trained male subjects is only 2 tones at the lower end of the vocal range, but 5,5 tones at the 100% frequency level. These highest pitches are situated in the falsetto range. Could it be that the untrained subjects used their falsetto voice, while the trained male choir singers or singing students in this study were not used (or allowed) to do this? Unfortunately, the authors do not relate their results to specific voice types.

Table 13 shows the distribution of the lowest tones in males in our study. With reference to Table 5 (Synthesis of the limits of voice range / tessitura of the six basic voice types), we can schematise the distribution of lowest tones in males by the next Table:

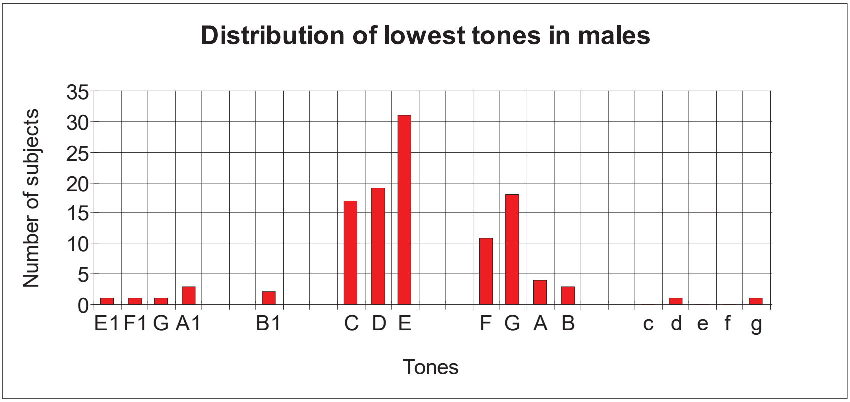


Table 13: Distribution of lowest tones in males (N = 113 measurements)

E (82 Hz) is the lowest tone most found in male voices (27%), while E1 (41 Hz), F1 (44 Hz), G1 (49 Hz),) can be considered as exceptional low tones.

Schultz-Coulon and Asche[1371] and Sulter et al[1368] found 87.3 and 86.1 Hz (+/- F), respectively, as lowest phonatory frequency, which means that 66% of our measuring points were lower than the lowest measured frequency by these authors! Could it be that, in their study, *no basses* were present, considering that "the subjects were instructed to produce phonations *at the physiological boundaries*, without, of course, injuring the voice during maximum intensity".[1368]

Note that the attribution of the lowest pitches of the basic male voice types is unevenly distributed:

Bass: E1 – F1 – G1 - A1
Bass – baritone: B1
Bass – baritone – tenor: C – D – E
Baritone – tenor: F – G – A – B
Tenor: c and higher

Table 14: Uneven distribution of lowest tones in males.

Four pitches (E1 – F1 – G1 – A1) are considered typical as the lowest pitches for a bass voice, while only one pitch (B1) is considered typical for a bass or a baritone. Three pitches (C – D and E) could indicate a bass or a baritone or a tenor. Four pitches (F – G – A and B) are considered being characteristic of a baritone or a tenor and tones from c upwards are considered as typical for a tenor voice.

These indications make the choice of voice classification, based on the perception of lowest tones of a male voice alone, very hazardous. That is indeed the case when one would conclude that, of the given population of male subjects, 5% should be basses, less than 2% should either be basses or baritones, 59% could be basses or baritones or tenors, 32% are supposed to be baritones or tenors, and less than 2% should be tenors.

Another approach is to consider the highest pitches a human voice can produce. While vocal fry could be interpreted as being a part of the vocal range, falsetto, however, seems to vastly complicate the attempts to a classification of male voices.

8.4.1.2. Highest tones

Table 15 shows the distribution of the highest tones in male voice production. Sulter et al.[1368] found that male subjects (specially trained) show the largest distribution in frequency values. As frequency level rises, the standard deviation shows an absolute increase in hertz. The relationship with voice categories, however, is not studied. In contrast to the remarks of the same authors, the capacities of the trained subjects in our study, especially baritones and basses, were not limited at high frequencies, just because they had an *extensive falsetto range* at their disposal . It may be that the trained singers in the Sulter et al.[1368] study did not want to sing in the falsetto range, because they were thought not to do so or because they did not like the falsetto sound at all and continued to sing the highest pitches with a covered (head) voice.

According to Ametrano Jackson et al.[1372], falsetto voices are almost always really basses or baritones.

With reference to Table 5 (Synthesis of the limits of voice range / tessitura of the six basic voice types), we can schematise the distribution of highest tones in males by the next table:

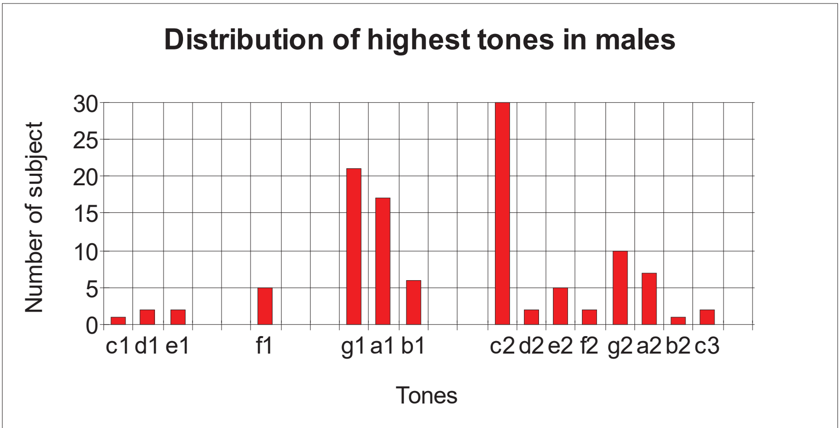


Table 15: Distribution of highest tones in males (N = 113)

The highly appreciated high c^2 (523 Hz), attributed to exceptional operatic tenor voices, happens to be the highest tone most found in male voice production (27%)! In our study, the highest male pitch was c3 (1047 Hz) in two subjects.

Note that the attribution of the highest pitches to the basic male voice types is unevenly distributed:

Bass: a – e1
Bass – baritone: f1
Bass – baritone – tenor: g1 – a1 – b1
Bass – tenor:c2 – d2
Bass: e2 and higher

Table 16: Uneven distribution of highest tones in males.

Five pitches (a – b – c1 – d1 and e1) are considered typical as the highest pitches for a bass voice, while only one pitch (f1) is considered typical for a bass or a baritone, three pitches (g1 – a1 and b1) could indicate a bass or a baritone or a tenor, two pitches (c2 and d2) are taken to be characteristic of a baritone or a tenor and tones from e2 upwards are again considered as typical for a bass voice!

These indications make the choice of voice classification, based on the perception of highest tones of a male voice alone, again very hazardous. That is indeed the case when one considers that, of the given population of our male subjects, 28% (4% + 24%) must be basses, 4% are either basses or baritones, 39% could be basses or baritones or tenors, 28% are supposed to be basses or tenors. This also means that no specific baritones or tenors could be discerned without hesitation, and moreover that in ALL predictions there would be a great chance that the subject is a bass! No one will accept this proposition.

8.4.1.3. Combination of lowest and highest tones

Of course, one could argue that one should consider the total voice range or the tessitura, and not separate extreme tones. However, the combination of the extreme tones of the voice range / tessitura of the *same* male subjects provides the following Table 17:

VOICE CLASSIFICATION based on	VOICE CLASSIFICATION based on		
Lowest tone	***Highest tone***	***N***	***Percentage***
B	B	3	3%
B	B - b	1	less than 1%
B	B - T	1	less than 1%
B	B - b - T	1	less than 1%
B - b	B	2	2%
B - b - T	B	22	19%
B - b - T	B - b	3	3%
B - b - T	B - T	15	13%
B - b - T	B - b - T	27	24%
b - T	B	4	4%
b - T	B - b	1	less than 1%
b - T	B - T	16	14%
b - T	B - b - T	15	13%
T	B	2	2%
	N =	113	

Table 17: Voice classification based on the combination of lowest and highest tones (Voice range / tessitura) of male voice production.

The most striking feature is that out of the 14 different combinations we found, based on the data from Table 5, only 3% of the guesses proved to match that a given voice was a real bass in both conditions (lowest tone and highest tone). In ALL other combinations a bass voice was one of the possible outcomes! Moreover, the most prominent combination of lowest and highest tone (24%) proved to be the possibility that a given voice was a bass, or a baritone, or a tenor in both ways!

8.4.2. Female voices

8.4.2.1 Lowest tones

With reference to Table 6 (Synthesis of the limits of voice range / tessitura of the six basic voice types), we can schematise the distribution of lowest tones in females by the next Table 18:

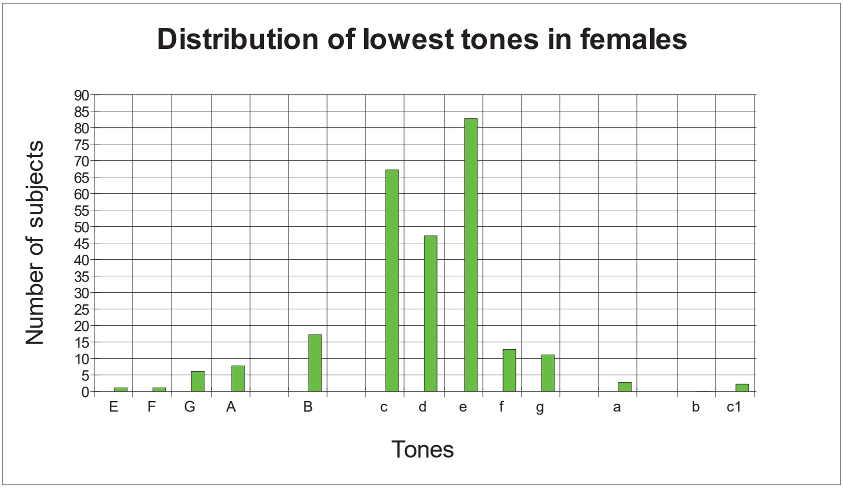


Table 18: Distribution of lowest tones in females (N = 258)

In parallel to the results of the male voice, but one octave higher, e (165 Hz) is the lowest tone most frequently found in female voices (32%). We noted E (82 Hz), F (87 Hz) and G (98 Hz) in our female population, which are extreme low tones, not even mentioned in the literature.

Note also that the attribution of the lowest pitches of the basic female voice types is unevenly distributed:

Contralto: A and lower
Contralto - Mezzo: B
Contralto - Mezzo – Soprano: c – d – e – f - g
Mezzo - Soprano: a
Soprano: b and higher

Table 19: Uneven distribution of lowest tones in females (N = 258)

Only one pitch (A) is considered typical as the lowest pitch for a contralto voice, and only one pitch (B) is considered typical for a contralto or a mezzo, five pitches (c- d - e - f and g) could indicate a contralto or a mezzo or a soprano, one pitch (a) is considered being characteristic of a mezzo and low tones from b on are considered as typical for a soprano voice.

These indications complicate the choice of voice classification, based on the perception of lowest tones of a female voice alone. This is obvious when one considers that, of our population of female subjects 6% must be contraltos, 7% are either contraltos or mezzos, not less than 86% could be contraltos, mezzo, or sopranos, only 1% is supposed to be a mezzo, and less than 1% must be a 'true' soprano. These results also indicate that the classification of female voices, based on the lowest tone alone, is even more difficult than that of the male population.

Another approach is to consider the highest pitches a female voice can produce.

8.4.2.2. Highest tones

Table 20 shows the distribution of the highest tones in female voice production:

With reference to Table 6 (Synthesis of the limits of voice range / tessitura of the six basic voice types) we can schematise the distribution of highest tones in females by the next Table 20:

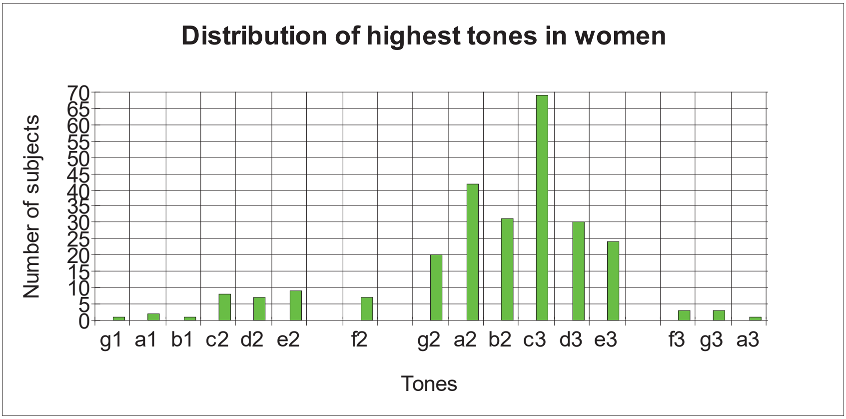


Table 20: Distribution of highest tones in females (N = 258)

Parallel to the results of the male voice, but one octave higher, c3 (1047 Hz), is the highest tone most found in female voices, with the same percentage as in male voices: 27%. The extreme high tones g3 (1568 Hz) and a3 (1760 Hz), noted in our study, are not mentioned in the scientific data.

Miller and Schutte[1373] situate the lower boundary of the "flageolet register" around b2 (988 Hz), if only a minority of *sopranos* have the capacity to employ this register effectively. Our results, however, demonstrate that 62 % of our female subjects could produce pitches between b2 (988 Hz) and a3 (1780 Hz). As we will discover later, these voices proved to be not always sopranos!

Note also that the attribution of the highest pitches of the basic female voice types is unevenly distributed:

Contralto: g1 - a1 - b1 - c2 – d2 – e2
Contralto - Mezzo: f2
Contralto – Mezzo - Soprano: g2 – a2 – b2 – c3 – d3 – e3
Soprano: f3 – g3 – a 3

Table 21: Uneven distribution of highest tones in females.

Not less than six pitches (g1 - a1 - b1 - c2 - d2 and e2) are considered typical as the highest pitches for a contralto voice, while only one pitch (f2) is considered typical for a contralto or a mezzo, not less than six different pitches (g2 - a2 – b2 – c3 – d3 and e3) could indicate a contralto or a mezzo or a soprano. There seem to be no specific pitches that could be attributed to a mezzo or a soprano, while three noted pitches (f3 – g3 and a3) are considered being characteristic of a soprano voice.

These indications make the choice of voice classification, based on the perception of highest tones of a female voice alone, again extremely difficult. That is indeed the case when one considers that, of our given population of female subjects, 11% are supposed to be contraltos, less than 3% are either contraltos or mezzos, almost 85% could be contraltos or mezzos or sopranos and less than 4% are supposed to be real sopranos.

8.4.2.3. Combination of lowest and highest tones

Of course, one could again argue one must consider the voice range, or the tessitura as a whole, and not speculate on separate extreme tones. However, the combination of the extreme tones of the voice range / tessitura of the *same* female subjects provides the following Table 22:

VOICE CLASSIFICATION based on	VOICE CLASSIFICATION based on		
Lowest tone	***Highest tone***	***N***	***Percentage***
C - M - S	C - M - S	196	76%
C - M - S	C	18	7%
C - M - S	C - M	5	Less than 2%
C - M - S	S	5	Less than 2%
C - M	C	3	1%
C - M	C - M - S	12	Less than 5%
C - M	S	1	Less than 1%
C	S	1	Less than 1%
C	C - M - S	5	Less than 2%
C	C	6	2%
C	C - M	1	Less than 1%
S	C - M - S	1	Less than 1%
S	C	1	Less than 1%
M - S	C - M - S	2	Less than 1%
M - S	C - M	1	Less than 1%

Table 22: Voice classification based on the combination of lowest and highest tones (voice range / tessitura) of female voice production. (N = 258)

We found 15 combinations of lowest and highest tones (voice range/ tessitura), pointing to different voice classifications.

Classification of the female voice, based on voice range alone, proved to be even more difficult than the classification of the male voice. Indeed, 76% of the attempts to classify the female voice by considering the combination of the lowest tones and the highest tones, resulted in a possible outcome of one of the three basic female voice categories! Only 7% of the cases resulted in a combination of contralto or mezzo or soprano (lowest tones) and contralto (highest tones), less than 5% of the subjects could be a contralto or a mezzo (lowest tones), but also a contralto or a mezzo or a soprano (highest tones). In only 2% of the cases there could be agreement on the voice type (contralto), based both on the lowest and the highest tone. The rest of the possible outcomes of different combinations remained under 2% for each combination of lowest and highest tones.

8.5. Voice intensity: Results and Discussion

The results of our study of the voice range / tessitura, based on extensive information from the literature, proves that, taking notice of the lowest and/or highest notes of a voice is not sufficient to classify a given voice. In fact, the many open discussions we had with people dealing with the vocal arts, demonstrated the huge difficulties they could experience during auditions of actors and singers, entering conservatories or postulating for a role in a play or concert.

In a *study on expert consensus in solo voice performance evaluation*, Wapnick and Ekholm[1374] stated:" *it is common lore that vocal experts often disagree with each other in their evaluations of vocal performance.*" The authors found *considerable variability in both inter- and intra-judge reliability among the judges*. We fully can confirm this statement, based on our own experiences in the world of theatre and music.

The mere artistic approach of the production of a given tone at a certain time is not satisfactory. As Bunch[1375] declared: "*Classification of voices is made chiefly according to where the quality notes are located in the voice, and where the depth and ease of sound are located in the range.*" Together with the (*subjective) appreciation of the quality of that tone*, ***the intensity of the produced tone is all important. What matters is the potential intensity of the tones allowing the subject to be heard on the scene, time after time, without hurting his vocal instrument***.

We hypothesized that different voice categories can be differentiated by specific differences in intensity measured at the same pitches. It seems logical, for instance, to assume that the lowest tones of the lowest voice categories (which, of course, are very weak), are still produced with more intensity than the same pitches of the other (higher) voice categories. *The intensity measurements of a given tone could provide an easy way for distinguishing voice categories.*

The huge variety of maximum and minimum intensities of the complete vocal range of human sounds has clearly clinical importance. In the literature, however, such data are missing. That's why, in this manual, so much attention is paid to this most important parameter of the voice: *intensity*. We will provide a whole series of data of minimum and maximum intensity for each tone of the vocal range and extensively discuss the results of our research, which ultimately have led to the *elaboration of a pattern card of the human voice*. Male and female results are separately discussed and compared.

8.5.1 Male voices

8.5.1.1. Results of maximum intensity measurements of each tone of the vocal range

The ***global results (for all ages) of the maximum intensity measurements*** are featured in Figure 1. The data demonstrate how the maximum intensity continuously increases as frequency increases.[1376,1377] There is a steep increase of the lowest tones. On specific frequency zones, however, there is a stagnation in maximum intensity increase (A-e, f-g, a-e1, and a1-a2). These frequency zones could correspond to *possible register transitions of all vocal types, one with another*.

All maximum values of the maximum intensity are situated above e (110 dB(A) – 120 dB(A).

Remark the sharp dip on c, on c1 and on d2.

The *minimum values* of the maximum intensity are situated on D, E, d, g, g1 and g2.

For the *average measurements* of maximum intensity, the stagnation zones are restricted to B1-C, b - c1, c2-d2, and e2-f2.

Most *standard deviations* are around 7 dB(A).

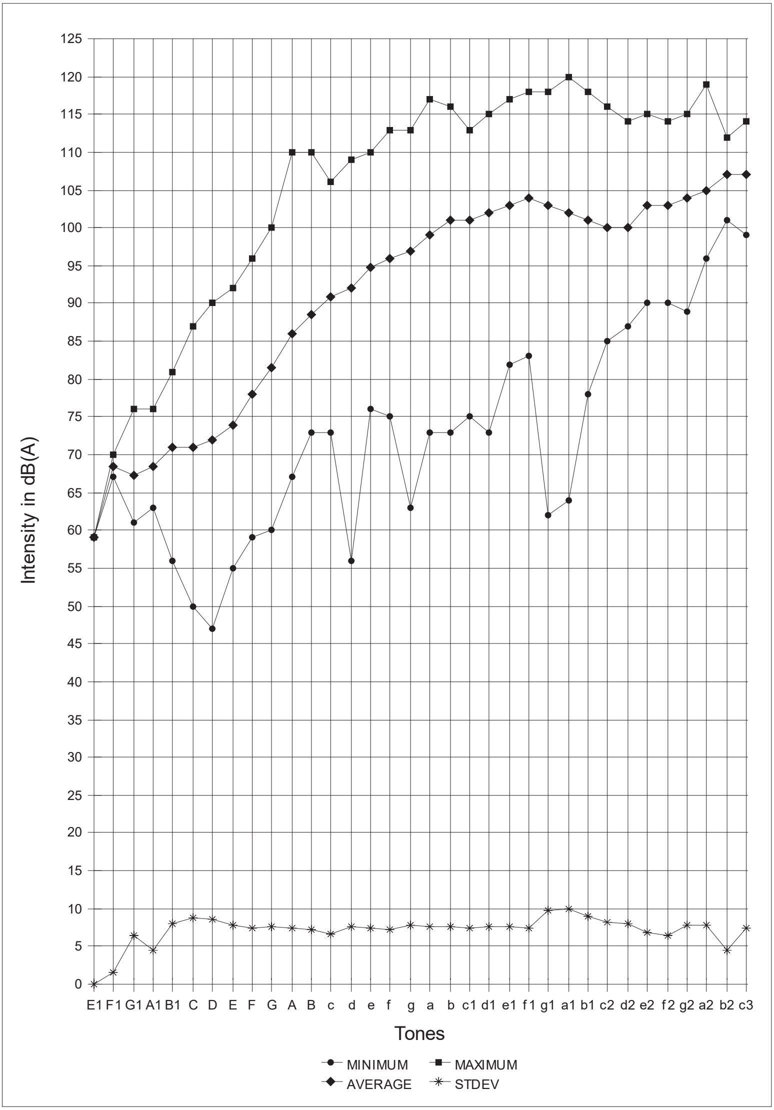


Figure 1: Minimum, maximum, average and standard deviation of maximum intensity measurements of ALL tones in males of ages 10 – 76 years (N = 164).

Interestingly, the ***maximum values of the maximum intensity*** **measurements** of a tone in the total vocal range for different age groups in males are situated on a = 117 dB(A)), a1 = 120 dB(A) and a2 = 119 dB(A)! Both a1 and a2 are situated in the frequency zone of the falsetto register, which was in earlier studies[1378-1385] considered as the weakest voice production area!

While a1 is considered as belonging to the extreme tones a baritone can produce, it is also a tone above the transition from modal to loft register for tenors. Pitches above d2 seem to be hardly producible by tenors and belong to the exceptional high falsetto-range of basses (cfr. Table 6)!

These results are in concordance with the self-reported estimates of their pitch ranges by four semi-professional countertenors (who were all baritones), in a videofiberscopic study on laryngeal and pharyngeal behaviour in countertenor and baritone singing.[1385] Their self-estimated baritone pitch ranges were +/- E (82 Hz) - dis1 (< 330 Hz), while their educated countertenor pitch range extended from f (175 Hz) to gis2 (< 880 Hz)! Unfortunately, Lindestad and Södersten[1385] did not measure the intensities of the pitches but acknowledge that these countertenor voices were neither weak nor breathy but had a rich and sonorous quality.

From B1 to A, there is a quick increase of the maximum intensity measured. From then on, this increase is more irregular throughout the highest pitches. From A on to c3 (the highest male pitch measured), maximum intensity is situated between 110 dB(A) and 120 dB(A)!

According to Sulter et al.[1388], intensities above 80 dB and below 60 dB normally will not be used during speech.

Phonating above 85 dB (A) is called yelling.[1389] Vocal abuses like shouting, screaming, cheering, and excessive, loud laughing, may sometimes reach an intensity level approaching 100 dB.[1390]

One has also to keep in mind that performing on the stage usually necessitates vocal intensities above 90 dB(A).[1391,1392] In our experience, 100 dB(A), and more, is necessary in a lot of stage opera productions.

Interestingly, in a study, using phonetography for assessment of the student teacher's voice, Orr et al.[1393] found mean maximum intensities 102 dB(A), which means that, regarding maximum vocal output, this population (ages between 17 and 44 years) of "normal untrained" subjects closely resembles our own more complex group of "artists" and "artists in spe.” (cfr. the 5 distinct assessments in Chapter 1 on Subject Classification in Voice Research).

In Awan’s study[1394], mean maximum intensities are 79,55 dB in male and female untrained subjects and 93,11 dB in male and female trained subjects. As he accepted only “quality” phonations, measured in the “musical” range, one can wonder if his subjects - even the trained ones - would be able to perform on stage. We thus don’t agree with his view that “under normal conditions, the upper and lower limits of the F° and SPL ranges (physiological limits) would rarely be used in either common or professional vocal situations. Experience on the stage and in voice clinics clearly proves the opposite happens every day!

According to Coleman[1395], “there is little objective research reported in the literature concerning vocal dynamic ranges used in performance”.

Our data have clinical value as they indicate which maximum intensities may be expected from a performer on stage (speaking and singing voice) or elsewhere.

The ***minimum values*** **of the maximum intensity measurements** are very irregular and approach the maximum values at both ends of the vocal range. This procures the well-known *ellipse model* of most phonetograms, as recognized also in the theoretical model of the VRP by Titze.[1386,1387]

The absolute minimum value of the maximum intensity measurement is 47 dB(A) on D. Other exceptional low maximum values are 50 dB(A) on C, 55dB(A) on E, 60dB(A) on G, 56 dB(A)on d, 63 dB(A) on g and 62 dB(A) on g1.

Interestingly, the minimum values of the maximum intensity in the midrange of our subjects correspond to the maximum values in the midrange in patients reported by Schutte and Van Den Berg[1396], i.e., 70 dB (A).

These grosso modo indications based on the global results of the maximum intensity measurements are, of course, *useless for individual voice classification*. They show, however, that the steady increase of the maximum intensity curves with increasing frequency is interrupted at specific frequency zones for all voices. These “weaker zones” correspond to possible register changes in all subjects.

According to Sataloff[1397], “there is little or no significant difference in maximum vocal intensity between a trained and an untrained singer”.

However, the often-huge differences between the maximum and minimum measurements of maximum intensity (up to 56 dB(A) on g1!), found in *different* subjects, as shown in Figure 1, clearly indicate the great *variability* in maximum produced intensity at certain frequencies, which could already give a hint to *voice classification*. (cfr. also, our comments on the results of dynamic range measurements, further on).

Scientific articles on the ***life- span changes in the human voice*** are rare and mostly limited to the speaking voice.

Lycke[1398] wrote a Master Thesis in Gerontology, comparing different voice parameters of *the same 54 adult choir members* (35 males and 19 females, aged 18-65 years), *spread over a period of 27 years*. The available data of other 55 scientific references we found at that time were compared to our own results. A *big intra-individual and inter-individual variability* could be demonstrated.

Harvey[1399] reports on broad age categories (ages 21 – 55), based on the supposed relative stability of the voice in a normal, healthy person over the four decades from approximately age 20 to 60. She acknowledges, however, that, although not perceptually or acoustically apparent, some of the age-related changes may begin in our 30s. Hence, she divides the professional voice users into two life stages: young adulthood from ages 21 to about 35 and mature adulthood from ages 35 to 55 years of age. Singers tend to reach their greatest ability in their 30s and maintain this plateau of performance for years.

In our study, we arbitrarily divided our population into 4 age-groups, based on some aspects of age-related voice development:

- in the age-group under 18 years, we have to do not only with children, but also with adolescents with puberty characteristics. As Ackermann[1400,1401] states, this is a difficult age group and voice research in the age group 14 - 15 years often poses a problem.
- in the age-group 18-29 years, we encountered mostly students and young performers, with or without specific voice training.
- from age 30 to 49 years on, we suppose the voice has matured in one way or another.
- above 50 years, age-related features can be expected.

Dividing the global results in age-related results shows some important differences between the ages (see Figures 2-5).

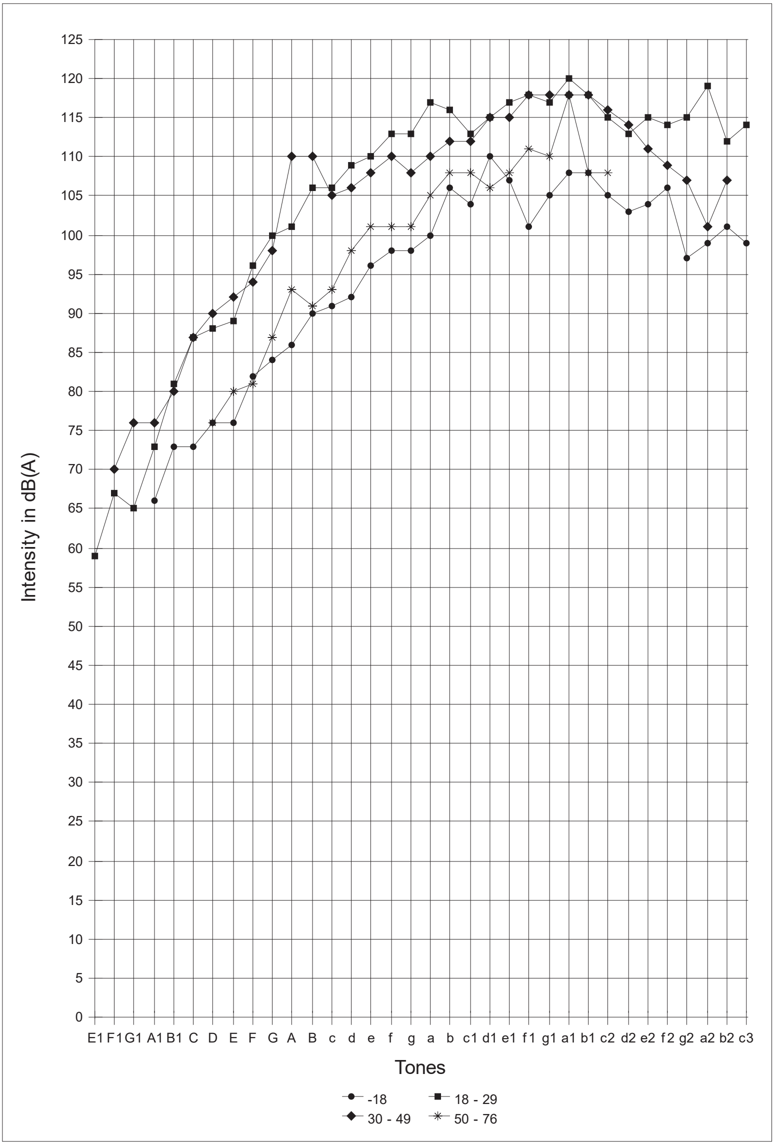


Fig. 2: Comparison of **maximum values of maximum intensity** curves for different age groups in males (N = 164).

In the age-group under 18 years the exceptional extreme low tones E1, F1 and G1 are missing, but all extreme high pitches (c2 to c3) are present. In the age-group 50-76 years, not only extreme low tones like E1, F1, G1, A1, B1 and C are missing, but also all pitches above c2. So, elderly people show the smallest vocal range, adults between 18-29 years have the greatest vocal range. These findings are consistent with previous research, proving a reduction of the phonational ranges for both professional singers and untrained speakers as a function of aging.[1402] Frank[1403] mentions that there exist no data, expressed in half tones, on the exact reduction of the vocal range as a function of age.

Considering *maximum intensity measurements* (Figure 2) obvious differences between age-groups are present: children and adolescents (under 18 years) feature the lowest curves, followed by the subjects between 50 and 76 years; then come the subjects between 18-29 years and 30-49 years with varying results, but slightly parallel curves, except for the lowest pitches (greater maximum intensity for the 30-49 years old) and the highest pitches (greater maximum intensity for the group of 18-29 years old).

Hodge et al.[1404] studied vocal intensity characteristics in two groups of healthy speakers. In the elderly group (68-85 years), sound pressure level was noted to be smaller than in the young adult male group (25-35 years).

Mc Allister et al.[1405] found that the upper contour of the VRPs of 10-year-old children was lower than that of adults. They concluded that this may reflect a restricted ability of the vocalis muscle to resist the high subglottal pressure to vibrate. The voices of mutational boys, however, showed an upper contour approximating that of adults.

We noted that 100 dB(A) and more is only attained at the pitch a for the – 18 years old, already one octave lower (G-A) for the adult groups, and only from e on for the older people (50-76 years). These age-related data clearly have clinical importance.

Pedersen et al.[1406] provide 4 “typical” phonetograms of a boy at the age of 9-11-14 and 18 years, which are different from the phonetograms we provide of boys in the age group 10-17 years.

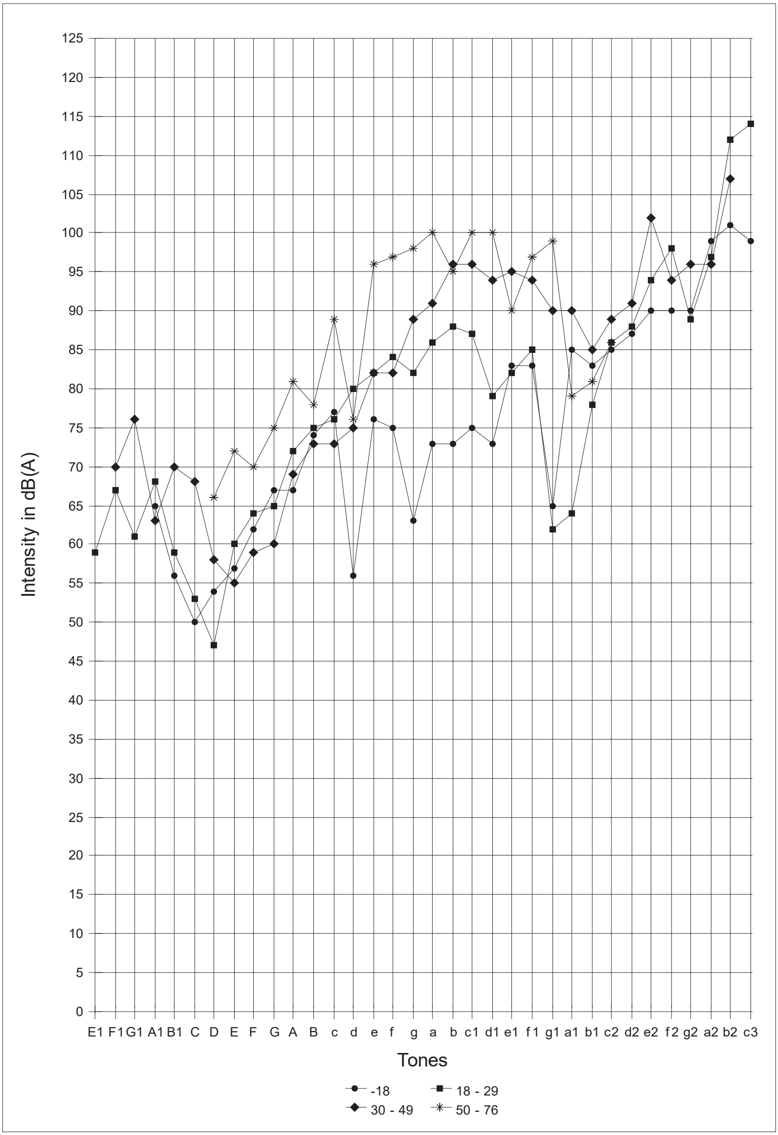


Fig. 3: Comparison of **minimum values of maximum intensity** curves for different age groups in males (N = 164).

The *minimum values* of the maximum intensity measurements (Figure 3) show quite other curves: despite a restricted voice range, the older subjects (50-76 years) show the highest curve (with exception of a few tones), while the other age groups show parallel curves, with exception of the tones above c, where the best results are obtained by the 30-49 years old, followed by the 18-29 years group. The age group under 18 years scores particularly low in the zone d-d1.

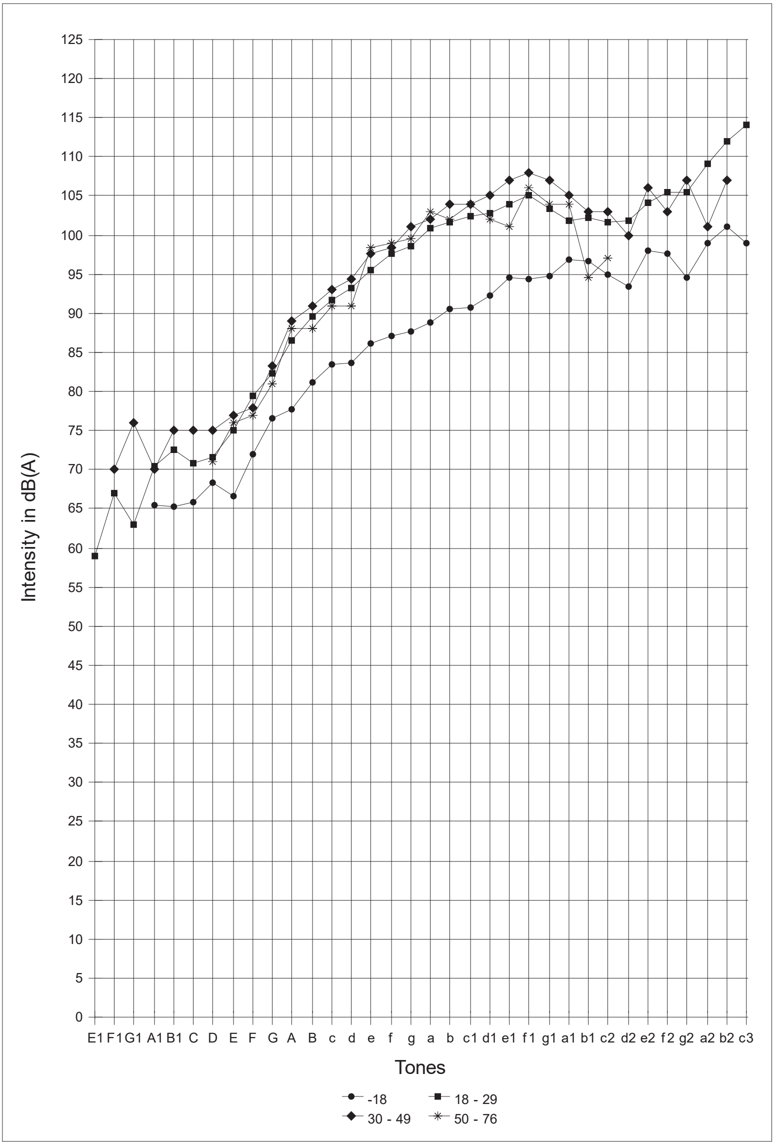


Figure 4: Comparison of **average values of maximum intensity** curves for different age groups in males (N = 164).

The lowest results for the *average values* of the maximum intensity measurements (Figure 4), again, belong to the youngest age group, while the curves of the three other age group approach.

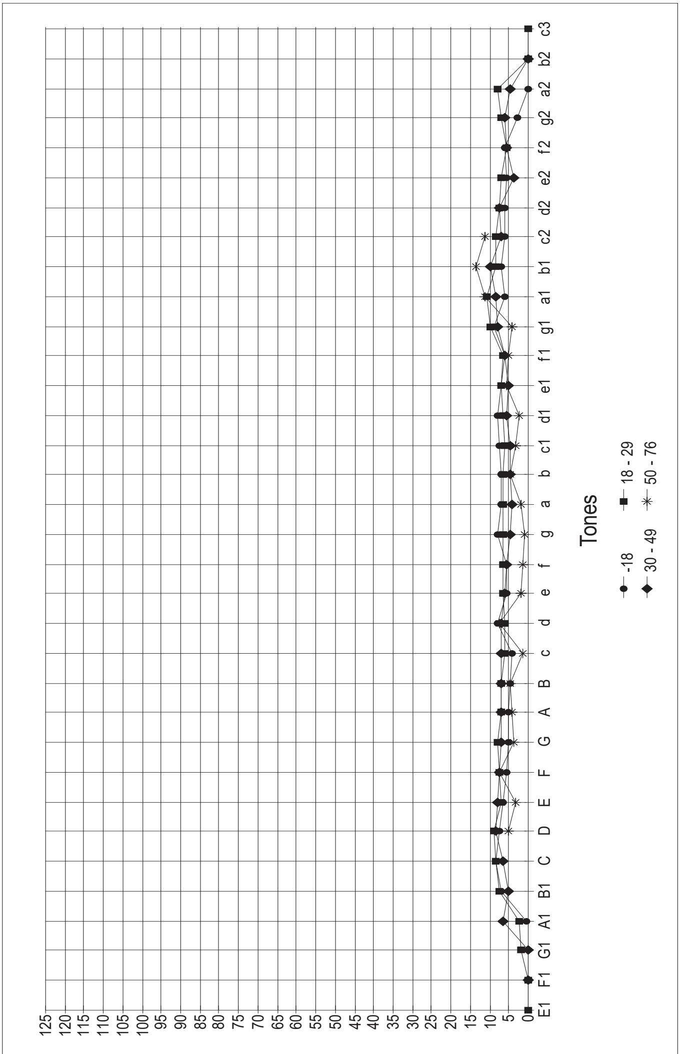


Figure 5: Comparison of **standard deviation values of maximum intensity** curves for different age groups in males (N = 164).

Most *standard deviations* (Figure 5) are situated between 6 dB(A) and 8 dB(A), conform the results of Sulter et al.[1407]

Strangely enough, few data on maximum, minimum, average, and standard deviation of maximum intensity measurements of each tone of the vocal range can be found in the literature.

Colton[1408] measured only three identical frequency levels in the modal and falsetto registers. The average magnitude of vocal intensity in the modal register ranged from 66 to 104 dB SPL. In the falsetto register, the average magnitude of vocal intensity ranged from 66 to 89 dB SPL. At the maximum intensity conditions, the falsetto register phonations were as much as 20 dB less than modal register phonations.

Denk and Frank[1409] mention only ranges of maximum intensity, going from 85 to 110 dB.

Sulter et al.[1410] concluded that male subjects were able to phonate more softly than female subjects, whereas female subjects could phonate louder at distinct low and high relative frequency ranges.

Kötter and Klingholz[1411] report maximum intensities for males and females between 119,7 and 123,2 dB, with averages between 100,4 and 100,8 dB.

In a phonetographic study for assessment of the student teacher’s voice, Orr et al.[1412] found a mean maximum intensity of 102 dB(A) for males and about 98 dB (A) for females.

In many phonetographic measurements only four pitches per octave are measured, or 11 averaged measuring points (Coleman method), which cannot be compared with other results.

To have clinical applicability, however, researchers and clinicians need to know the specific variations of the maximum intensity measurements for each tone of the entire vocal range they (normally) can expect.

Focusing exclusively on the speaking voice, Sihvo et al.[1413], however, think that the measurement of five target pitches “within the average speaking range” is more important than the tracking of the patients’ whole frequency range.

We don’t agree with this viewpoint, based on the argument of a less time-consuming procedure! We think a lot of indications are missed if only a few frequencies are measured. For instance, studies on the frequency and effects of teachers' voice problems revealed that over a third of the teaching population has difficulties with high note singing and difficulty speaking in low tones.[1414-1417] Moreover, *the need to speak louder and higher over the background classroom noise or in a large space is evident*.

Another study on the effects of a vocally fatiguing task on Phonation Threshold Pressure (i.e., the minimum tracheal pressure required to initiate vocal fold oscillation), showed that the PTPs markedly elevated at 80% of the pitch range (register change?)[1418].

We agree with Titze[1419,1420] that "*a better understanding of the VRP will be helpful in guiding strategies for diagnosis and treatment of voice disorders*."

We are convinced that voice training should also benefit from a better understanding of the acoustic interactions between F° and I. That's why the next Figures 6- 9 provide an *overview per octave for each age group of male voices*, which can be used in clinical practice as a *pattern card of the human voice*. The performance of a subject of a given age can thus be situated at the maximum, average or minimum level.

This diagnostic procedure also opens perspectives about *what results can be obtained, tone by tone, by voice education or voice therapy.*

The *differentiation in four octave zones* enables the clinician to compare the results of his own maximum intensity measurements with ours: *all four octave zones provide information on the singing voice, while octave zone C – c and c – c1 also give information on the speech area, and zone c1 – c2 will also reflect frequencies often used in shouting*. (Figures 6-7-8, and 9).

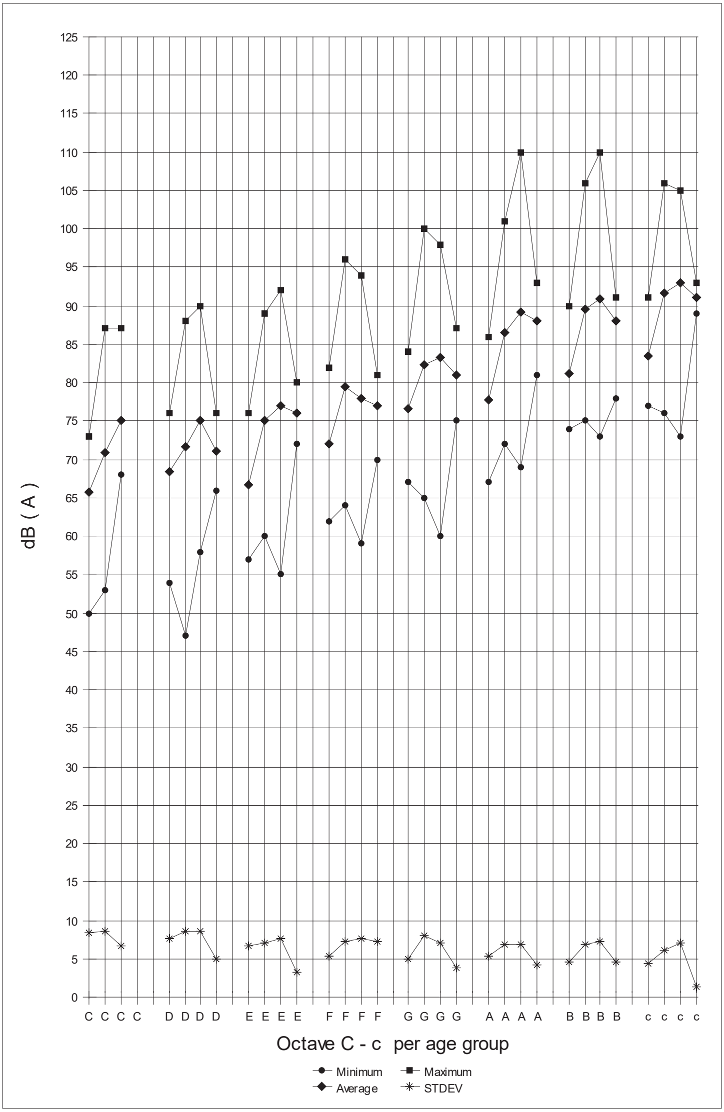


Figure 6: Results of variations of maximum intensity measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in the **male voice range C – c** (N = 164)

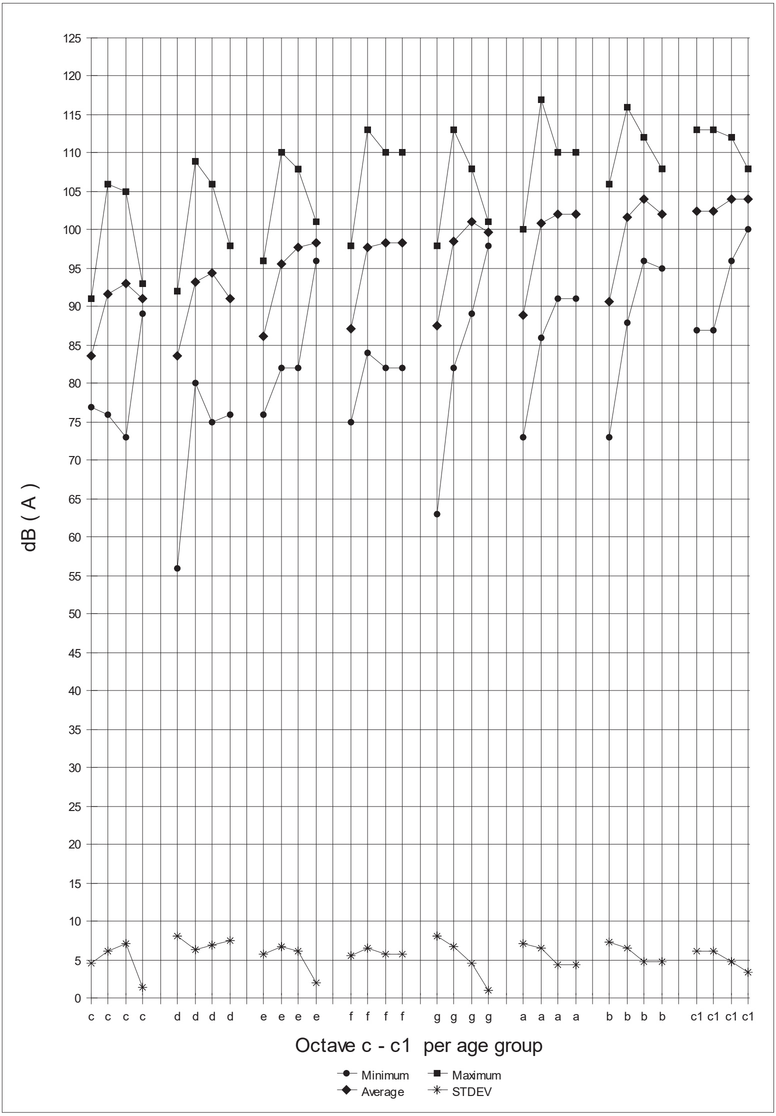


Figure 7: Results of variations of maximum intensity measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in the **male voice range c – c1** (N = 164).

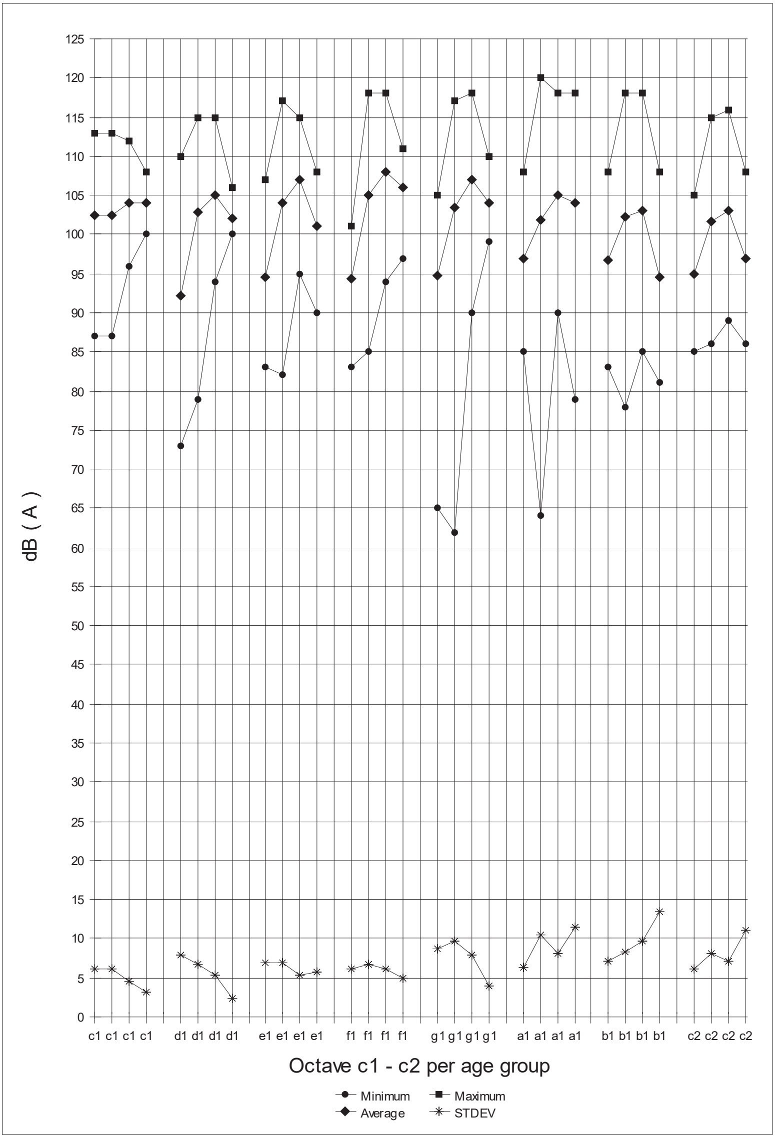


Figure 8: Results of variations of maximum intensity measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in the **male voice range c1 – c2** (N = 164).

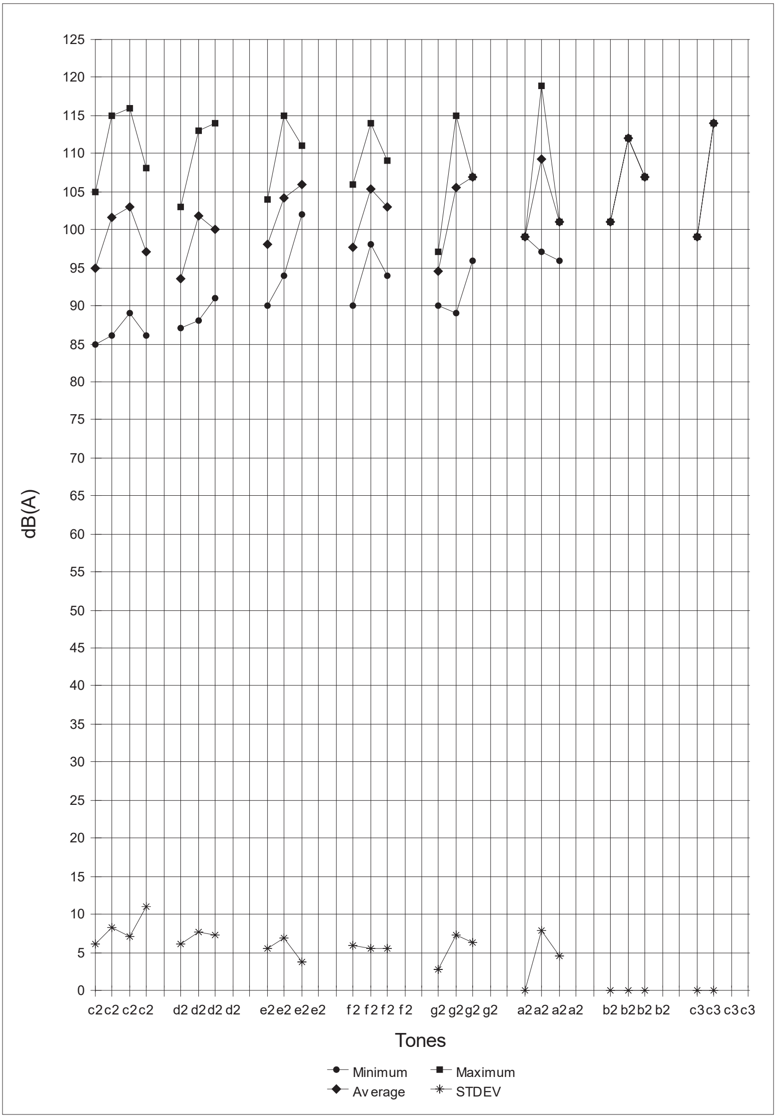


Figure 9: Results of variations of maximum intensity measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in **the male voice range c2 – c3** (N = 164).

To prove the importance of the intensity measurements for each tone with respect to *voice classification*, it is obligatory to analyse ALL pitches and *to examine if differences in intensity measurements are related to voice categories.*

Based on Table 6, the lowest tones E1, F1, G1 and A1 must correspond to a bass voice, whatever their minimum intensity might be.

From B1 upward to B, however, it could be revealing to analyse the minimum intensities of the lowest tones, as these tones could also belong to a higher voice category. To illustrate this, let us look at the *ascending pitches and the corresponding variations in **maximum** intensity in the lower part of the vocal range of our subjects in every age category. (Table 23):*

C	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	50,00	73,00	65,80	8,47	57,33 - 74,27
18 - 29 years	53,00	87,00	70,80	8,57	62,23 - 79,37
30 - 49 years	68,00	87,00	75,00	6,70	68,30 - 81,70
50 - 76 years					

D	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	54,00	76,00	68,40	7,63	60,77 - 76,03
18 - 29 years	47,00	88,00	71,60	8,63	62,97 - 80,23
30 - 49 years	58,00	90,00	75,00	8,60	66,40 - 83,60
50 - 76 years	66,00	76,00	71,00	5,00	66,00 - 76,00

E	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	57,00	76,00	66,70	6,61	60,09 - 73,31
18 - 29 years	60,00	89,00	75,10	6,97	68,13 - 82,07
30 - 49 years	55,00	92,00	77,00	7,70	69,30 - 84,70
50 - 76 years	72,00	80,00	76,00	3,30	72,70 - 79,30

F	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	62,00	82,00	72,00	5,41	66,59 - 77,41
18 - 29 years	64,00	96,00	79,40	7,23	72,17 - 86,63
30 - 49 years	59,00	94,00	78,00	7,60	70,40 - 85,60
50 - 76 years	70,00	81,00	77,00	7,30	69,70 - 84,30

G	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	67,00	84,00	76,60	4,99	71,61 - 81,59
18 - 29 years	65,00	100,00	82,30	8,08	74,22 - 90,38
30 - 49 years	60,00	98,00	83,20	7,08	76,12 - 90,28
50 - 76 years	75,00	87,00	81,00	3,90	77,10 - 84,90

A	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	67,00	86,00	77,70	5,36	72,34 - 83,06
18 - 29 years	72,00	101,00	86,60	6,94	79,66 - 93,54
30 - 49 years	69,00	110,00	89,10	6,78	82,32 - 95,88
50 - 76 years	81,00	93,00	88,00	4,20	83,80 - 92,20

B	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	74,00	90,00	81,10	4,66	76,44 - 85,76
18 - 29 years	75,00	106,00	89,50	6,93	82,57 - 96,43
30 - 49 years	73,00	110,00	90,90	7,15	83,75 - 98,05
50 - 76 years	78,00	91,00	88,00	4,50	83,50 - 92,50

Table 23: Variations in minimum intensity measurements and differentiating ranges (= average maximum intensity +/- the standard deviations), based on the results provided in Figures 6-7-8, and 9).

As Titze[1419,1420] noted, fortissimo production is difficult at very low pitches. The relationship with *voice classification*, however, has never been explored. In our opinion, the combination of Table 14 with Table 23 should provide indications for specific voice categories: maximum intensities below the lowest value of the differentiating range belong to a higher voice category; maximum intensities above the highest value of the differentiating range belong to a lower voice category. For instance, for the tone E:

E	Differentiating range	Bass	Tenor
< 18 years	60,09 - 73,31	> 73,31	< 60,09
18 - 29 years	68,13 - 82,07	> 82,07	< 68,13
30 - 49 years	69,30 - 84,70	> 84,70	< 69,30
50 - 76 years	72,70 - 79,30	> 79,30	< 72,70

Table 24: example of interpretation of the differentiating range between the values of maximum intensities in dB(A), specific for basses and tenors (tone E).

The data provided for *each* tone, combined with the differentiating range, allow a *gradual survey of how the maximum intensities of a given voice evolve within a specific voice category.*

The proposed method is to be interpreted as just another step in the step-to-step methodology of voice classification by phonetography.

We consider this method less suitable for the highest pitches of the male voice, because of the complications of interpreting the falsetto register.

8.5.1.2. Results of minimum intensity measurements of each tone of the vocal range

In his acoustic study of the VRP, Titze [1419,1420] predicted that the bottom curve of the VRP should rise faster than the top curve, if soft phonation produces a more sinusoidal glottal waveform than loud phonation.

An analysis of the global results (for all ages) of the minimum intensity measurements (Figure 10) of our male subjects demonstrates how the minimum intensity increases as frequency increases.

Just like the maximum intensity, the minimum intensity also increases with ascending pitches.

The *maximum values of minimum intensity* show a plateau form of 83 dB(A) on g-a-b and c1 for all ages and show a steep increase in maximum intensity from c1 on, with distinct dips on f1 and d2. At both ends of the voice range maximum and minimum intensities approach or are equal, producing the well-known egg-form of common phonetograms.

The *maximum values of the minimum intensity* measurements of a tone in the total vocal range (Figure 10)) are situated on the falsetto tones g2 = 115 dB(A) and a2 = 119 dB(A), which should be attributed to bass voices! (Table 6).

The increase of the *minimum and average values of the minimum intensity* is rather regular, in contrast to the maximum values of the minimum intensity.

Interesting to note is the plateau form of the average intensities in the zone C (65 Hz) to c (131 Hz): between 56,4 –57,7 dB(A). From d (147 Hz) on, however, there is a steep increase of the average minimum intensities from 60,1 dB(A) to 100 dB(A) on c3 (1047 Hz).

Most *standard deviations* are situated between 4,81 dB(A) and 9,68 dB(A) in the broad vocal range between G1 (49 Hz) and d2 (587 Hz), conform the results of Sulter et al.[1421]. In the “speaking zone”, the standard deviations are situated around 5 dB(A).

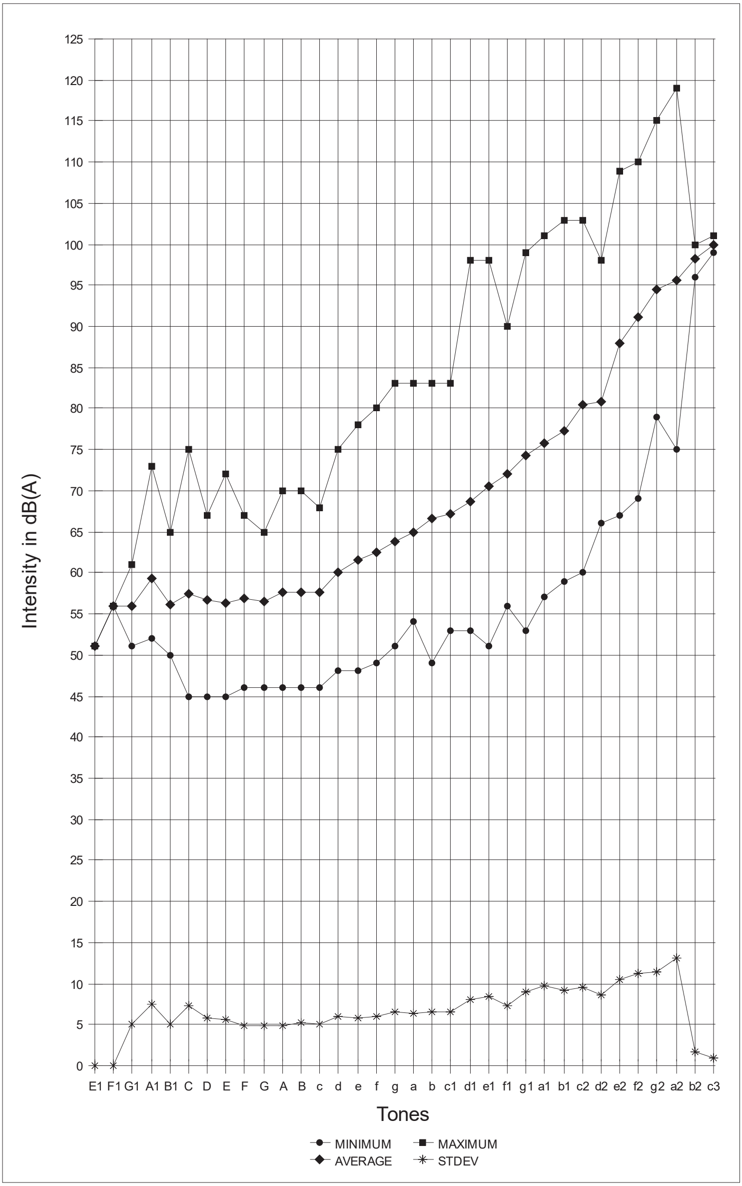


Figure 10: Minimum, maximum, average and standard deviation of minimum intensity measurements of ALL tones in males of ages 10 – 52 years (N = 68).

From a clinical viewpoint, the *minimum values of the minimum intensity* measurements are very relevant, because they tell us how soft a voice can be produced on a given pitch, which is an important diagnostic parameter for voice disorders. Phonation threshold pressure (PTP), the minimum subglottal pressure required to initiate phonation, is used[1422].

Behrman et al.[1422] reported that minimum intensity levels below 60 dB(A), especially in the lower frequencies, are considered as criteria for normal VRPs.

The average minimum intensities in the lower vocal range of all our subjects are below 60 dB(A). Moreover, In the same range, the minimum intensities of our subjects vary between an absolute minimum of 45 dB(A) and an absolute maximum of 48 dB(A).

Especially the highest pitches are difficult to produce. Kitch et al.[1423] found high soft notes to be particularly sensitive to performance effects.

Our findings are in concordance with the conclusions of Wuyts et al[1424], providing an explanation for the importance of these variables in a more pathological context.

Pianissimo voice productions can be discerned from *mezza voce* productions, which also include a certain expressive voice quality. Low SPLs are known to be typically associated with reduced overall tension in the muscular body of the vocal folds[1425].

According to Pabon[1426], the irregularity of the lower contour of the phonetogram is typical, caused by the inconstancy of the vibration of the vocal folds. He cautions against interpretations of the total surface of the phonetogram, while *the lower contour of the phonetogram can be strongly influenced by training*.

A lot of explicit examples of the *considerable influence of voice training* will be provided in Chapter 9, featuring a selection of our longitudinal case studies.

Interestingly, for all age-groups, the curves of the maximum, minimum, average, and standard deviation values of the minimum intensity (Figures 11 to 14) are very similar.

In a phonetographic study for assessment of the student teacher's voice, Orr et al.[1429] found a mean minimum intensity of 42, 43 –45,43 dB(A) for males and 44,76 – 47,42 dB (A) for females.

Clinically important is the finding that the best minimum values in our study - between 45 dB(A) and 54 dB(A) - are, for all ages, situated in the frequency zone C – e1. These frequencies are typically situated in the (broad) area of the speaking voice.

By consulting these data, voice clinicians can easily situate the *voice controlling capacities* of their patients. In voice education and in voice therapy, these data may also provide a *guideline to what may be expected by appropriate lessons or therapy with respect to voice control.* Moreover, the gradual improvement of a given subject can be followed by regular measurements of maximum and minimum intensities of specific frequencies (cfr. Chapter 9).

Stone et al.[1430] tested only the minimum intensities of voice. They stressed the diagnostic and therapeutic implications of this method, despite the large intra- and inter- subject differences they found.

A sharply increasing piano curve is considered by Airainer and Klingholz[1431] as the most conspicuous feature in the phonetogram of a hyperfunctional voice disorder.

Only few studies mention data on maximum, minimum, average and standard deviation of minimum intensity measurements of each tone of the vocal range. With respect to voice classification, ALL pitches must be analysed. Starting with the lowest pitches in every age category, we can hypothesize that the lowest voice category (basses) can produce the lowest pitches with lower minimum intensities, than do higher voice categories on the same pitches. Baritones and tenors thus must make a bigger effort to produce the same lowest tones as the basses, this resulting not only in a lower maximum intensity, but also in a higher minimum intensity measurement for that specific tone.

The next Figures 11-12-13 and 14 give an *overview per octave* for each age group of our male subjects, which can be used in clinical practice as a *pattern card of the human voice*. The performance of a subject of a given age can thus be situated at the maximum, average or minimum level, in comparison with our Figures. Here too, the clinician can compare the results of his own minimum intensity measurements with ours. All four octave zones give useful information on the singing voice, while octave zones C – c and c – c1 also give information on the speech area, and octave zone c1 – c2 will also reflect frequencies commonly used in shouting.

With exception for the highest frequencies, the age-group 18-29 years obtains the best results for the minimum values, which means that *adult subjects have a better control over the vocal instrument*. These findings are in concordance with the findings of McAllister et al.[1427], who concluded that the vocal fold structure of the children demands relatively high subglottal pressure to vibrate. Frank[1428] stated that *piano singing becomes more and more difficult in aging voices.*

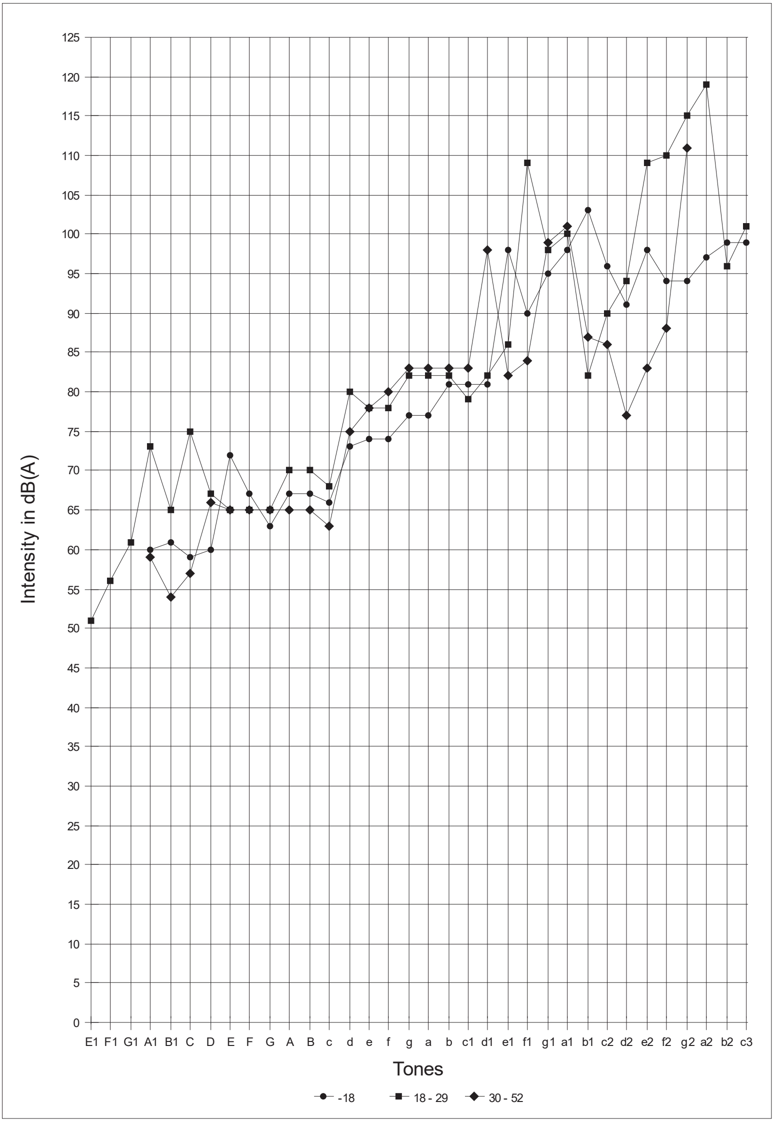


Figure 11: Comparison of maximum values of minimum intensity curves for different age groups in males (N = 68).

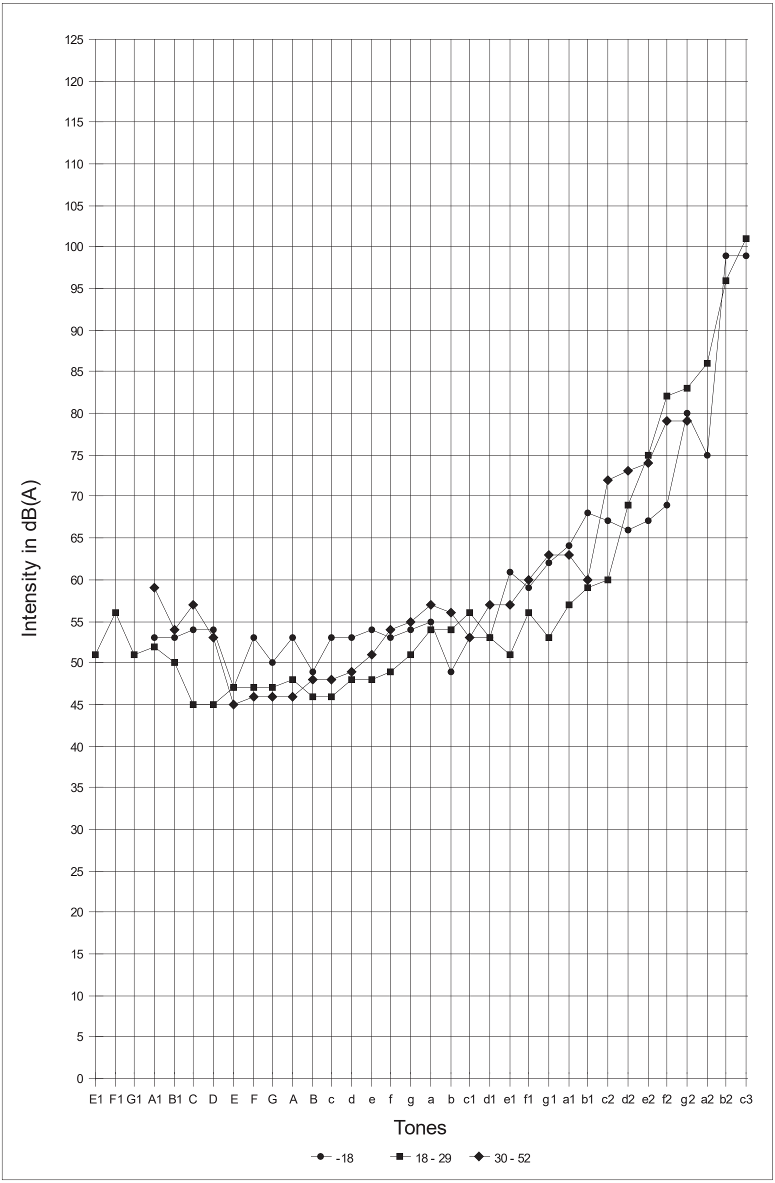


Figure 12: Comparison of minimum values of minimum intensity curves for different age groups in males (N = 68).

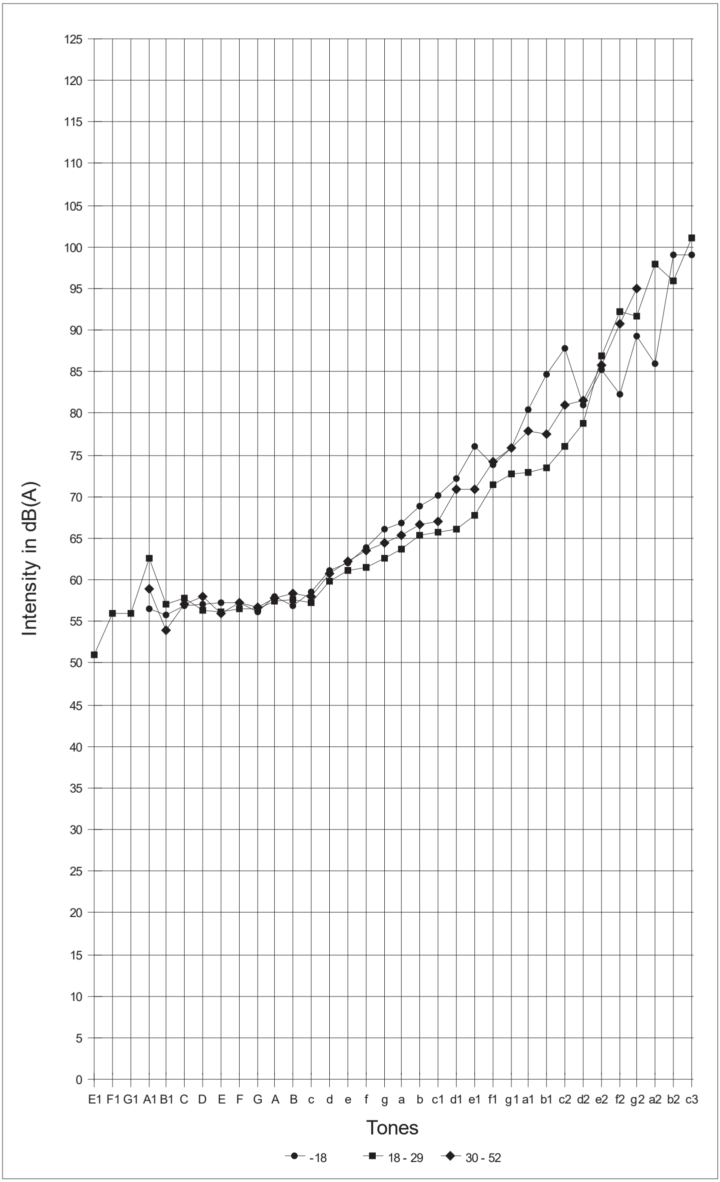


Figure 13: Comparison of average values of minimum intensity curves for different age groups in males (N = 68).

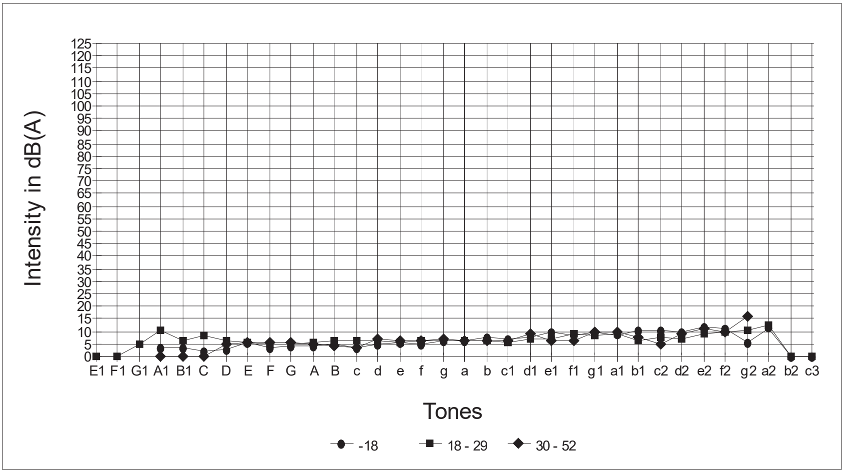


Figure 14: Comparison of STDEV values of minimum intensity curves for different age groups in males (N = 68).

Here too, voice training should benefit from a better understanding of the acoustic interactions between frequency and minimum intensity.

The *differentiation in four octave zones* enables the clinician to compare the results of his own minimum intensity measurements with ours: *all four octave zones provide information on the singing voice, while octave zone C – c and c – c1 also give information on the speech area, and zone c1 – c2 will also reflect frequencies often used in shouting*. (Figures 15-16 -17, and 18).

To prove the importance of the minimum intensity measurements for each tone with respect to *voice classification*, it is obligatory to analyse ALL pitches and *to examine if differences in intensity measurements are related to voice categories.*

Based on Table 6, the lowest tones E1, F1, G1 and A1 must correspond to a bass voice, whatever their minimum intensity might be.

From B1 upward to B, however, it could be revealing to analyse the minimum intensities of the lowest tones, as these tones could also belong to a higher voice category. To illustrate this, let us look at the *ascending pitches and the corresponding variations in **minimum** intensity in the lower part of the vocal range of our subjects in every age category. (Table 25):*

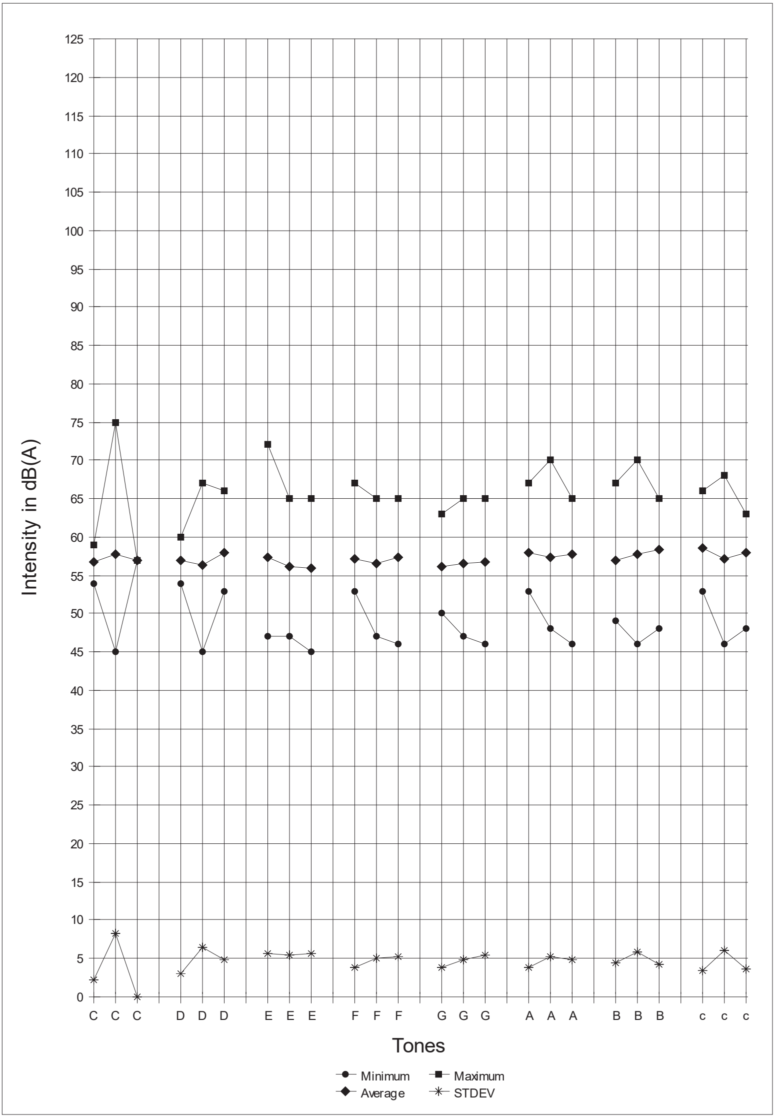


Figure 15: Results of variations of minimum intensity measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in the male voice range C – c (N = 68).

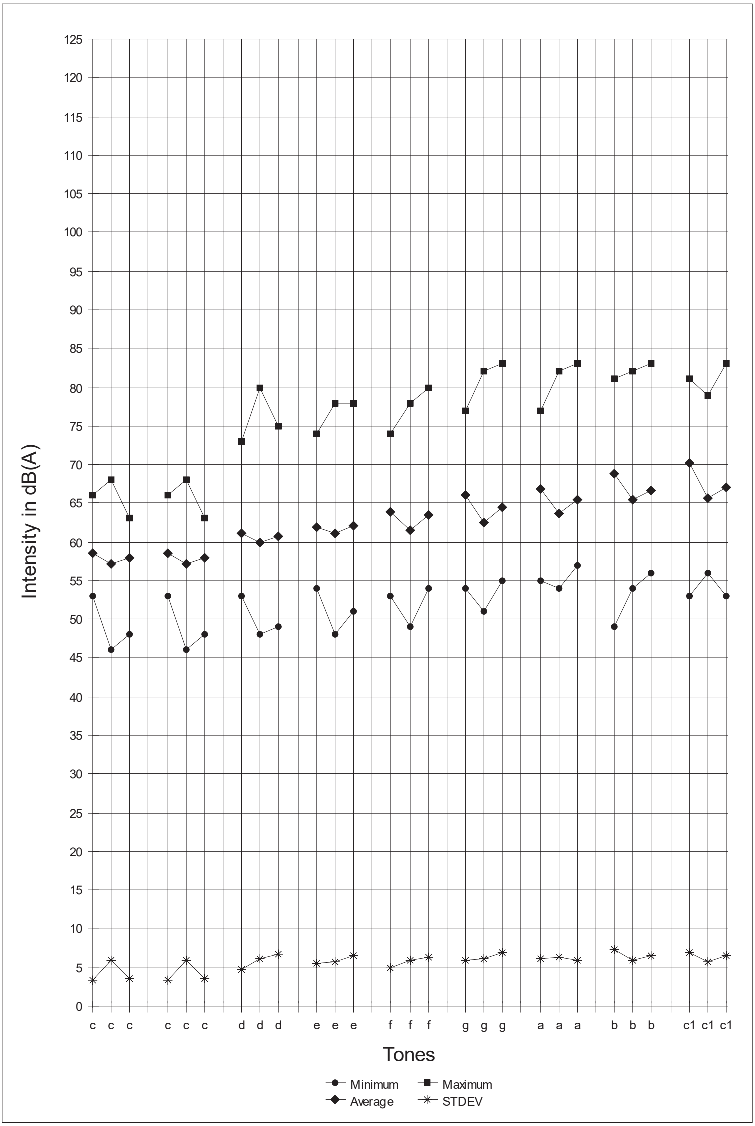


Figure 16: Results of variations of minimum intensity measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in the male voice range c – c1 (N = 68).

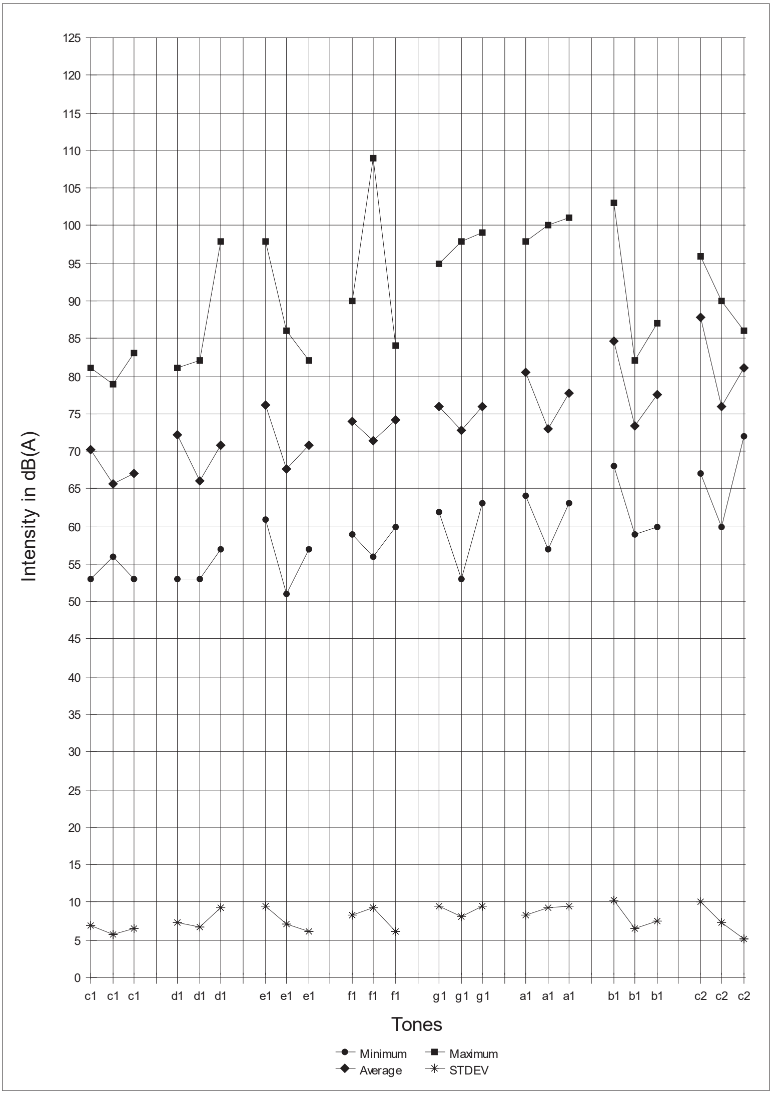


Figure 17: Results of variations of minimum intensity measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in the male voice range c1 – c2 (N = 68).

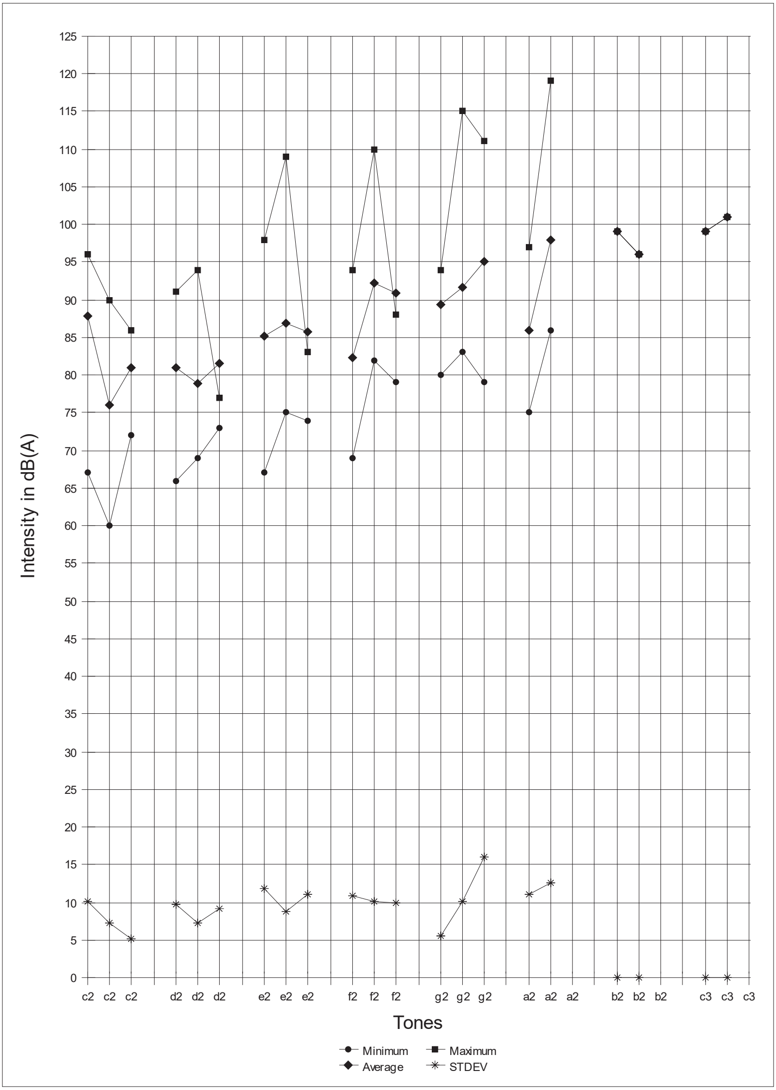


Figure 18: Results of variations of minimum intensity measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in the male voice range c2 – c3 (N = 68).

Let us look now at the *ascending pitches and the corresponding variations in minimum intensity in the lower part of the vocal range of our subjects in every age category*. (Table 25):

As an example, taking notice again of Table 6, indicating the limits of voice range / tessitura of the basic voice categories, we can assume that the lowest tones E1, F1, G1 and A1 must correspond to a bass voice, whatever their minimum intensity might be. It is worthwhile, however, to scrutinize the results of the variations of the **minimum** intensity measurements of our subjects within the range B1 – B, because these pitches could also belong to another voice category:

B1	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	53	61	55,7	3,77	51,93 – 59,47
18 - 29 years	50	65	57,0	6,03	50,97 – 63,03
30 - 52 years	54	54	54,0	0,00	54,0 – 54,0

C	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	54	59	56,8	2,27	54,53 – 59,07
18 - 29 years	45	75	57,8	8,37	49,43 – 66,17
30 - 52 years	57	57	57,0	0,00	57,0 – 57,0

D	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	45	67	56,3	6,39	49,91 – 62,69
18 - 29 years	53	66	58,0	4,83	53,17 – 62,83
30 - 52 years	54	60	57,0	3,00	54,00 – 60,00

E	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	47	72	57,3	5,67	51,63 – 62,97
18 - 29 years	47	65	56,2	5,38	50,82 – 61,58
30 - 52 years	45	65	55,9	5,57	50,33 – 61,47

F	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	53	67	57,2	3,74	53,46 – 60,94
18 - 29 years	47	65	56,6	5,04	51,56 – 61,64
30 - 52 years	46	65	57,3	5,30	52,0 – 62,6

G	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	50	63	56,1	3,90	52,2 – 60,0
18 - 29 years	47	65	56,5	4,92	51,58 – 61,42
30 - 52 years	46	65	56,7	5,44	51,26 – 62,14

A	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	53	67	57,9	3,84	54,06 – 61,74
18 - 29 years	48	70	57,4	5,26	52,14 – 62,66
30 - 52 years	46	65	57,8	4,81	52,99 – 62,61

B	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	49	67	56,9	4,53	52,37 – 61,43
18 - 29 years	46	70	57,7	5,93	51,77 – 63,63
30 - 52 years	48	65	58,3	4,21	54,09 – 62,51

Table 25: Variations in minimum intensity measurements and differentiating ranges (= average minimum intensity +/- the standard deviations), based on the results provided in Figures 15, 16, 17, and 18).

In our opinion, the combination of Table 16 with Table 25 should provide indications for specific voice categories: maximum intensities below the lowest value of the differentiating range belong to a lower voice category; maximum intensities above the highest value of the differentiating range belong to a lower voice category. For instance, for the tone E:

E	Differentiating range	Bass	Tenor
< 18 years	51,63 – 62,97	< 51,63	> 62,97
18 - 29 years	50,82 – 61,58	< 50,82	> 61,58
30 - 52 years	50,33 – 61,47	< 50,33	> 61,47

Table 26: example for differentiating between the values of minimum intensities in dB(A), specific for basses and tenors (tone E).

The data provided for each tone in Table 25, combined with the differentiating range, allow a gradual survey of how the minimum intensities of a given voice evolve within a specific voice category.

Again, the proposed method is to be interpreted as just one step in the step-to-step methodology of voice classification by phonetography.

Titze[1419,1420] stated that pianissimo production in singing can be problematic at high pitches. With respect to the highest pitches of the male voice (including the falsetto tones), the results of the minimum intensities can be very revealing.

At this stage some researchers could be tempted to construct a *standard F°-SPL profile,* derived from the results of the average maximum and minimum intensity measurements of all tones for every age group. So, we too constructed some standard phonetograms (Figures 19-22), based on our own results of male voices (Figures 15 to 18).

Let's have a look now at these constructed averaged phonetograms, just to compare them with a few attempts made by other authors.

In general, the age group 18-29 years shows comparable results with those of the 30-52 years age group. The age group under 18 years performs much less well than the two other age groups. Boys under 18 years miss the necessary vocal capacities (100 dB(A) and more) to safely perform in big stage productions.

In general, the average minimum curves are very similar, but the difference in minimum intensities grows with increasing pitches especially in children.

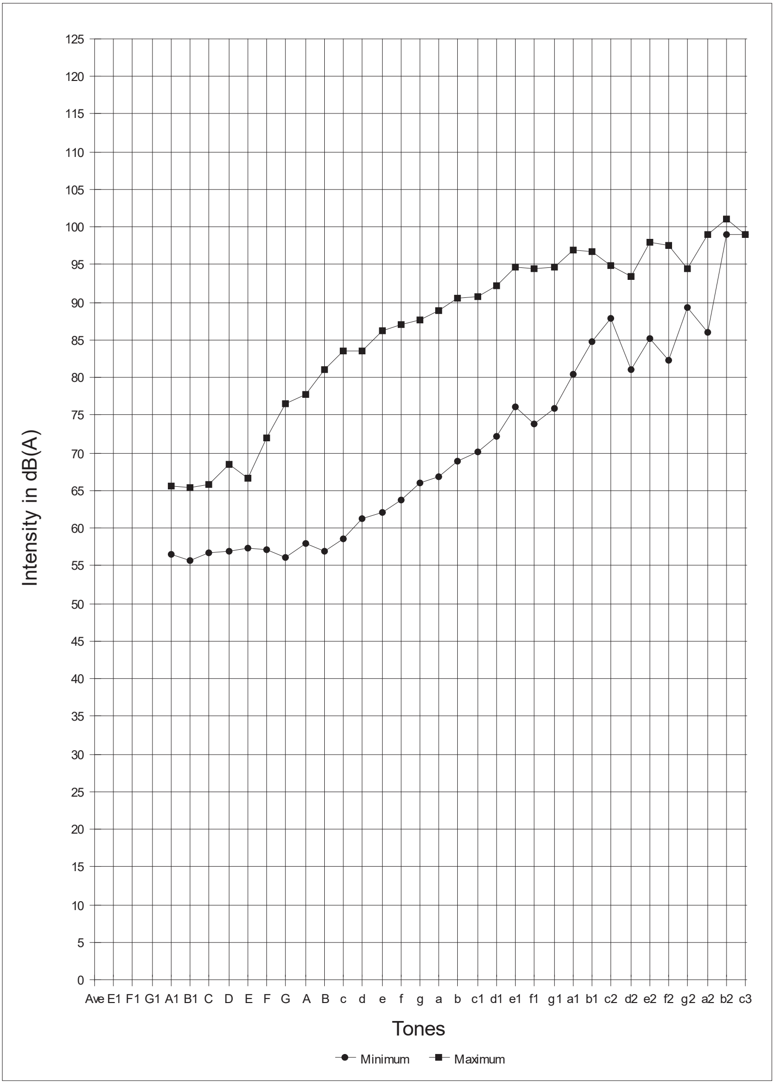


Figure 19: Standard Phonetogram for males aged under 18 years.

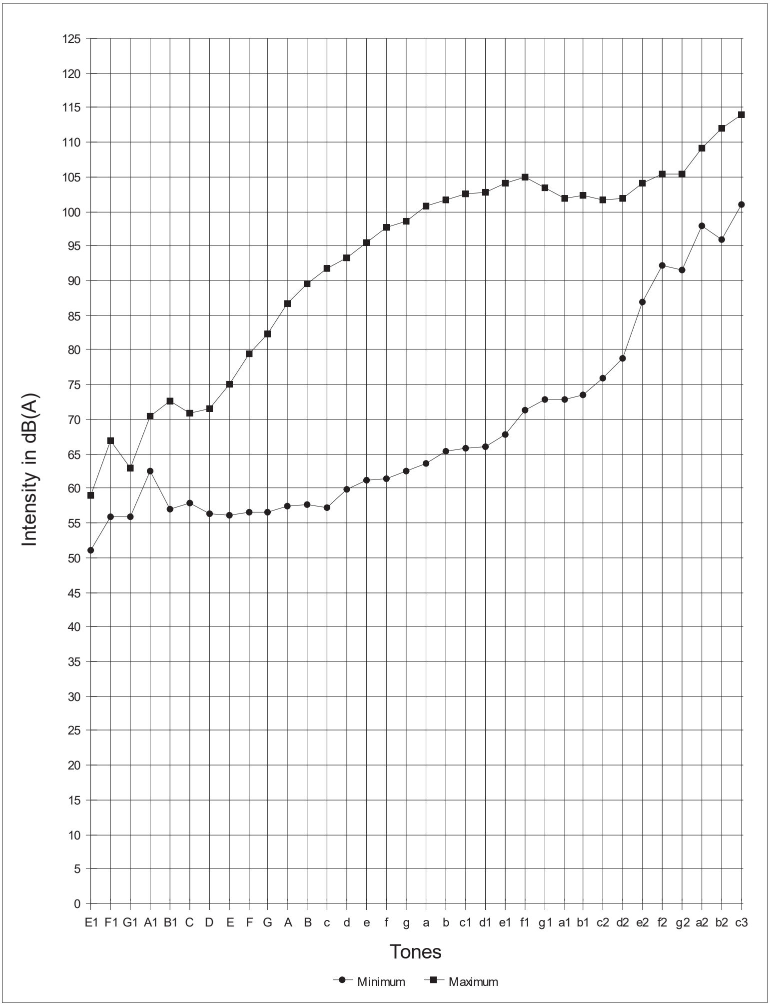


Figure 20: Standard Phonetogram for males aged 18 – 29 years.

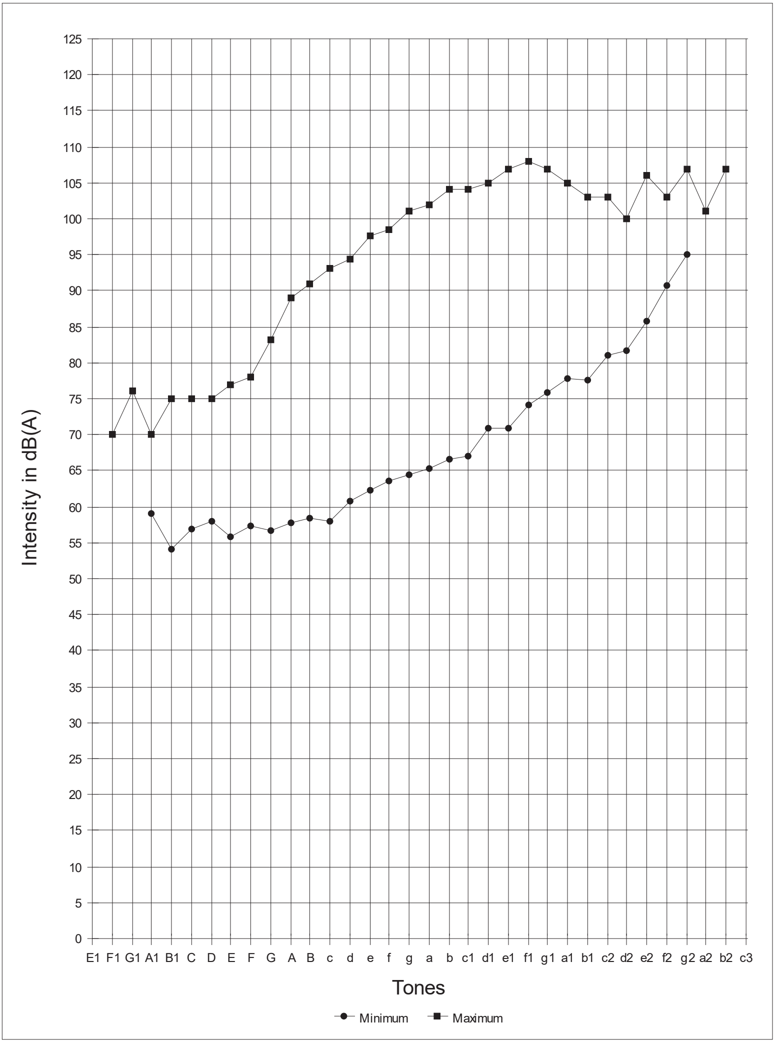


Figure 21: Standard Phonetogram for males aged 30- 52 years.

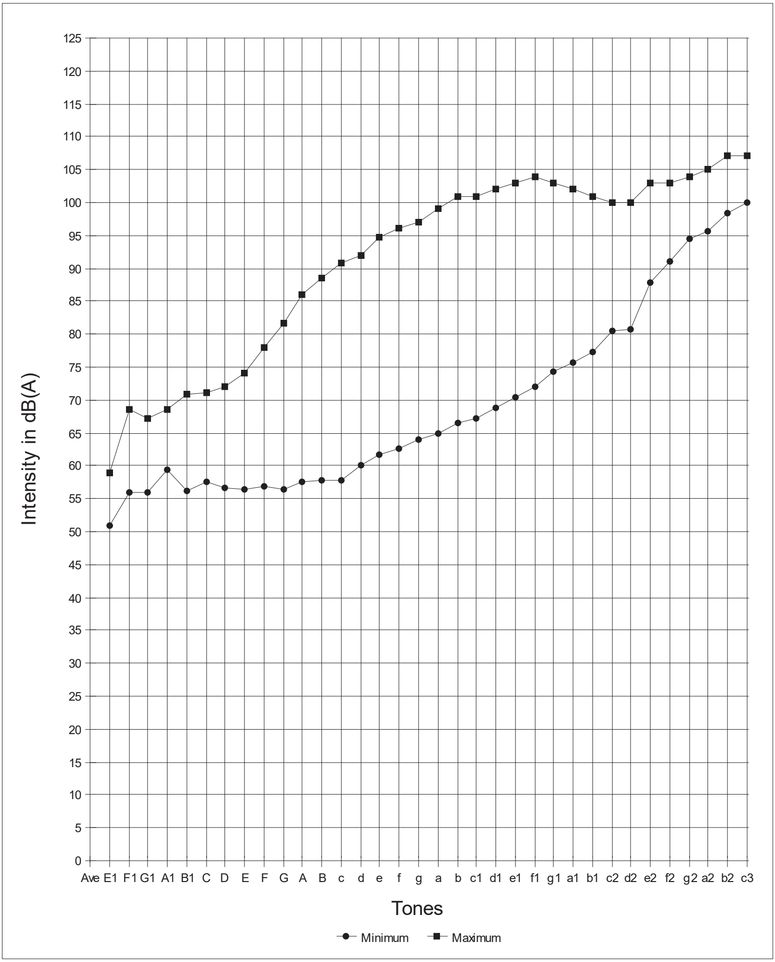


Figure 22: Standard Phonetogram for males (all ages included).

We tried to compare the "Standard Phonetogram" for males aged 30-52 years with the "Normstimmfeld for male voices" featured by Schultz-Coulon[1371] by superposing both average curves for maximum and minimum intensity.(Figure 23)

The differences are striking, even when considering that Schultz-Coulon only measured 11 frequencies (4 per octave) which do not match which those measured by this author (halve tones versus tones). Moreover, Schultz-Coulon don't mention the age group, nor the aspect of training of the subjects. In our study, however, at least five more frequencies are measured at both sides of the voice range. The average minimum curves measured by Schultz-Coulon are +/- 10dB (A) lower than those measured by this author, while the average maximum curves by Schultz-Coulon are also +/- 10 dB(A) lower than those measured by this author.

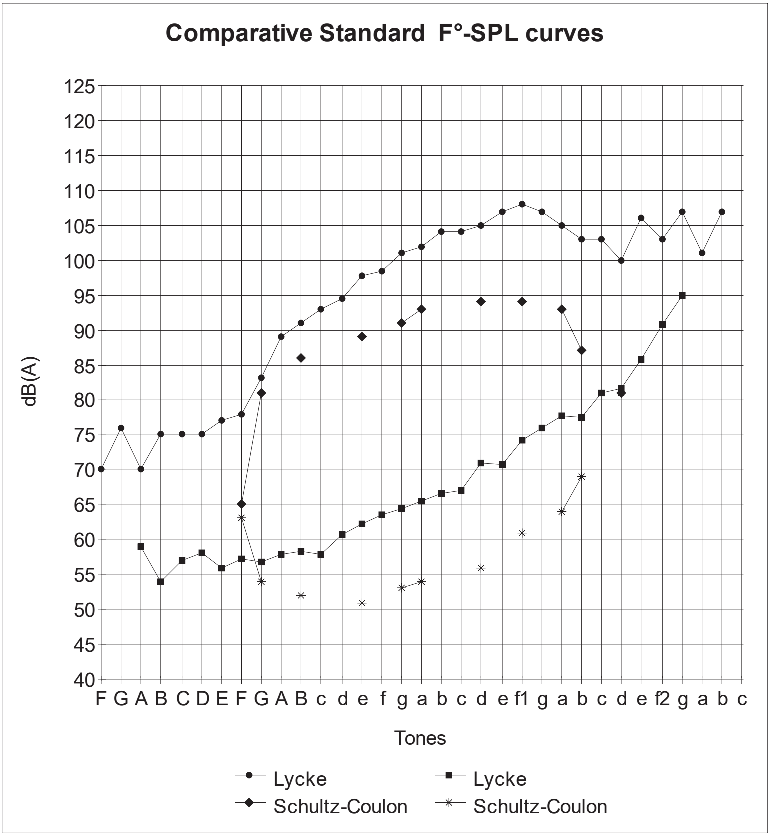


Figure 23: Comparative female Standard F°-SPL curves.

We also tried to compare the extreme values of maximum and minimum intensities and the maximum dynamic range for male voices, found in the literature[1333], with our own extreme measurements, only to confirm that those data too are very divergent:

	Klingholz		Lycke	
Parameter	min.	max.	min.	max.
SPL min. dB(A)	38	66	45	119
SPL max. dB(A)	94	126	47	120
DYN max. dB(A)	30	62	8	59

Table 27: Comparative data intensity measurements of male voices.

The same remarks can be made when comparing the results of children's voices:

	Klingholz		Lycke	
Parameter	min.	max.	min.	max.
SPL min. dB(A)	53	64	47	103
SPL max. dB(A)	92	117	50	110
DYN max. dB(A)	28	56	2	46

Table 28: Comparative data intensity measurements of children's voices.

The results of Schultz-Coulon and Assche[1371], based on phonetographic measurements of 25 vocally healthy students of both sexes (ages 20-25 years), and averaged according to the method of Coleman et al.[1295], are more in concordance with our own results of 95 young *male* subjects (ages 18 – 29 years), except for the absolute maximum intensity:

Parameter	S.-C. and A.	Lycke
SPL min. dB(A) absolute	45,00	45,00
SPL min. dB(A) average	50,00	67,33
SPL max. dB(A) absolute	107,00	120,00
SPL max. dB(A) average	96,50	92,42
DYN max. dB(A) absolute	59,00	59,00
DYN max. dB(A) average	46,50	37,91

Table 29: Comparative data intensity measurements of healthy student's voices.

Sulter et al.[1388] still provide other mean maximal dynamic ranges: 39.1 dB for female untrained subjects, 42.8 dB for male untrained subjects. Our results, however, are presented for all ages (-18 – 52 years). If compared to the age groups of the Sulter et al. study, however, the differences are less striking: 36,5 dB in our age group 18 – 29 years, and 36,4 dB in our age group 30-52 years.

In their discussion on the differences of their results with those of other authors, Frank and Sparber[397], Coleman et al[1295] and Colton and Hollien[1061] refer to *differences in subject categories*. As a result, *"Standard Phonetograms" are difficult to serve the purpose for what they are intended for.*

According to Wirth[1054], the physiological dynamic range amounts to 50-55 dB. The intensity of conventional speech is 70- 80 dB, with a dynamic range of 27 dB for adults; unqualified voices and children have a dynamic range of 5 – 12 dB. The minimum intensity at which a phonation is still possible would be around 50 dB, the maximum intensity around 126 dB.

According to Schultz-Coulon[1145,] the "Normstimmfeld" cannot inform where the upper of lower contour borders must be situated of an individual voice. The Standard Voice Profile, however, can give an indication about which vocal range can be expected for a healthy voice, how soft and how loud a healthy voice can grow and give information on the mean dynamics of the voice.

CONCLUSION: anno 1988, Schultz-Coulon and Asche wrote that, at that time, strangely enough, nobody had tried to define a "Standard Voice Field", because *it seemed absurd, at first sight, to try to press voices with different ranges and inherent variable upper and lower voice limits, into one common voice field.*

This precise remark could explain the strongly varying "Standard Voice Profiles" made ever since (cfr. the given examples).

In our opinion, whoever wants to construct Standard Voice Profiles, first has to consider the important aspect of voice classification, which takes into account the different voice ranges and other specific measurable features, belonging to each voice category. This means that **Standard Voice Fields should be made for every voice category and that voice analyses should be made within the voice category of each subject.** However, this is not the purpose of our study, as we feel that many more subjects are necessary to realize this most important scientific objective.

8.5.1.3. Results of the differences between the maximum and minimum intensity measurements of each tone of the vocal range (dynamic range)

An analysis of the global results (for all ages) of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range (dynamic range) (Figure 24), demonstrates that this clinically important parameter features a Gauss curve. We can see a very steep increase of the maximum value from the lowest pitches to f (175 Hz). The *maximum dynamic range* is 59 dB(A) at e1 (330 Hz). There is a large, irregular plateau (from A to a1): this is the zone best suited for *extreme voice dynamics*: between 49 dB(A) and 59 dB(A) for exceptional voices.

As known from so many phonetograms, the maximum and minimum values of intensity approach at the highest and lowest pitches. In some cases, frequencies can only be phonated at maximum intensity! This is an important observation for clinical practice.

The *minimum values of the differences between the maximum and the minimum intensity* measurements are, as expected, very irregular and vary between 0 dB(A) and 11 dB(A).

The *average dynamic range* features a Gauss curve, like the maximum dynamic range, but at a much lower level: the plateau, situated between B (123 Hz) and f1 (349 Hz) is characterized by intensity fluctuations around 30 dB(A), with a maximum of 32,5 dB(A) on a (220 Hz). At the highest frequencies (from g1 on), the average dynamic range fluctuates between 7 dB(A) and 27 dB(A).

Colton[1408] , measuring only three identical frequency levels, found an average difference of 26 dB between the most intense modal register phonation and an average difference of 13 – 18 dB for falsetto phonations.

Denk and Frank[1409] found maximal dynamic ranges between 30 and 36 dB for untrained voices and between 39 and 59 dB for trained voices, while Eichel[1444] reported an average physiologic dynamic range of 50 dB.

Coleman[1445] found large differences in total dynamic range (18 to 37 dB), with an average of 25,7 dB, among his subjects (10 male and 10 female singers of different categories and with varying levels of training) and pointed to the resulting problem, especially for amateur choral groups.

Sulter et al.[1446] reported 42,8 dB for untrained male subjects.

Kötter and Klingholz[1447] report maximum dynamic ranges for males and females between 50,1 and 52,1 dB, with averages between 38,4 and 39,6 dB.

Orr et al.[1448] found mean maximum dynamic ranges of 40.35 and 45.44 dB(A) in normal adult subjects.

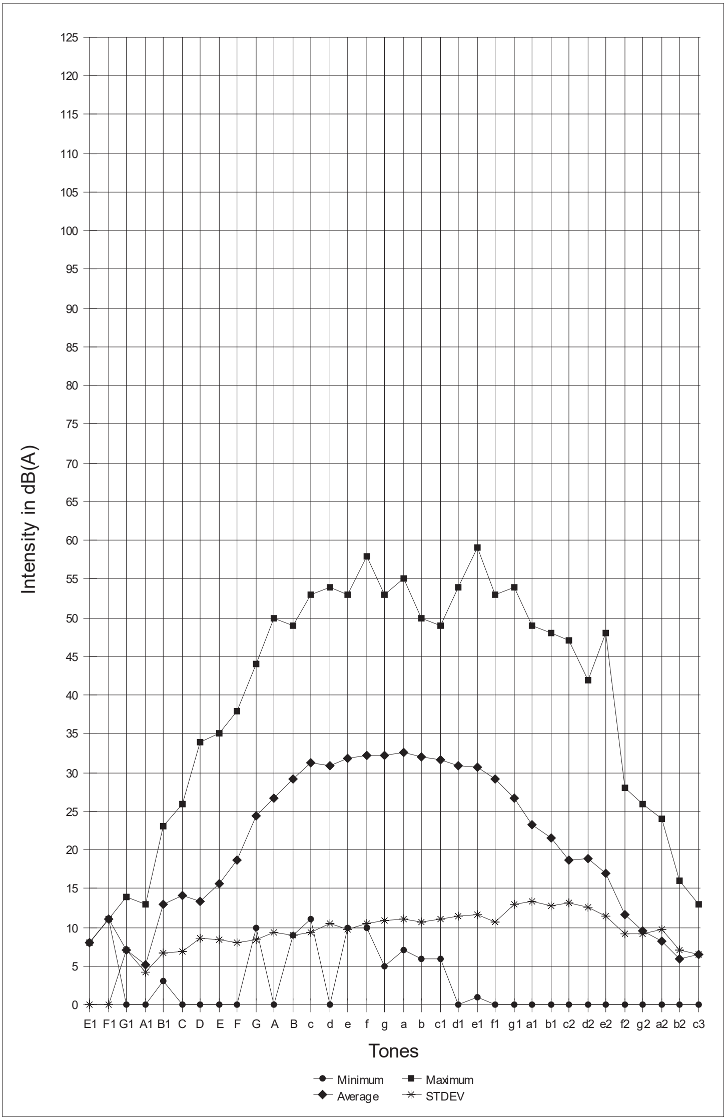


Figure 24: Minimum, maximum, average and standard deviation of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range (dynamic range) in males of ages 10 – 52 years (N = 68).

Dividing the global results in age-related results (Figures 25,26,27, and 28, shows some differences between the ages. As can be expected, the lowest values of the maximum values of the dynamic range are found with the – 18 years old subjects, indicating less dynamic vocal capacities (Figure 25).

The curve of the *maximum dynamic range* is irregular; the best results are obtained in the mid-range zone. The maximum value of the dynamic range is 46 dB(A) for the less than 18 years old boys and 59 dB(A) for the 18-29 years old male adults. The maximum dynamic range is 49 dB (A) for the 30-52 years old male subjects.

Mc Allister et al.[1449] found a maximum dynamic range of 26 dB(A) in a group of 10 years old children. They concluded that, as compared with adults, children in general seem to have somewhat compressed dynamic VRP contours, reflecting restricted dynamic vocal capabilities. The voices of mutational boys, however, showed an upper contour approximating that of adults.

The *minimum dynamic range* (Figure 26) varies between 0 and 16 dB(A) for the – 18 years old boys and the 18-29 years old adults, and between 0 and 27 dB(A) for the 30-52 years old men.

The curve of the *average dynamic range* (Figure 27*)* is similar for the adult male voices (18-52 years old), with a maximum of 36,5 dB(A). In this plateau zone between B and f1, the average dynamic range is between 30,9 and 36,5 dB(A) for both adult groups, while that of the –18 years old group fluctuates between 19 and 24,9 dB(A).

In a phonetographic study for assessment of the student teacher's voice, Orr et al.[1448] found a mean maximum dynamic range of 40,35 – 45,44 dB(A), while we found an average maximum dynamic range of 37,97 dB(A) for 18-29 years old male adults.

The *standard deviations (*Figure 28*)* vary considerably but, on the average, fluctuate around 8 dB(A).

These great differences in dynamic range have clinical importance as they clearly demonstrate the extremes of vocal capacities in different age groups.

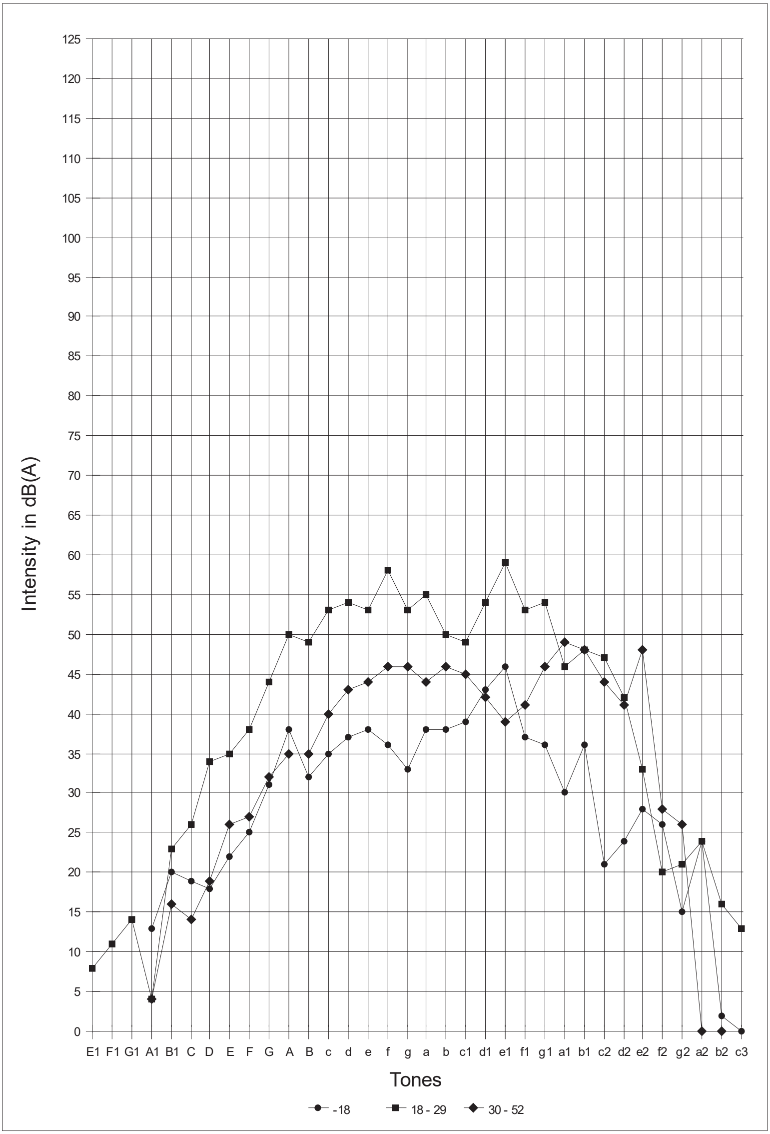


Figure 25: Comparison of maximum values of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range. (dynamic range) for different age-groups in males (N = 68).

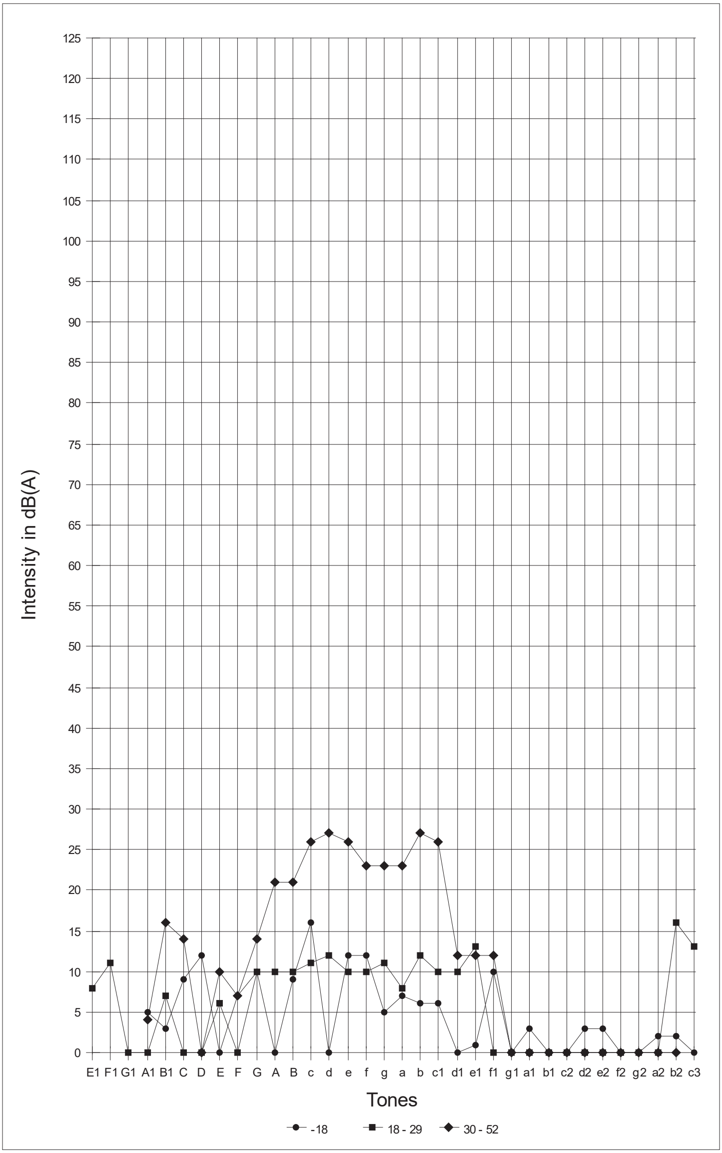


Figure 26: Comparison of minimum values of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range. (dynamic range) for different age-groups in males in males (N = 68).

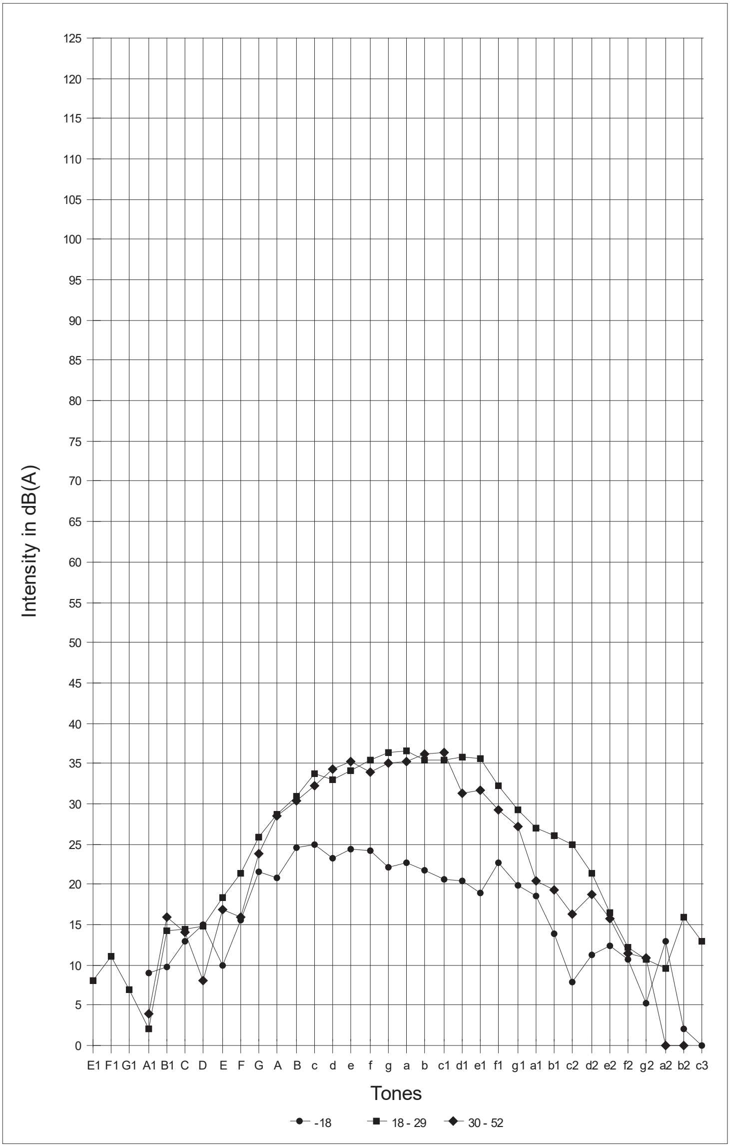


Figure 27: Comparison of average values of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range. (dynamic range) for different age-groups in males (N = 68).

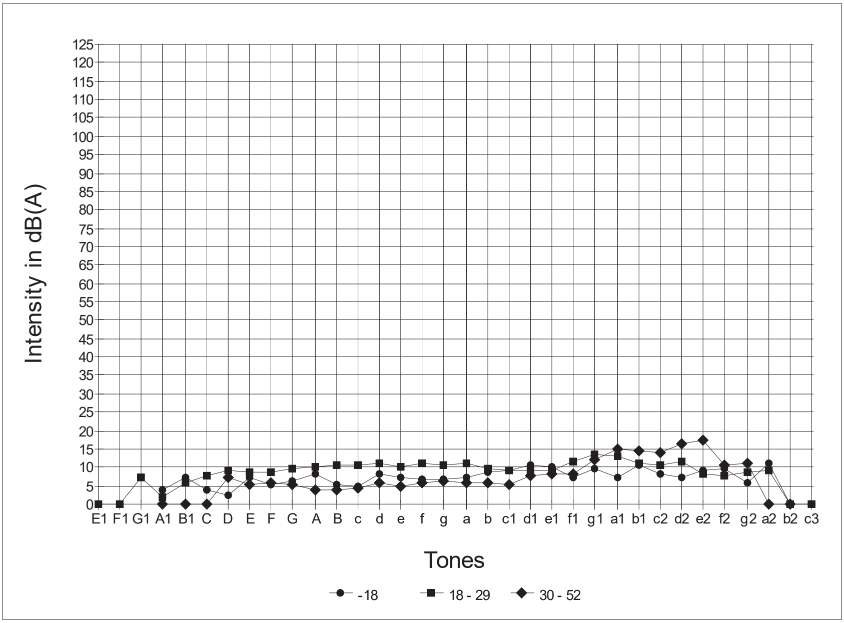


Figure 28: Comparison of standard deviation values of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range. (dynamic range) for different age-groups in males (N = 68).

Aiming at a better understanding of the VRP, and especially the acoustic interactions between F° and I, we assume that the next Figures 29-30-31, and 32 which provide **an overview per octave for each age group of male voices, can be used in clinical practice as a pattern card of the human voice.** The *differentiation in four octave zones* enables the clinician to compare the results of his own maximum intensity measurements with ours: all four octave zones provide information on the singing voice, while octave zones C – c and c – c1 also give information on the speech area, and zone c1 – c2 also reflects frequencies often used in shouting.

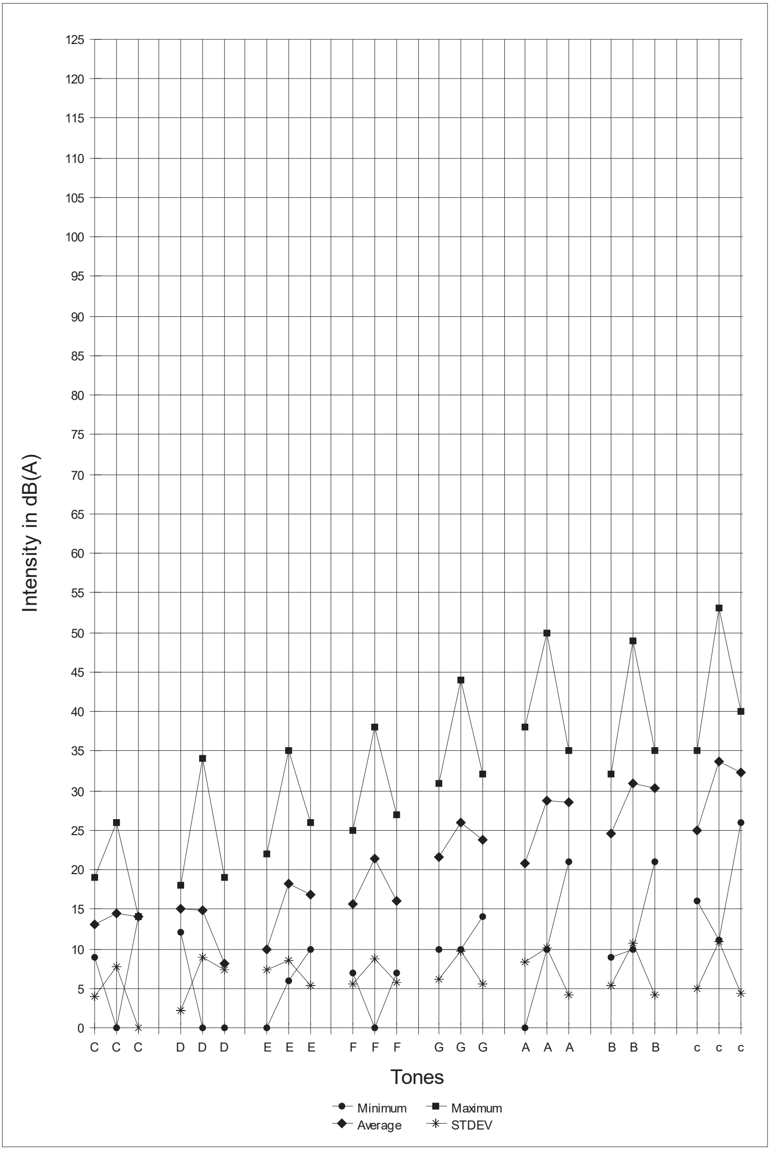


Figure 29: Results of variations of dynamic range measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in the male voice range C – c (N = 68).

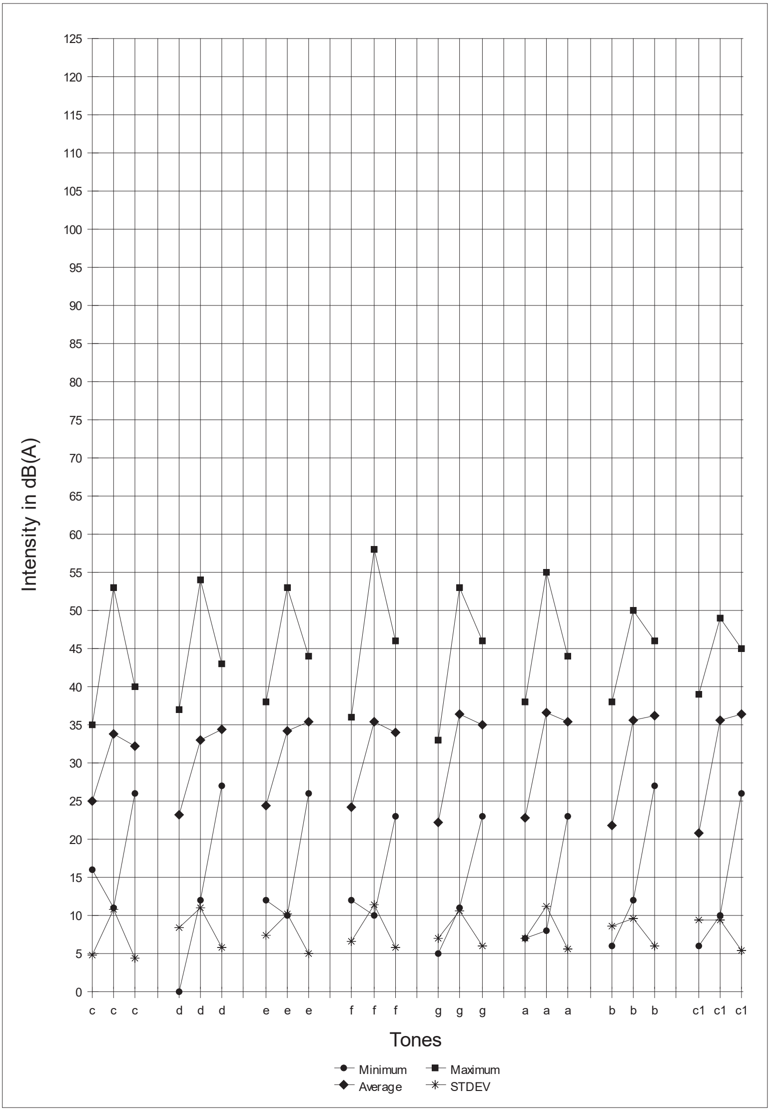


Figure 30: Results of variations of dynamic range measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in the male voice range c – c1 (N = 68).

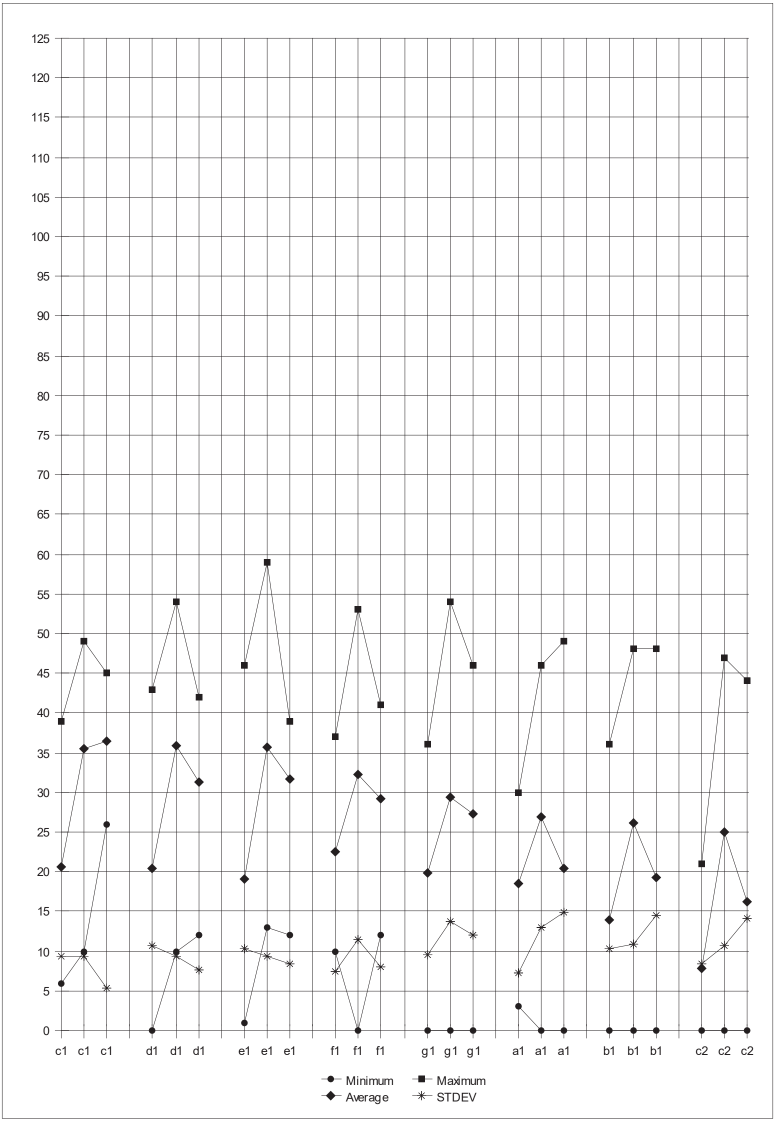


Figure 31: Results of variations of dynamic range measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in the male voice range c1– c2 (N = 68).

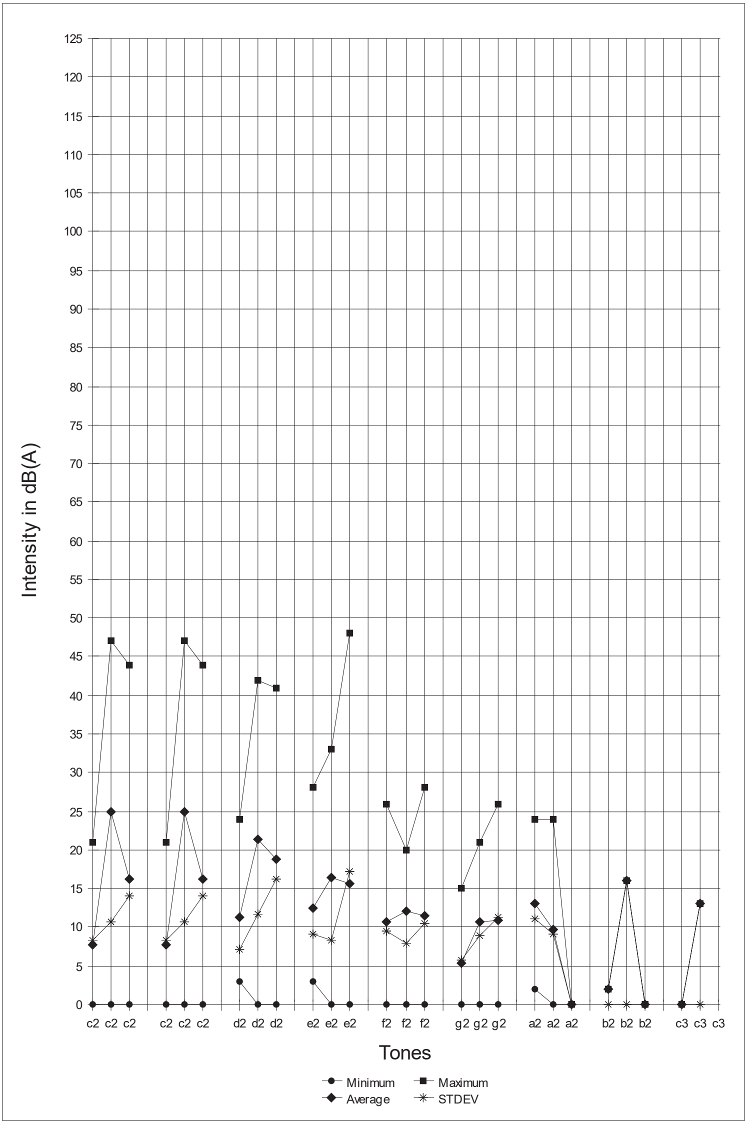


Figure 32: Results of variations of dynamic range measurements for each age group in males (the first notation relates to the age group under 18 years, the second to the age group 18 – 29 years, and so on) in the male voice range c2– c3 (N = 68).

The results of the differences between the maximum and minimum intensity measurements of each tone of the vocal range (**dynamic range**) are considered as an important parameter in the interpretation of the phonetogram. However, in the literature, the possible relationship with voice classification is missing. That's why we looked a little closer at the results of our own group of subjects.

Here again, we assume the necessity of ALL pitches to be analysed. As an example, taking notice again of Table 6, indicating the limits of voice range / tessitura of the basic voice categories, we can say that the lowest tones E1, F1, G1 and A1 undoubtedly must correspond to a bass voice, whatever their dynamic range might be. (cfr. Figure 31). Higher pitches, however, can correspond to a higher voice category. That's why we think it is worthwhile to scrutinize the results of the variations of the **dynamic range** of our subjects within the range B1 – B:

B1	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	3	20	9,7	7,41	2,29 – 17,11
18 - 29 years	7	23	14,2	6,01	8,19 – 20,21
30 - 52 years	16	16	16,0	0,00	
C	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	9	19	13,0	3,94	9,06 – 16,94
18 - 29 years	0	26	14,4	7,67	6,73 – 22,07
30 - 52 years	14	14	14,0	0,00	
D	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	12	18	15,0	2,24	12,76 – 17,24
18 - 29 years	0	34	14,8	8,94	5,86 – 23,74
30 - 52 years	0	19	8,1	7,28	0,82 – 15,38
E	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	0	22	9,9	7,41	2,49 – 17,31
18 - 29 years	6	35	18,3	8,46	9,84 – 26,76
30 - 52 years	10	26	16,8	5,35	11,45 – 22,15

F	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	7	25	15,6	5,53	10,07 – 21,13
18 - 29 years	0	38	21,3	8,81	12,49 – 30,11
30 - 52 years	7	27	16,0	5,73	10,27 – 21,73
G	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	10	31	21,5	6,06	15,44 – 27,56
18 - 29 years	10	44	25,9	9,71	16,19 – 35,61
30 - 52 years	14	32	23,8	5,48	18,32 – 29,28
A	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	0	38	20,8	8,26	12,54 – 29,06
18 - 29 years	10	50	28,7	10,07	18,63 – 38,77
30 - 52 years	21	35	28,5	4,08	24,42 – 32,58
B	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	9	32	24,6	5,41	19,19 – 30,01
18 - 29 years	10	49	30,9	10,70	20,2 – 41,6
30 - 52 years	21	35	30,4	4,08	26,32 – 34,48

Table 30: Variations in dynamic range and differentiating ranges (= average dynamic range +/- the standard deviations), based on the results provided in Figures 43 – 44 and 45).

The combination of Table 6 with Table 30 could give an indication of the level of vocal training and performance capacities: dynamic ranges below the lowest value of the differentiating range belong to a lower voice level; dynamic ranges above the highest value of the differentiating range belong to a higher voice level. For instance, for the tone E:

E	**Differentiating range**	**Bass**	**Tenor**
< 18 years	2,49 – 17,31	> 17,31	< 2,49
18 - 29 years	9,84 – 26,76	> 26,76	< 9,84
30 - 52 years	11,45 – 22,15	> 22,15	< 11,45

Table 31: example for differentiating between the values of the dynamic range in dB(A), specific for basses and tenors (tone E).

The data provided for each tone, combined with the differentiating range, allow a gradual survey of how the dynamic range of a given voice evolves. The correlation with voice category still must be further explored.

Once again, the proposed method is to be interpreted as just one step in the step-to-step methodology of voice classification by phonetography.

8.5.1.4. Results of the differences between the minimum values of the maximum and the maximum values of the minimum intensity measurements of each tone of the vocal range

Producing great vocal power and in the meantime being able to keep the voice under control at a minimum intensity level are highly appreciated voice qualities.

Intrigued by the many obtained meaningful data, illustrating the different aspects of voice intensity, collected in this chapter, we thought it could, perhaps, be interesting to compare the results of the differences between the minimum values of the maximum and the maximum values of the minimum intensity.

The next Figure 33, based on Figure 3 and Figure 11 demonstrates, for instance, that, for each tone of the vocal range of male subjects of all ages, the maximum values of the minimum intensity measurements are, in general, higher than the minimum values of the maximum intensity measurements.

The clinical aspects of these findings still must be studied.

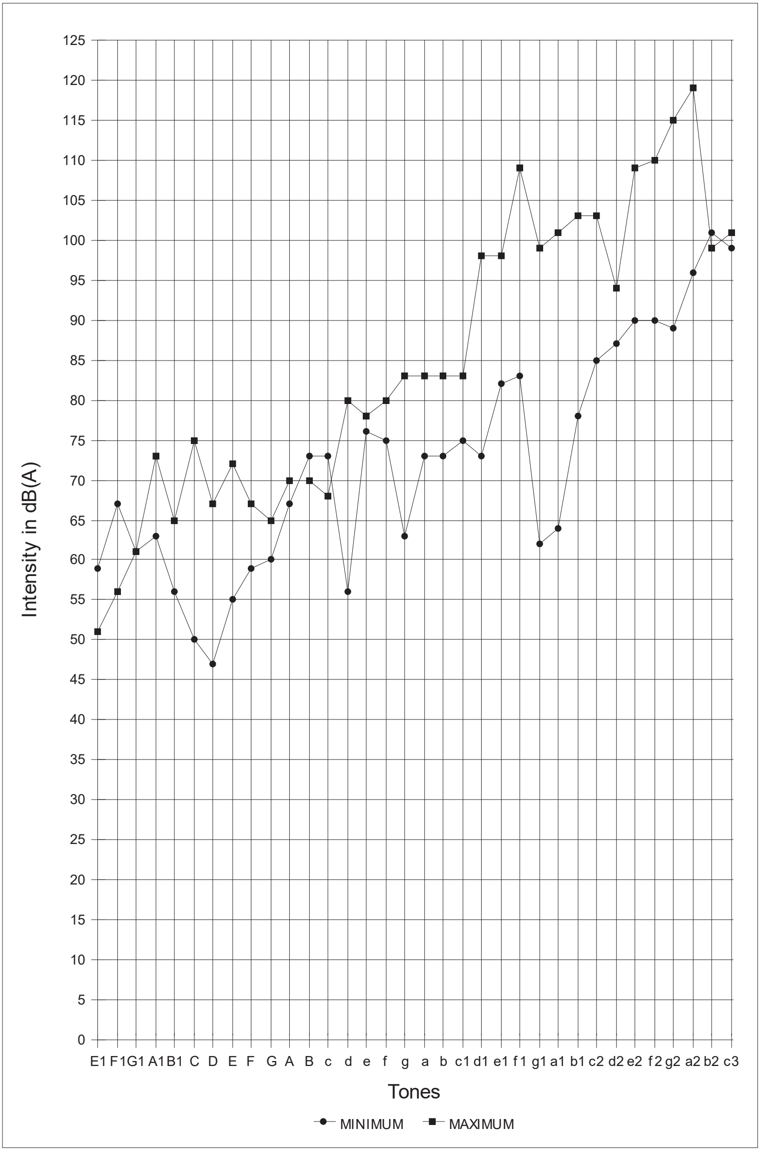


Fig. 33: Results of the differences between the minimum values of the maximum and the maximum values of the minimum intensity measurements of each tone of the vocal range in males of all ages. (N = 68).

8.5.2. Female voices

8.5.2.1. Results of maximum intensity measurements of each tone of the vocal range

An analysis of the global results (for all ages) of the maximum intensity measurements (Figure 34), demonstrates how the maximum intensity continuously increases as frequency increases. There are striking differences with the curves of maximum intensity in males (Fig. 1). At first sight, the surface of the global VPR of female voices is much larger than the global surface of the male voices.

Considering the one octave difference between the male and the female vocal range, the extremes of male vocal range (E1- c3) exceed the extreme limits of the female vocal range (E-a3), but the *maximum intensity* produced by our female subjects largely exceeds that of our male subjects: 125 dB(A) on a2-b2-c3 and d3 vs. 120 dB(A) on a1. Although the curves of maximum, minimum and average maximum intensities are similar for both genders, the female minimum curve of maximum intensity is much more regular.

There is a parallel stagnation in the *maximum intensity* curve in the zones A-e and a-e1. The dips in the male maximum curve (c, c1, and d1) are similar to those in the female maximum curve (d1, d2).

These stagnations are, of course, less visible in the *average curve*.

In contrast to the male extreme high pitches which, produced in falsetto, are typical for basses, the extreme female highest pitches f3-a3 are unanimously attributed to soprano voices. The highest female pitches g2-e3, with absolute maximum intensities 124-125 dB(A), however, could again cause confusion in view of voice classification, as they could belong to contralto, mezzo, or soprano voices (Table 6).

From the low pitch d to the extreme high pitch a3 maximum intensity can exceed 100 dB(A)! Referring to our remark on necessary intensities in stage productions and elsewhere, female voices are exceedingly suited!

Akerlund and Gramming[1450,1451] reported that 10 professional classically trained female singers produced a significantly higher upper phonetogram contour than 10 female non singers, while no corresponding difference was found for male voices.

The *minimum values of the maximum intensity* approach the maximum values at both ends of the vocal range. The absolute minimum value of the maximum intensity measurement is 54 dB(A) on A and c. From a2 on, minimum values of the maximum intensity are situated above 75 dB(A). Dips in the *minimum curve* are visible at the pitches A, c, ,e, e1, c2, and f2.

The *average maximum intensities* regularly increase with frequency, except beyond d3. An average maximum intensity of 95 dB(A) and more is available from c1 on for all female voice categories.

Most standard deviations are, as with male voices, situated around 7 dB(A), conform the results of Sulter et al.[1452] Akerlund and Gramming[1450] compared VRP's in relationship to subglottal pressure of female singers and non-singers. They too found great interindividual differences among the singers as well as among the non-singers, as expressed by the large standard deviations.

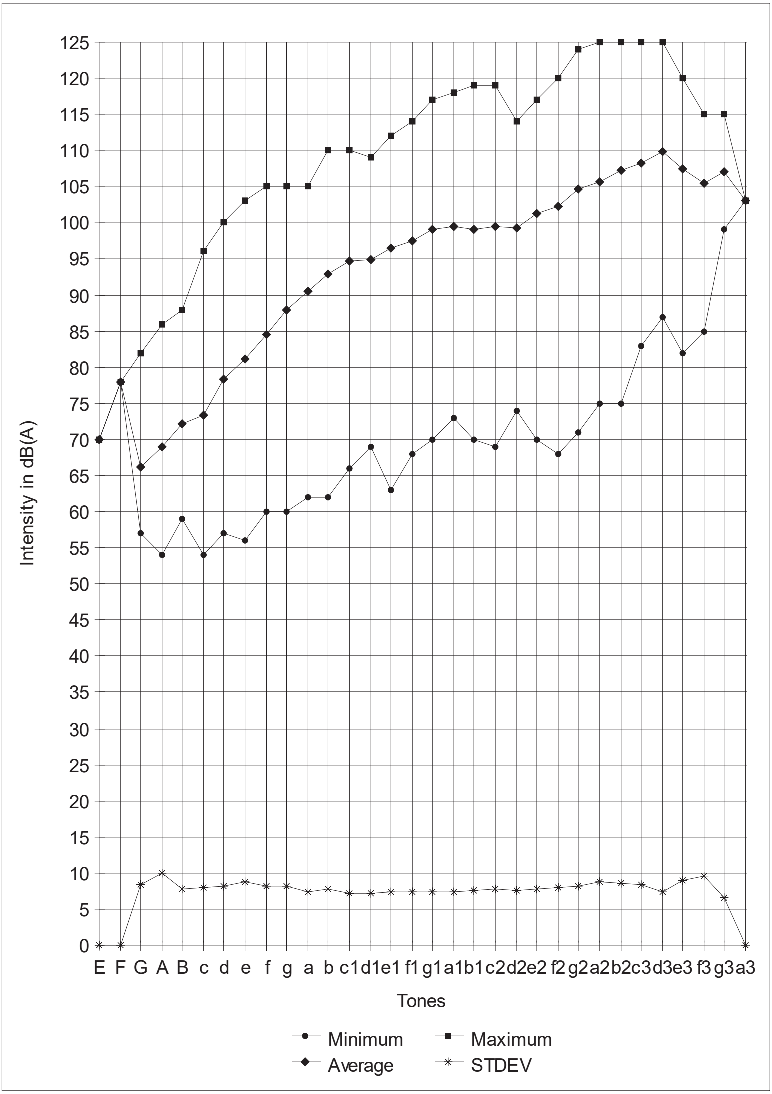


Figure 34: Minimum, maximum, average and standard deviation of maximum intensity measurements of ALL tones in females of ages 8 – 65 years (N = 311).

To compare the age-related results of our male population with those of our female population, we divided our female population into 3 age-groups, corresponding to those of the male population: under 18 years, 18-29 years, and 30-49 years. (Figures 35,36,37, and 38). The 3 women above 50 years (53, 59, and 65 years) we tested, were omitted in our statistical analysis.

In the age group under 18 years the exceptional low tones E, F and G are missing, just like with the boys, and their *maximum intensities* are also much weaker than those of older female subjects. More than 100 dB(A) is only obtained from b on.

Interestingly, the register dip on d2 is of the same maximum intensity for all ages. The age group 18-29 years produce their absolute maximum intensities at the extreme high pitches g2-a2-b2-c3 and d3.

The *minimum curves of the maximum intensity* are irregular for all age groups, but like the male subjects, the female older subjects (30-49 years) show the highest minimum curves of maximum intensity.

The lowest results for the *average values of maximum intensity* again, belong to the youngest age group, followed by the 18-29 years group. The best results are those of the eldest age group.

In our population, we had only 3 older females (53,59, and 65 years). They obtained maximum intensities of 116 dB(A), 104 dB(A) and 113 dB(A), respectively. It is hard to believe that, in the study of the elderly females' voice by phonetography by Teles-Magalhaës et al[1453] none of the 40 healthy females, ranging in age from 60 to 84 years, could obtain 100 dB(A). Three comparable females of 65 years of age obtained maximum intensities of only 84,94, and 91 dB(A), in contrast to our subjects who obtained up to 113 dB(A).

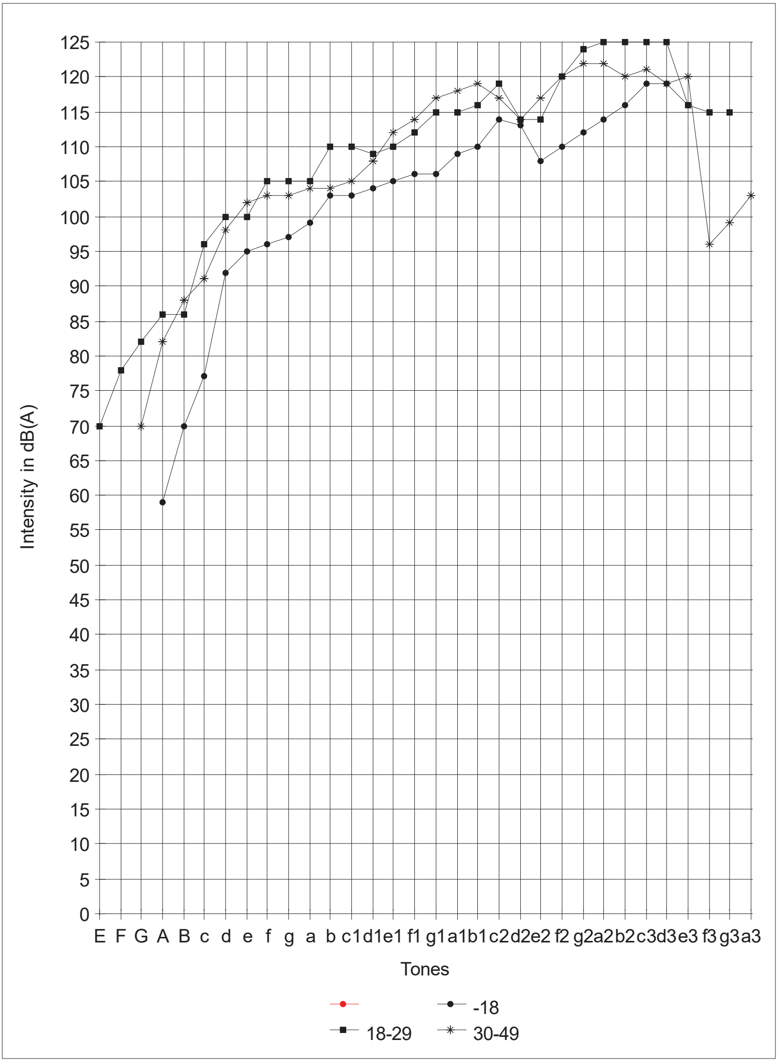


Figure 35: Comparison of maximum values of maximum intensity curves for different age-groups in females (N = 308).

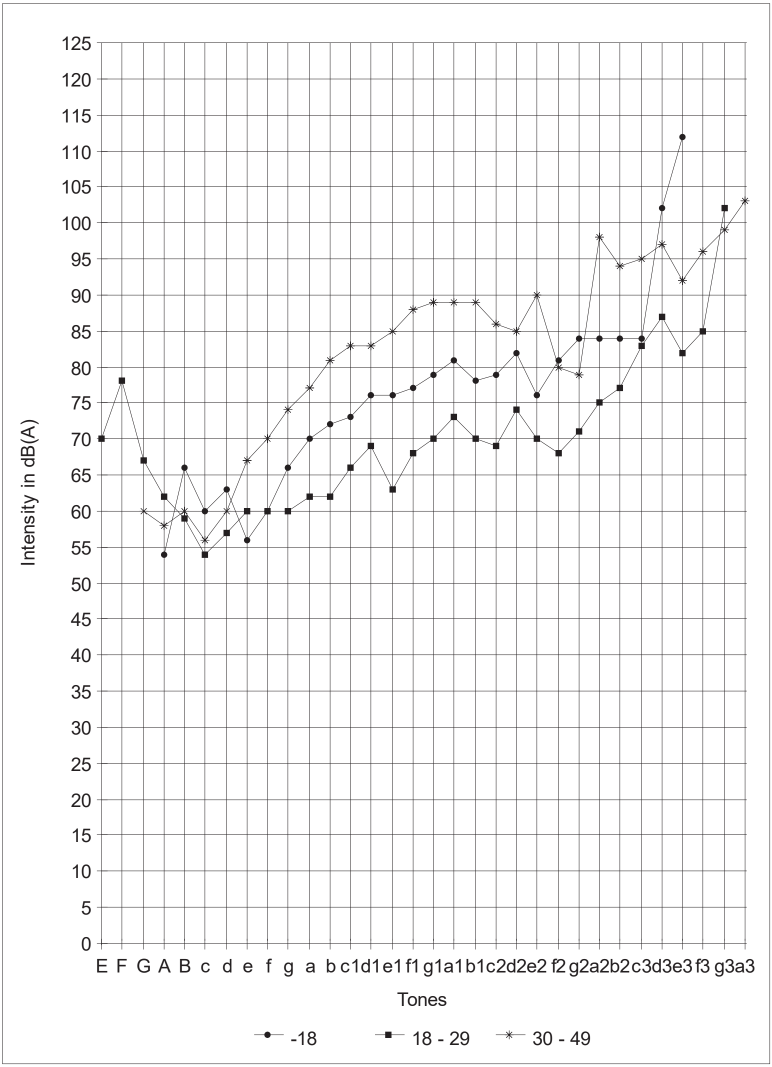


Figure 36: Comparison of minimum values of maximum intensity curves for different age-groups in females (N = 308).

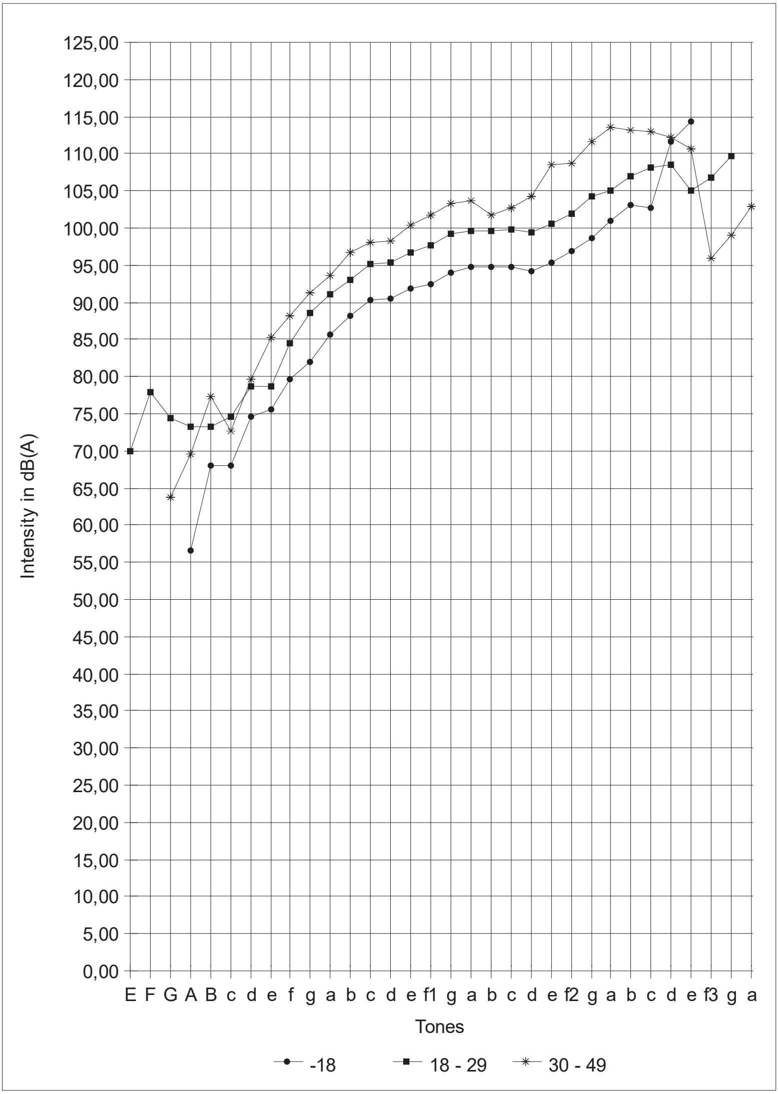


Figure 37: Comparison of average values of maximum intensity curves for different age-groups in females (N = 308).

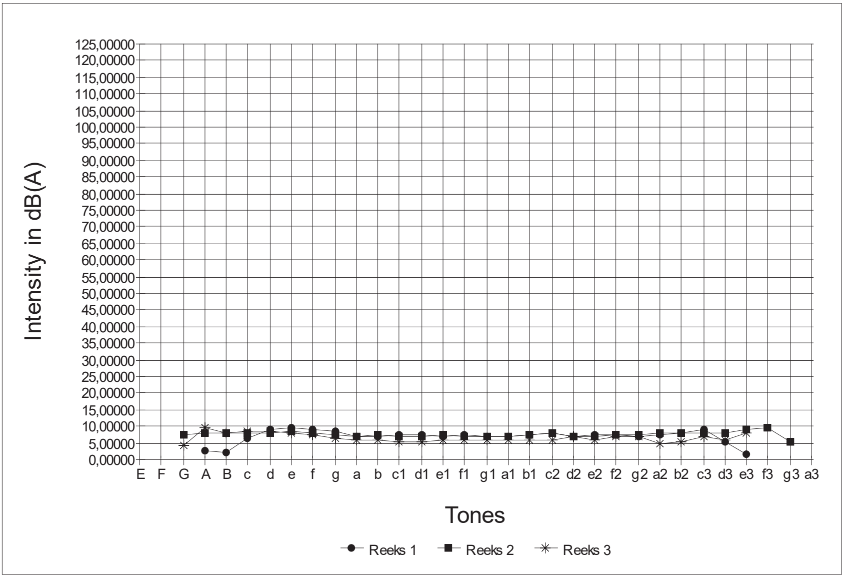


Figure 38: Comparison of standard deviation measurements of maximum intensity curves for different age-groups in females (N = 308).

The next Figures 39, 40, 41, and 42, provide an overview *per octave* for each age group of female voices, readily useful in clinical practice as a *pattern card of the human voice*. The differentiation in four octave zones enables the clinician to compare the results of his own maximum intensity measurements with ours.

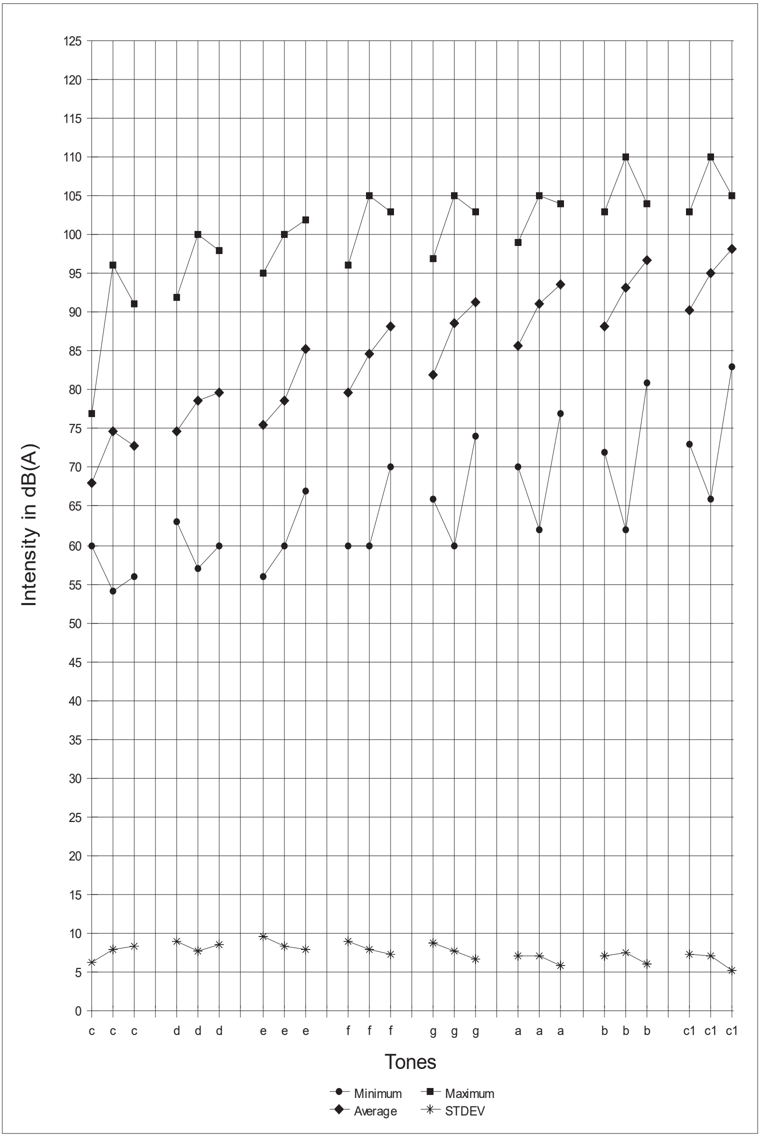


Figure 39: Results of variations of maximum intensity measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c-c1. (N = 308).

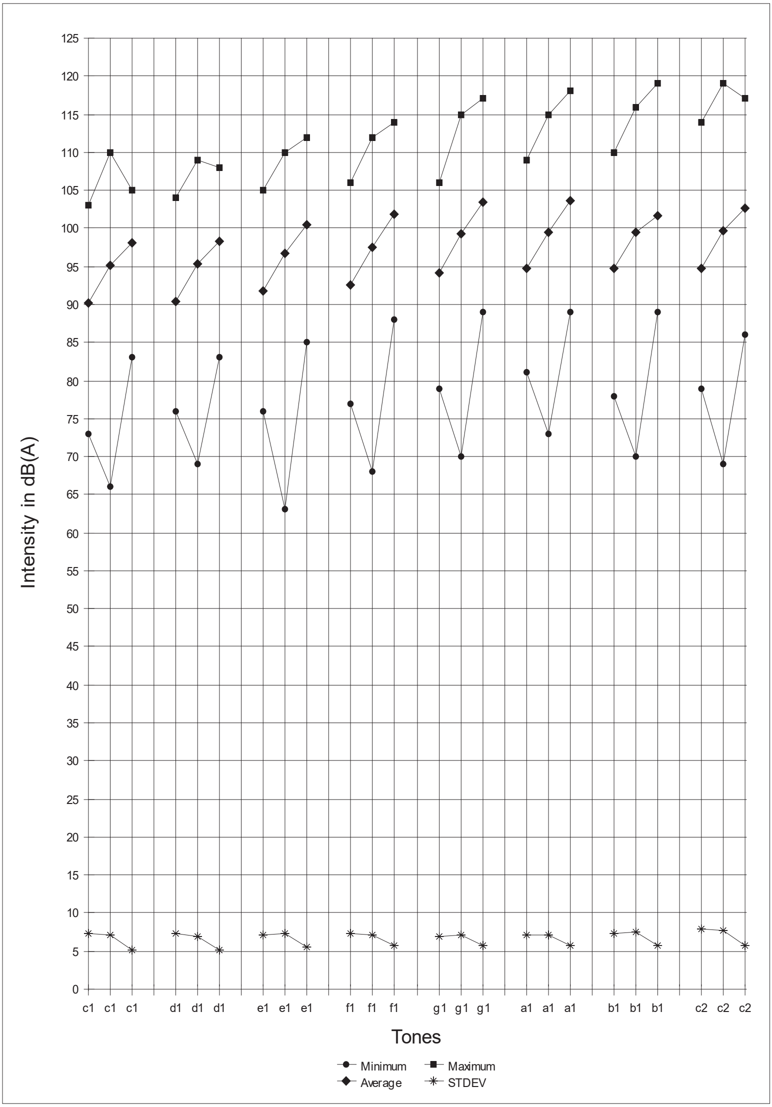


Figure 40: Results of variations of maximum intensity measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c1-c2. (N = 308).

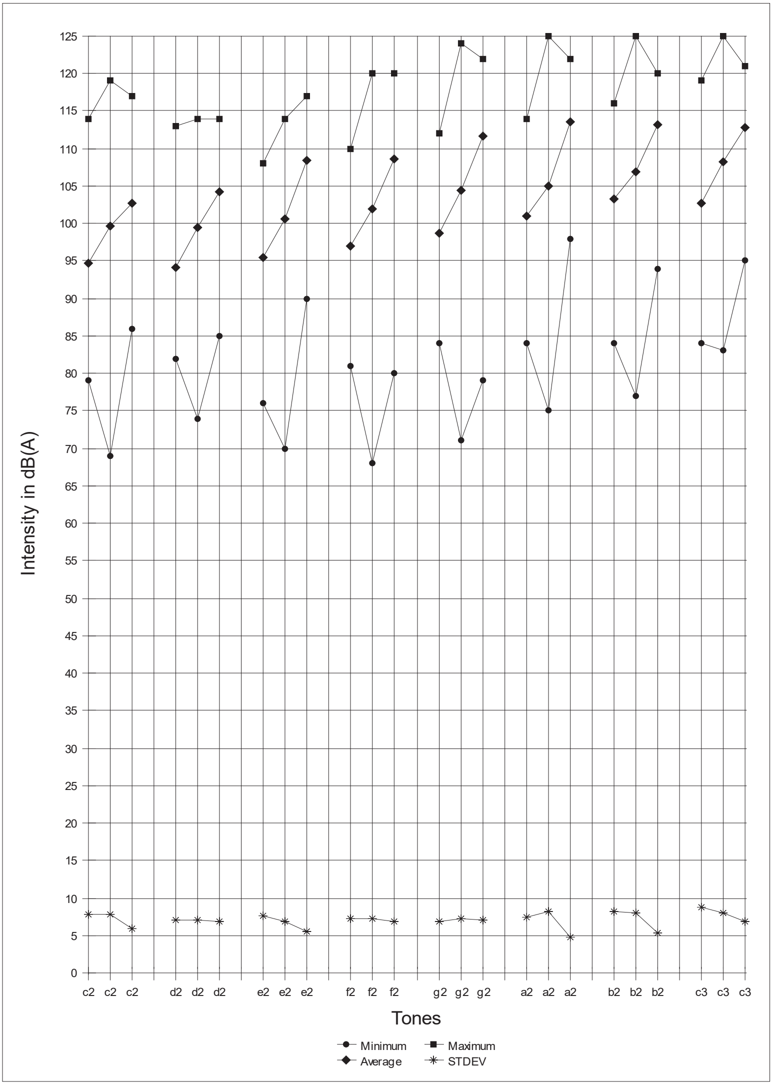


Figure 41: Results of variations of maximum intensity measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c2-c3. (N = 308).

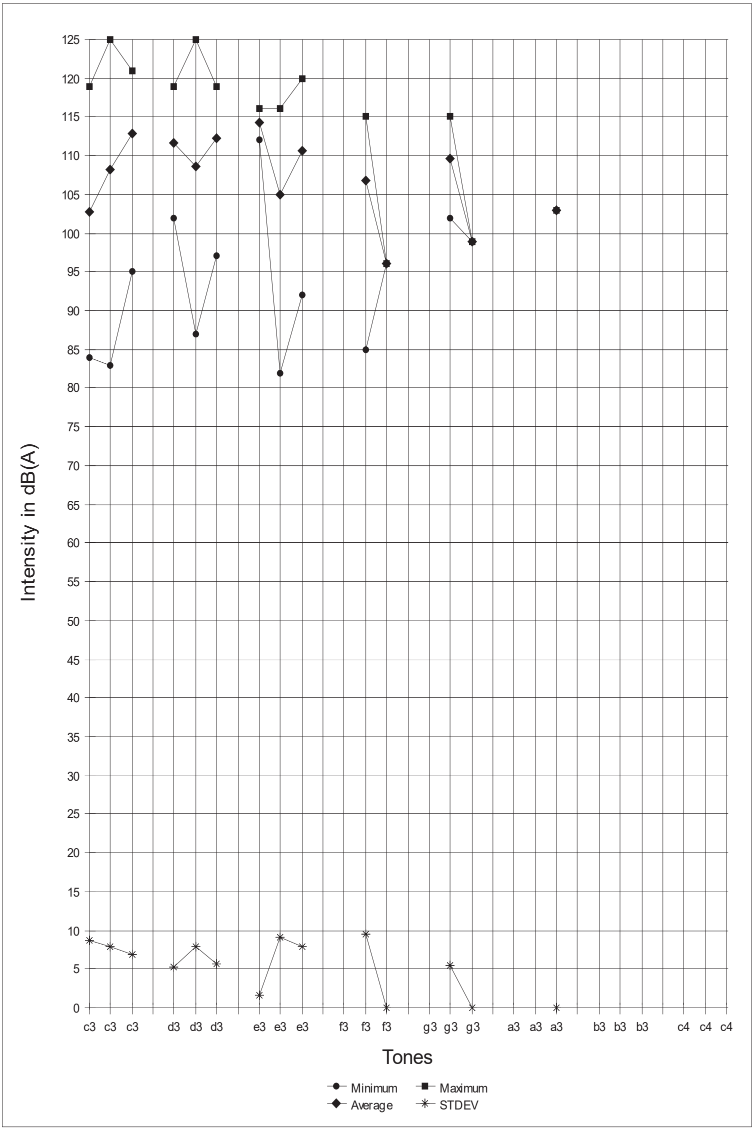


Figure 42: Results of variations of maximum intensity measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c3-c4. (N = 308).

To prove the importance of the intensity measurements for each tone with respect to *voice classification*, it is obligatory to analyse ALL pitches and *to examine if differences in intensity measurements are related to voice categories.*

Based on Table 6, we can assume that the lowest tone A and lower must correspond to a contralto voice, whatever her maximum intensity might be. From B upward to a, however, it could be revealing to analyse the maximum intensities of the lowest tones, as these tones could also belong to a higher voice category. To illustrate this, let us look at the ascending pitches and the corresponding variations in **maximum** intensity in the lower part of our female subjects in every age category:

B	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	66	70	68,00	2,00000	64,00 - 70,00
18 - 29 years	59	86	73,25	7,81425	65,43 - 81,06
30 - 49 years	60	88	72,25	7,75806	64,49 - 80,00
c	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	60	77	68,00	6,23164	61,76 - 74,23
18 - 29 years	54	96	74,66	7,80844	66,77 - 82,46
30 - 49 years	56	91	72,73	8,26373	64,46 - 80,99
d	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	63	92	74,61	8,90155	65,70 - 83,51
18 - 29 years	57	100	78,63	7,79058	70,83 - 86,42
30 - 49 years	60	98	79,62	8,57588	71,04 - 88,19
e	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	56	95	75,54	9,49991	66,04 - 85,03
18 - 29 years	60	100	78,63	8,28336	70,34 - 86,91
30 - 49 years	67	102	85,3	7,81409	77,48 - 93,11
f	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	60	96	79,68	8,89899	70,78 - 88,57
18 - 29 years	60	105	84,57	7,93475	76,63 - 92,50
30 - 49 years	70	103	88,27	7,2078	81,06 - 95,47
g	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	66	97	81,95	8,67063	73,27 - 90,62
18 - 29 years	60	105	88,55	7,63875	80,91 - 96,18
30 - 49 years	74	103	91,27	6,60755	84,66 - 97,87
a	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	70	99	85,70	7,12850	78,57 - 92,82
18 - 29 years	62	105	91,11	7,13679	83,97 - 98,24
30 - 49 years	77	104	93,59	5,78887	87,80 - 99,37

Table 32: Variations in maximum intensity measurements and differentiating ranges (= average maximum intensity +/- the standard deviations) of female voices.

Take for instance the tone e: the combination of Table 8, showing the uneven distribution of lowest tones in females, with Table 32, should provide indications for specific voice categories: maximum intensities below the lowest value of the differentiating range belong to a higher voice category, maximum intensities above the highest value of the differentiating range belong to a lower voice category.

e	Differentiating range	Alto	Soprano
< 18 years	66,04 - 85,03	> 85,03	< 66,04
18 - 29 years	70,34 - 86,91	> 86,91	< 70,34
30 - 49 years	77,48 - 93,11	> 93,11	< 77,48

Table 33: Example of interpretation of the differentiating range between the values of maximum intensities in dB(A), specific for altos and sopranos (tone e).

The data provided for *each* tone, combined with the differentiating range, allow a *gradual survey of how the maximum intensities of a given female voice evolve within a specific voice category.*

The proposed method is to be interpreted as just one step in our step-to-step methodology of voice classification by phonetography.

8.5.2.2. Results of minimum intensity measurements of each tone of the vocal range

An analysis of the global results (for all ages) of the minimum intensity measurements (Figure 43), of our female subjects demonstrates how the minimum intensity increases as frequency increases.

The *maximum curve of the minimum intensity* of female voices is very irregular, with a marked basin-shaped dip between f and c2. The absolute dip in situated on d1 and repeated on d2. Maximum values of minimum intensity vary between 60 dB(A) and 120 dB(A).

The *average curve* of the minimum intensity regularly increases with ascending pitches, while the *minimum curve of minimum intensity* fluctuates between 40 dB(A) and 50 dB(A) in a large frequency zone between G and f2. All three curves demonstrate that the highest pitches cannot be phonated softly with ease!

Behrman et al.[1454] reported that minimum intensity levels below 60 dB(A), especially in the lower frequencies, are considered as criteria for normal VRPs. The average minimum intensities in the lower vocal range of all our subjects are below 60 dB(A). In the same range of low frequencies, the minimum intensities of our subjects vary between an absolute minimum of 40 dB(A) and an absolute maximum of 88 dB(A).

Most standard deviations are situated between 6 dB(A) and 8 dB(A), apart from the values at the highest pitches, and are conform with the results of Sulter et al.[1455]

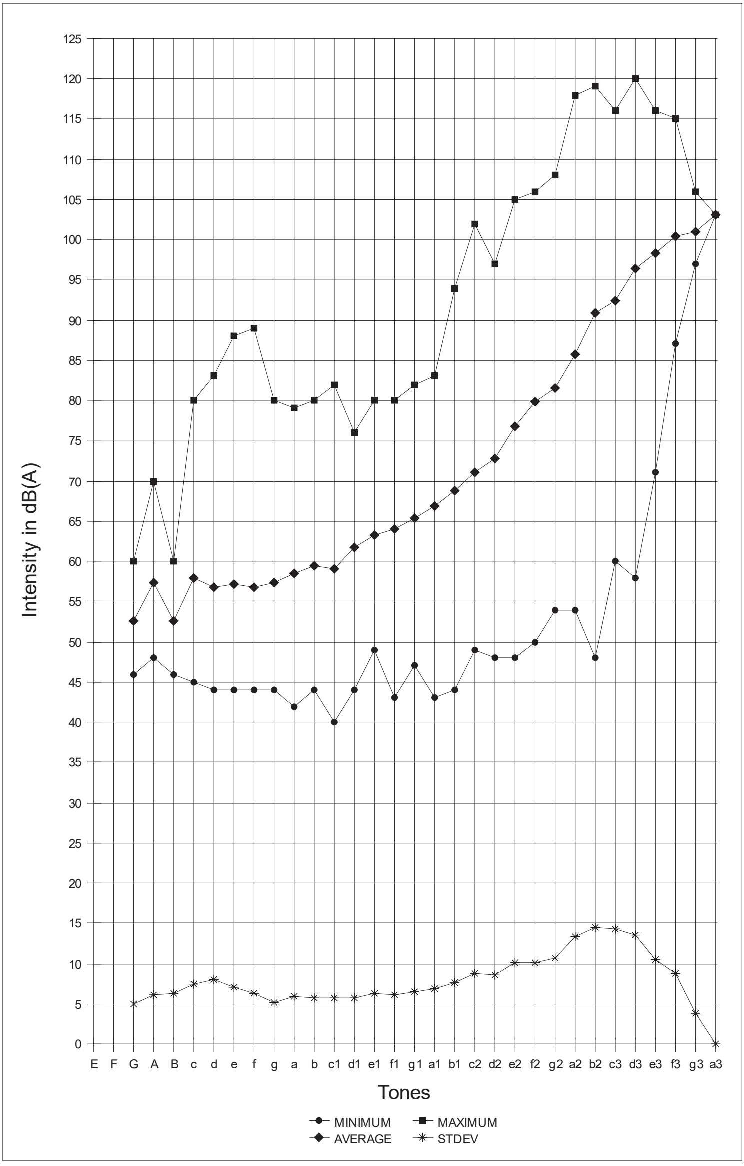


Figure 43: Minimum, maximum, average and standard deviation of minimum intensity measurements of ALL tones in females of ages 8 – 59 years (N = 133).

Dividing these global results of minimum intensity in age-related results (Figures 44,45, and 46) allows us to discover some differences between the female voices. The most striking feature is the exceptional good results for the age groups 18-29 years, which can be explained as a *training effect (lowest minimum and lowest average values of the minimum intensity measurements*).

Bad results are obtained by the age groups 30-49 years for the minimum and average measurements of the minimum intensity. In older female singers piano singing is often much more difficult than forte singing.

The age group under 18 years falls somewhere in between the other age groups.

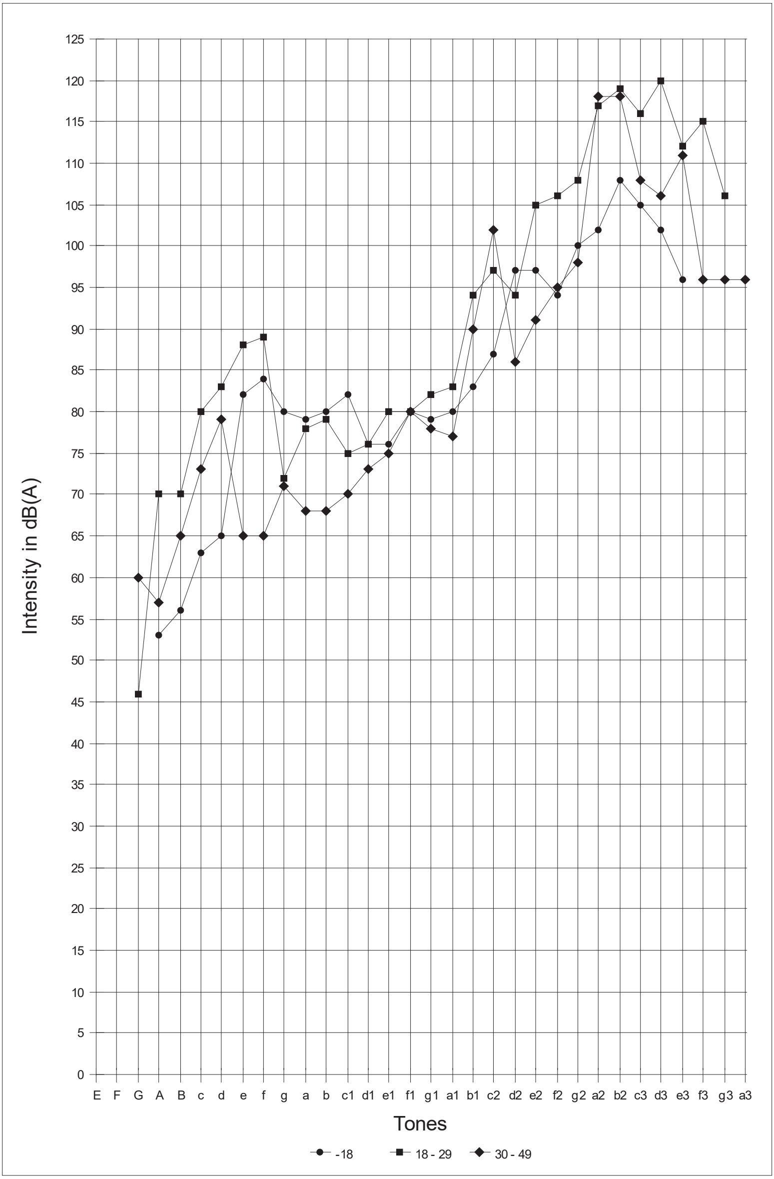


Figure 44: Comparison of maximum values of minimum intensity curves for different age-groups in females (N = 130).

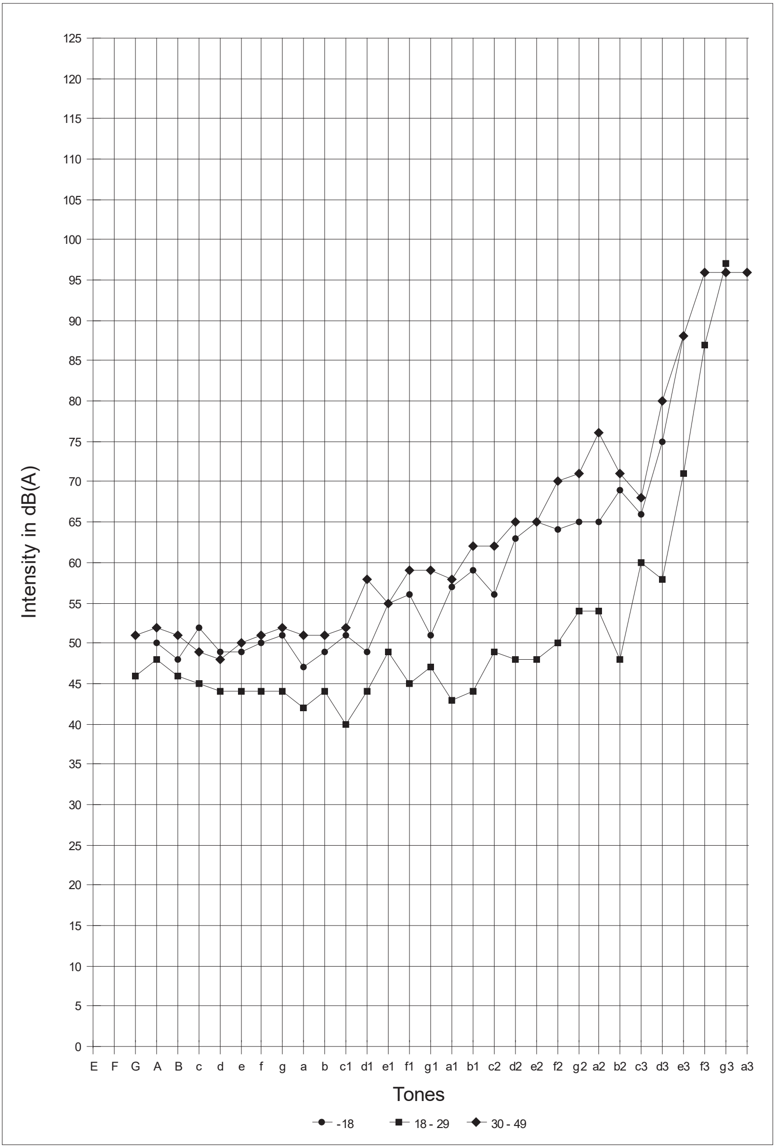


Figure 45: Comparison of minimum values of minimum intensity curves for different age-groups in females (N = 130).

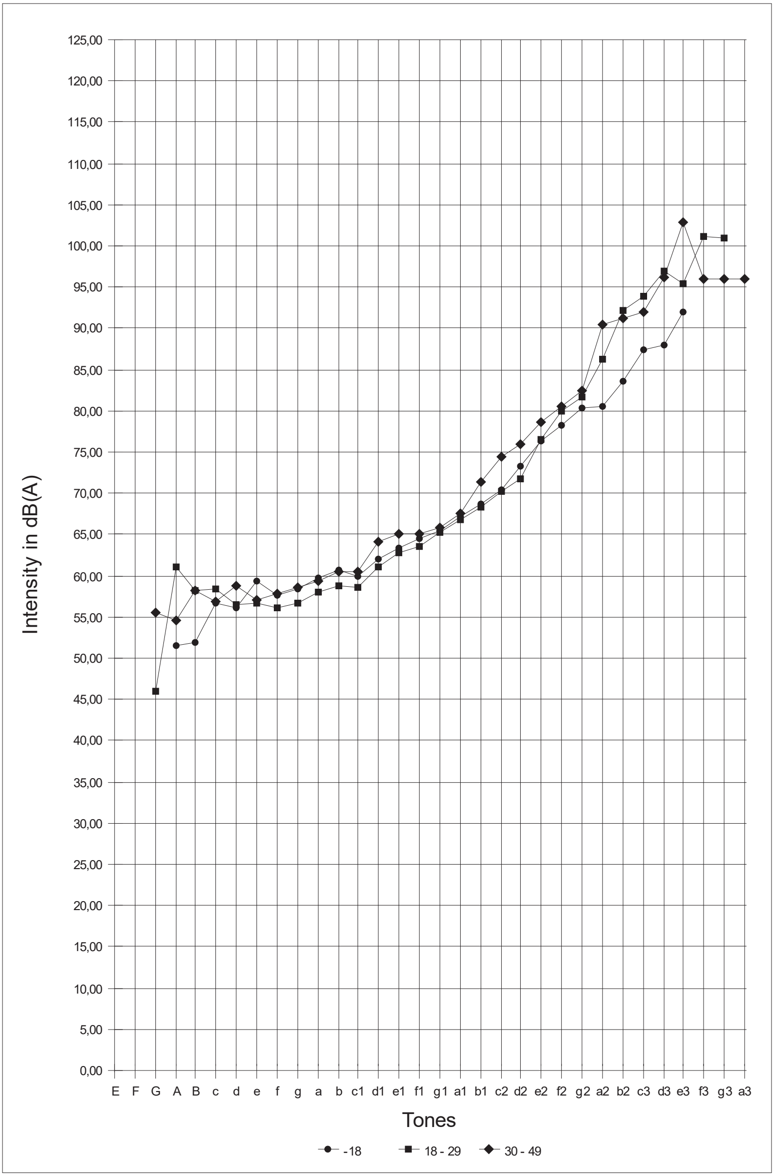


Figure 46: Comparison of average values of minimum intensity curves for different age-groups in females (N = 130).

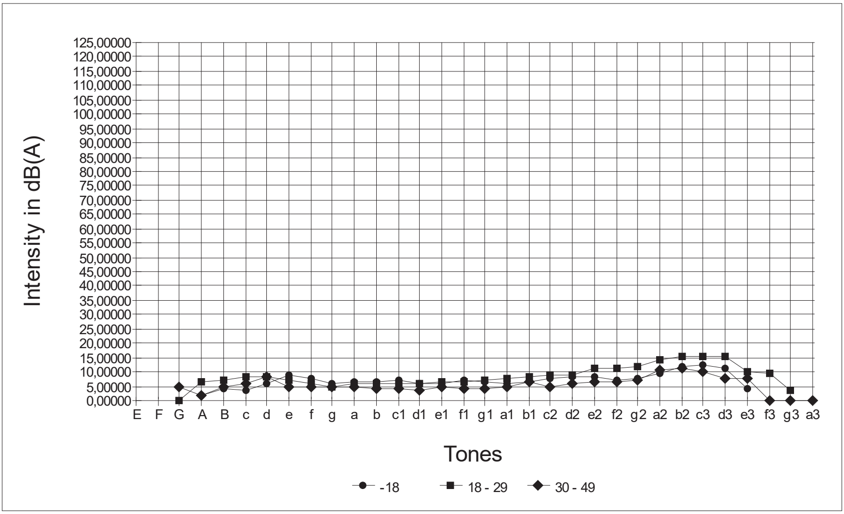


Figure 47: Comparison of standard deviation values of minimum intensity curves for different age-groups in females (N = 130).

The next Figures 48,49,50, and 51 provide an **overview *per octave* for each age group of female voices, readily useful in clinical practice as a *pattern card of the human voice*.** The differentiation in four octave zones enables the clinician to compare the results of his own maximum intensity measurements with ours.

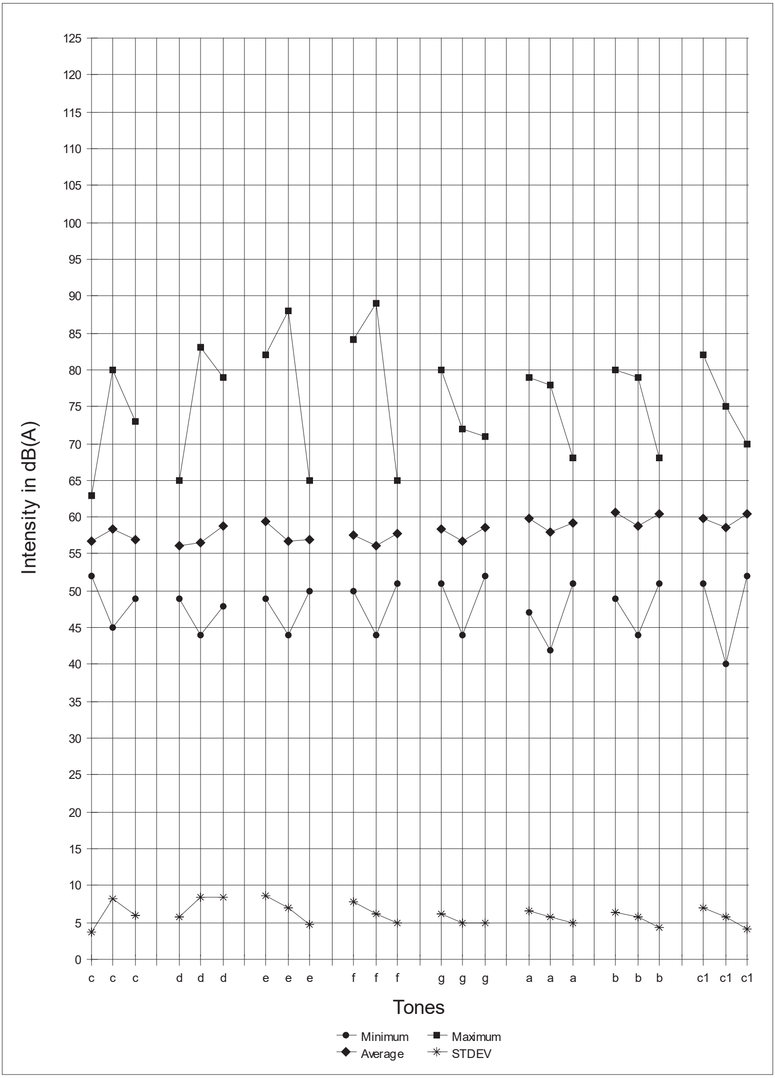


Figure 48: Results of variations of minimum intensity measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c-c1. (N = 130).

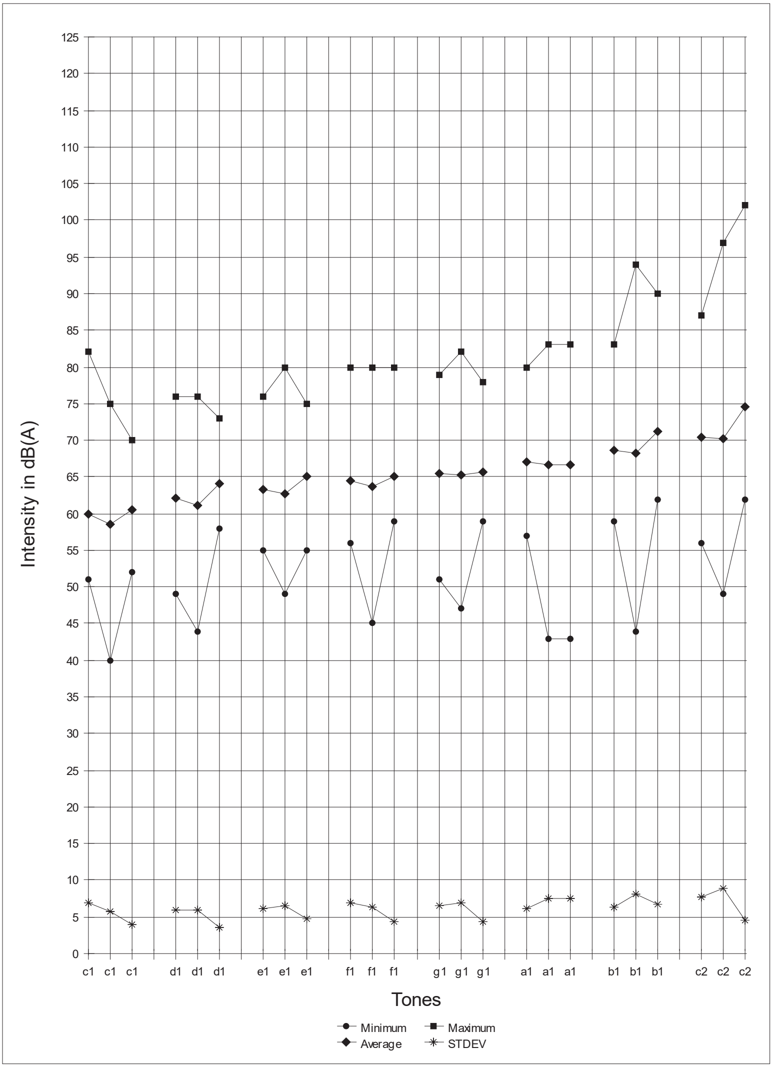


Figure 49: Results of variations of minimum intensity measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c1-c2. (N = 130).

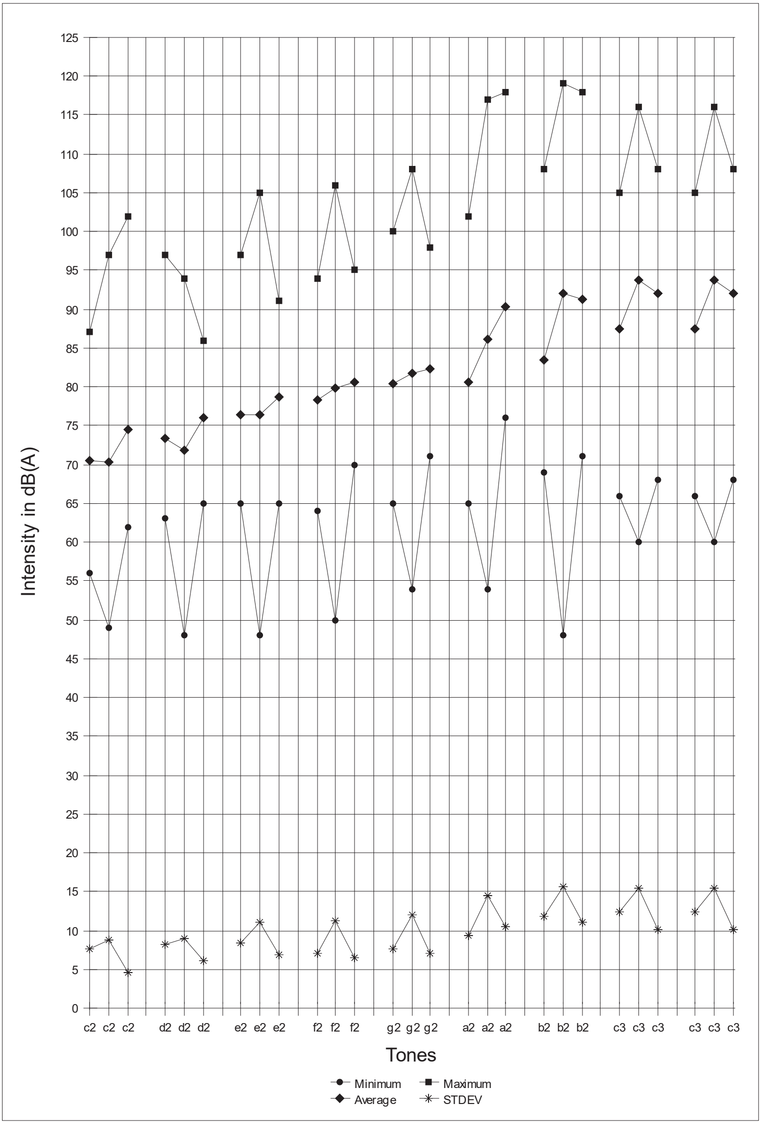


Figure 50: Results of variations of minimum intensity measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c2-c3. (N = 130).

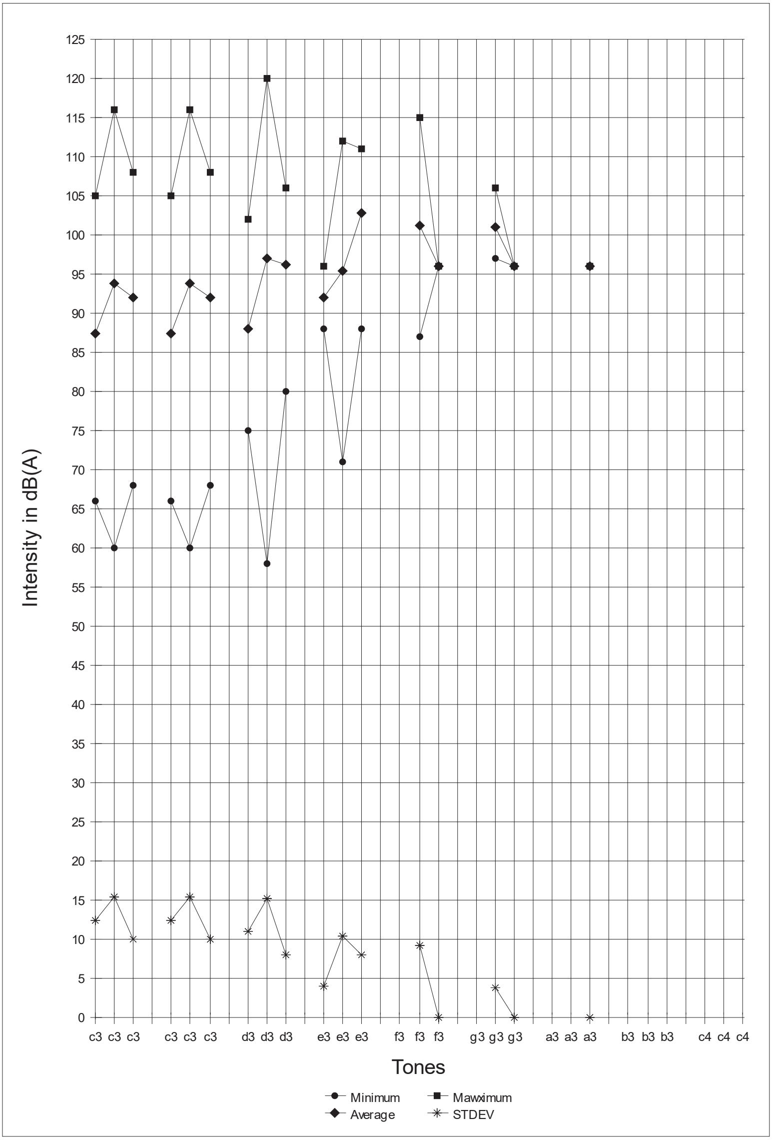


Figure 51: Results of variations of minimum intensity measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c3-c4. (N = 130).

With exception for the tone A and lower, which only can belong to a contralto voice, according to Table 6, tones from B upward to a could belong to a higher voice category. As an illustration we will show how these ascending pitches and their corresponding variations in minimum intensity in the lower part of the voice range of our female subjects, correspond to specific voice categories:

B	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	48	56	52,00	4,00000	48,00 - 56,00
18 - 29 years	46	70	58,15	7,13438	51,01 - 65,28
30 - 49 years	51	65	58,30	4,81768	53,48 - 63,11
c	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	52	63	56,75	3,79967	52,95 - 60,54
18 - 29 years	45	80	58,46	8,32397	50,13 - 66,78
30 - 49 years	49	73	56,87	5,97625	50,89 - 62,84
d	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	49	65	56,15	5,77589	50,37 - 61,92
18 - 29 years	44	83	56,50	8,34529	48,15 - 64,84
30 - 49 years	48	79	58,76	8,32805	50,43 - 67,08
e	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	49	82	59,36	8,64736	50,71 - 68,00
18 - 29 years	44	88	56,68	7,05643	49,62 - 63,73
30 - 49 years	50	65	57,00	4,65833	52,34 - 61,65
f	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	50	84	57,59	7,72634	49,86 - 65,31
18 - 29 years	44	89	56,18	6,12646	50,05 - 62,30
30 - 49 years	51	65	57,86	4,86274	52,99 - 62,72
g	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	51	80	58,39	6,07016	52,31 - 64,46
18 - 29 years	44	72	56,65	4,85000	51,80 - 61,50
30 - 49 years	52	71	58,57	4,89481	53,67 - 63,46
a	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	47	79	59,74	6,50229	53,25 - 66,24
18 - 29 years	42	78	57,92	5,73398	52,18 - 63,65
30 - 49 years	51	68	59,29	4,99660	54,29 - 64,28

Table 34: Variations in minimum intensity measurements and differentiating ranges (= average maximum intensity +/- the standard deviations) of female voices.

The combination of Table 8, showing the uneven distribution of lowest tones in females, with Table 34 should provide indications for specific voice categories: minimum intensities below the lowest value of the differentiating range belong to a lower voice category, maximum intensities above the highest value of the differentiating range belong to a higher voice category. Take for instance the tone e:

e	Differentiating range	Alto	Soprano
< 18 years	50,71 - 68,00	< 50,71	> 68,00
18 - 29 years	49,62 - 63,73	< 49,62	> 63,73
30 - 49 years	52,34 - 61,65	< 52,34	> 61,65

Table 35: Example of interpretation of the differentiating range between the values of minimum intensities in dB(A), specific for altos and sopranos (tone e).

The data provided for *each* tone, combined with the differentiating range, allow a gradual survey of how the minimum intensities of a given female voice evolve within a specific voice category.

The proposed method is to be interpreted as just one step in the step-to-step methodology of voice classification by phonetography.

Derived from the results of the average maximum and minimum intensity measurements of all tones of female voice (Figures 37 and 46), *3 age-related Standard F°-SPL Profiles* and one for all ages of female voices were constructed (Fig. 52,53, 54 and 55).

Girls under 18 years lack the extreme low pitches E-F and G and the extreme high pitches f3-g3 and a3.

30-49 years old women produce by far the highest intensities: from e1 on, they produce, on the average, vocal intensities above 100 dB(A), while 18-29 years old women do this only one octave higher (e2); girls under 18 years only produce 100 dB(A) at extreme high pitches (from a2 on).

Concerning the necessary vocal capacities for the stage, it is obvious that, on the average, only women in the age-group 30-49 possess enough vocal power (100 dB(A) and more). These facts also confirm the need for phonetographic measurements with vocal auditions for stage productions. V*ery powerful voices are indeed exceptional*!

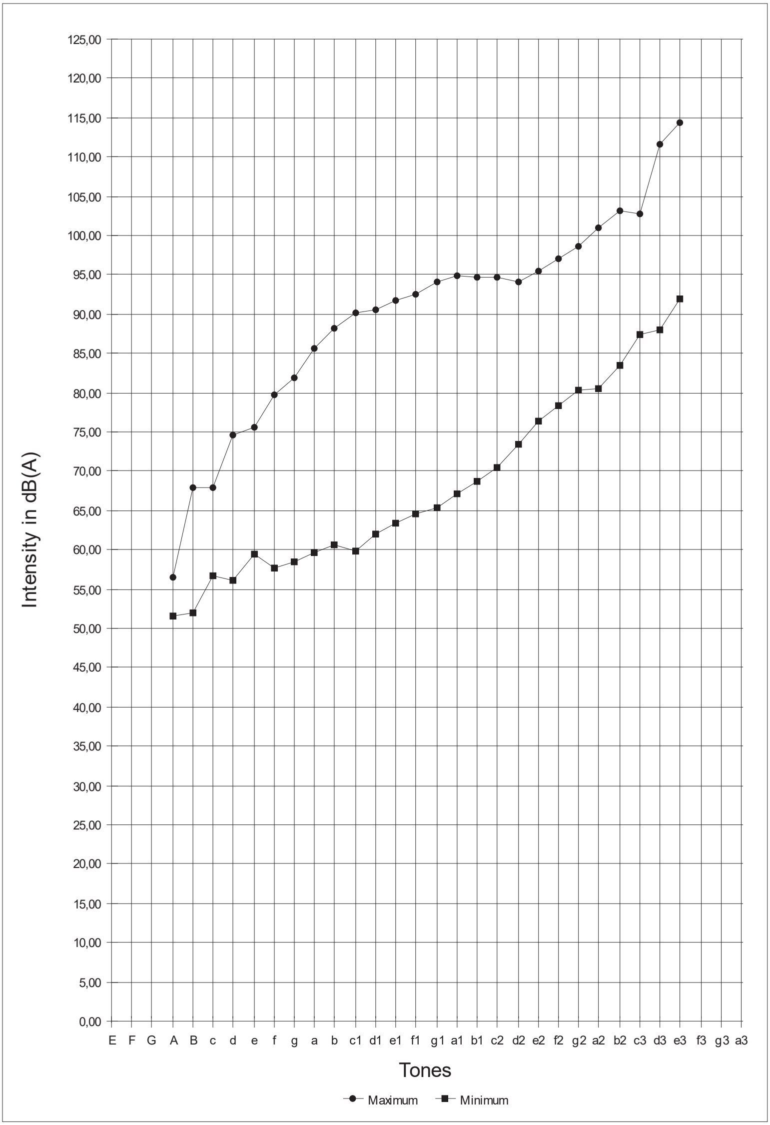


Figure 52: Standard phonetogram for females aged under 18 years.

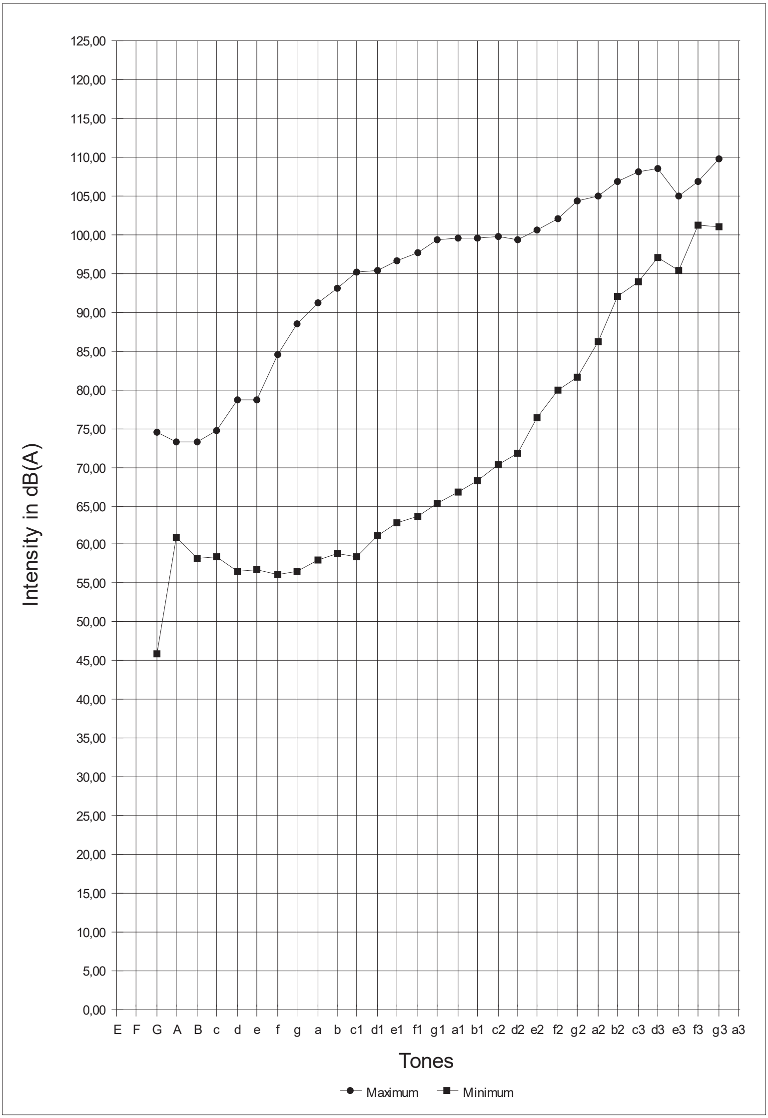


Figure 53: Standard phonetogram for females aged 18 – 29 years.

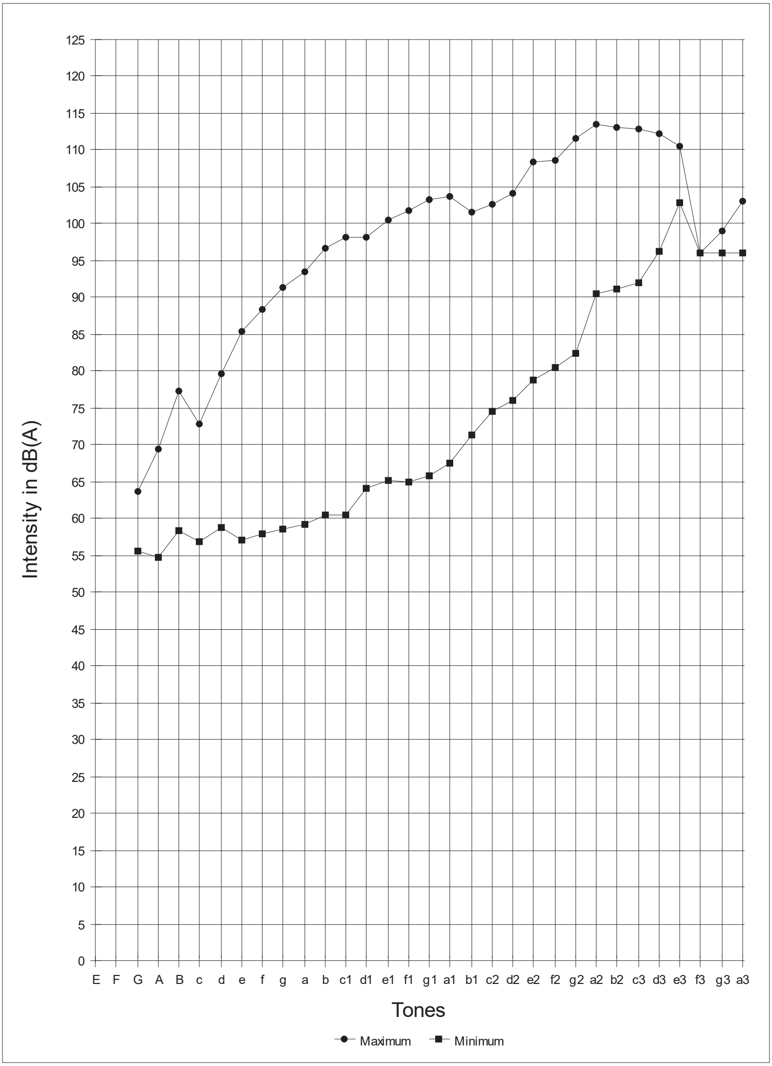


Figure 54: Standard phonetogram for females aged 30- 49 years.

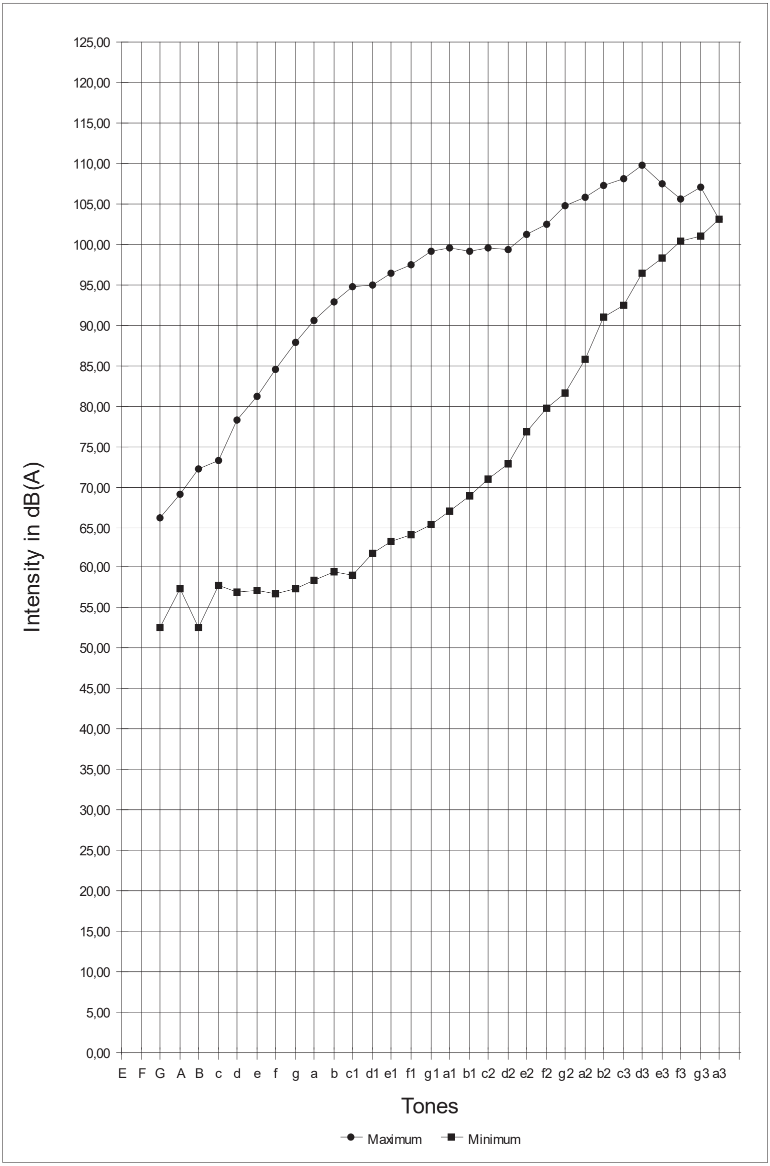


Figure 55: Standard phonetogram for females all ages included.

We compared our “Standard Phonetogram” for females of all ages with the “Normstimmfeld for female voices” featured by Schultz-Coulon[1459] by superposing both average curves for maximum and minimum intensity (Figure 56).

Again, the differences are striking, even when considering that Schultz-Coulon only measured 11 frequencies (4 per octave) which do not completely match which those measured by this author (halve tones versus tones). Moreover, Schultz-Coulon doesn’t mention his age group, nor the aspect of training of his subjects. In our study, however, six more frequencies at the lower end and 8 more frequencies at the upper end of the vocal range are measured; the average minimum curves measured by Schultz-Coulon are up to 10 dB (A) lower than those measured by this author, while the average maximum curves by Schultz-Coulon are up to 21 dB(A) lower than those measured by this author.

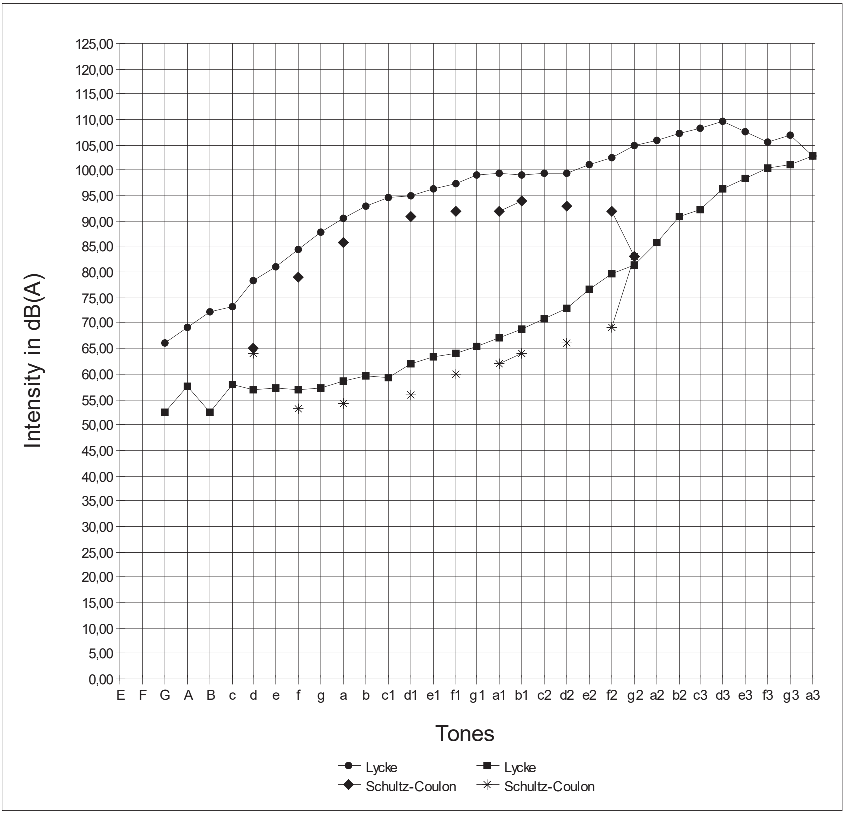


Figure 56: Comparative female Standard F°-SPL curves.

We also compared the extreme values of maximum and minimum intensities and the maximum dynamic range for female voices, cited from the literature by Klingholz[1460] with our own extreme measurements, only to confirm that those data are, again, very divergent.

	Klingholz		Lycke	
Parameter	min.	max.	min.	max.
SPL min. dB(A)	46	48	42	120
SPL max. dB(A)	104	122	54	125
DYN max. dB(A)	30	63	18	60

Table 36: Comparative data intensity measurements of female voices.

The same remarks can be made when comparing the results of children's voices:

	Klingholz		Lycke	
Parameter	min.	max.	min.	max.
SPL min. dB(A)	53	64	47	103
SPL max. dB(A)	92	117	50	110
DYN max. dB(A)	28	56	6	54

Table 37: Comparative data intensity measurements of children's voices.

For further comments we refer to our remarks, concerning the comparative male "Standard F°-SPL curves.

8.5.2.3. Results of the differences between the maximum and minimum intensity measurements of each tone of the vocal range (dynamic range)

An analysis of the global results (for all ages) of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range (dynamic range) of female voices (Figure 57) demonstrates that this clinically important parameter features an irregular Gauss curve.

We can see a very steep increase of the maximum value from the lowest pitches to b (247 Hz). The *maximum dynamic range* is 60 dB(A) on a1 (440 Hz). There is a large, irregular plateau (from a to e2): this is the zone best suited for *extreme voice dynamics*: between 53 dB(A) and 60 dB(A) for exceptional voices. There is a sharp decrease in maximum dynamic range on f2 (698 Hz), then an increase up to b2, followed by a very sharp decrease up to the highest pitches.

The *minimum values* of the differences between the maximum and the minimum intensity measurements are, as expected, very irregular and vary between 0 dB(A) and 12 dB(A). The maximum and minimum values of intensity approach at the highest and lowest pitches. In many cases, frequencies can only be phonated at maximum intensity! This is an important observation for clinical practice. The best results are obtained in the region a-a1.

The *average dynamic range* features a more regular Gauss curve. After a sharp increase from the lowest pitches up to c1 (262 Hz), there is a small plateau up to a1 (440Hz), characterized by intensity fluctuations around 33 dB(A) and followed, again, by a sharp decrease in dynamic range up to the highest pitches.

Colton[1442] found 26 dB as average difference for modal register phonations and 13 dB (for the non-singers) to 18 dB (for the singer subjects) for falsetto phonations. Interestingly, he found that significant differences in sound pressure level between his two subjects groups occurred at only a few experimental conditions.

Sulter et al.[1446] reported an average difference of 39,1 dB for untrained female subjects.

As expected, *standard deviations* are high: between 8 and 13 dB(A).

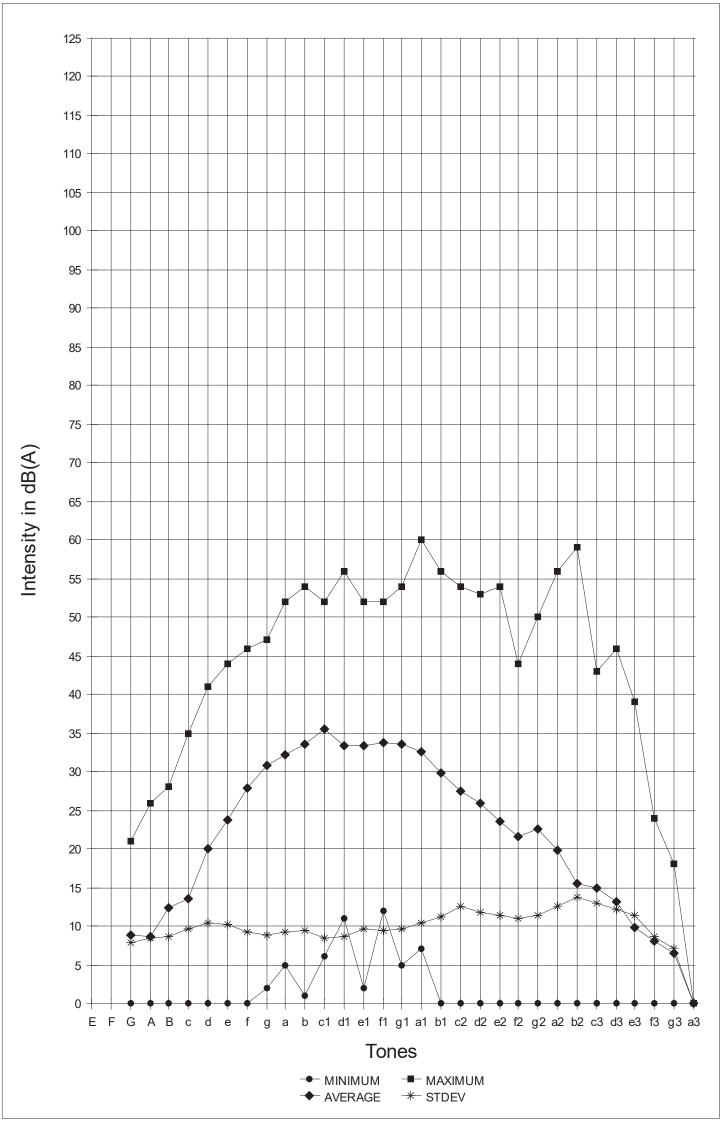


Figure 57: Minimum, maximum, average and standard deviation of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range. (dynamic range) in females of ages 8 – 59 years (N = 133).

When we consider the age-related results, based on Figures 58, 59, and 60, there are some differences. The best results of *maximum dynamic range* are obtained by the 18-29 years old age group, indicating much better vocal capacities. Then follow the –18 years old girls. The 30-49 years group of women thus produce less maximum dynamic range capacities than the two other groups. In the study of Coleman and Mott[1456] , the greatest SPL range on a single pitch for 9 young females ranging in age from +/- 10 – 13 years, was 49 dB(A), while we measured 54 dB(A) for the age group under 18 years. In 12 adult females, from 2 to 39 years of age, Coleman et al.[1457], the greatest SPL range on a single pitch was 63 dB(A), comparable to the maximum dynamic range of 60 dB(A) we measured in our female subjects in the age groups 18 – 29 years.

The age-group of 30-49 years old women features *minimum dynamic ranges.* In many cases, however, and above all, at the extremes of the vocal range, maximum intensities equal minimum intensities.

Coleman[1241] mentions 50-55 decibels as an average range of intensity readings in female adolescent voices, which seems quite large, compared to the maximum SPL ranges, mentioned by the same author(s). Our female subjects under 18 years only had a maximum average range of 32,7 dB(A).

The best *average results of dynamic range* are obtained by the 18-29 and the 30-49 years old group: 36,5 dB(A) and 35,62 dB(A) respectively. The 18-29 years old females obtain better results in the lower vocal range, while the 30-49 years old women have the best results at frequencies above the zones of register change.

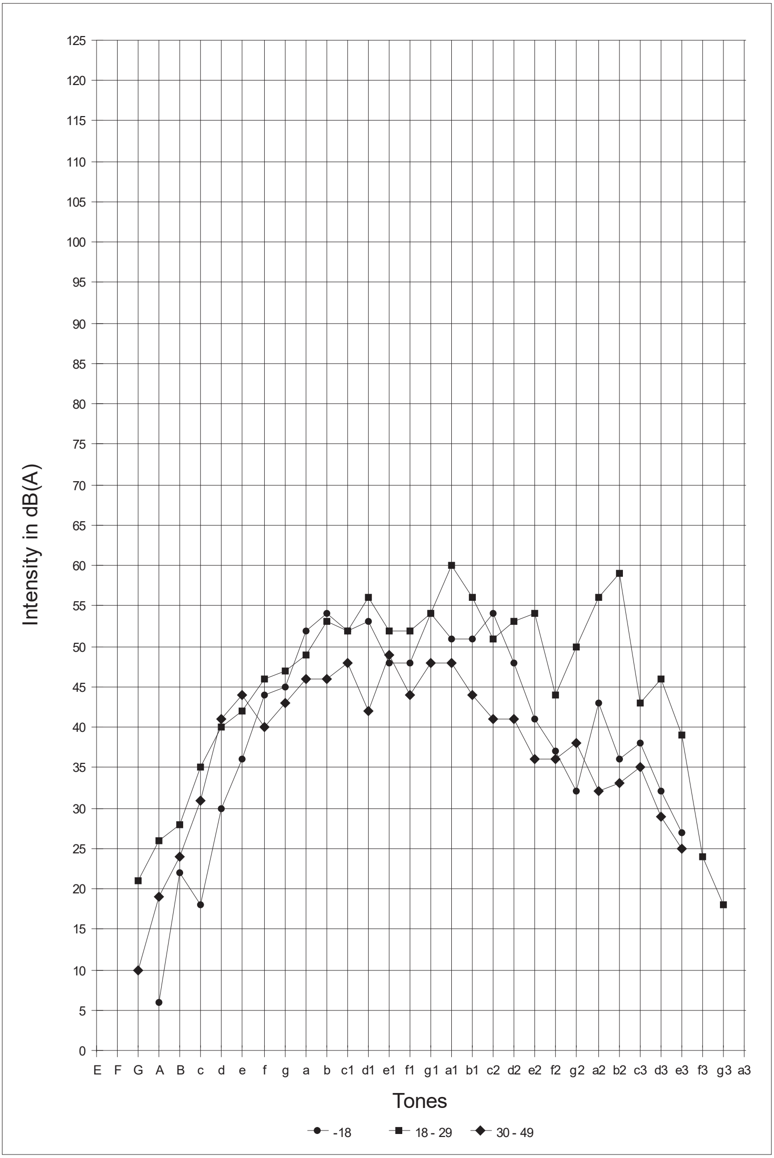


Figure 58: Comparison of maximum values of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range. (dynamic range) for different age-groups in females (N = 132).

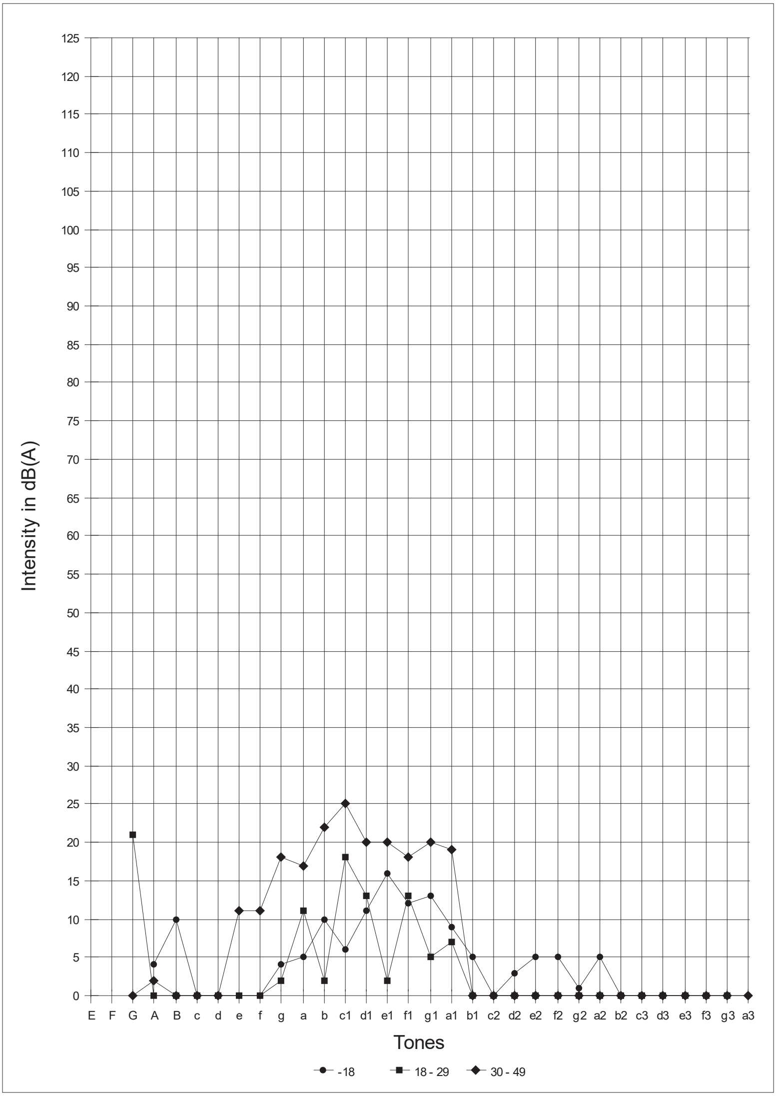


Figure 59: Comparison of minimum values of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range. (dynamic range) for different age-groups in females (N = 132).

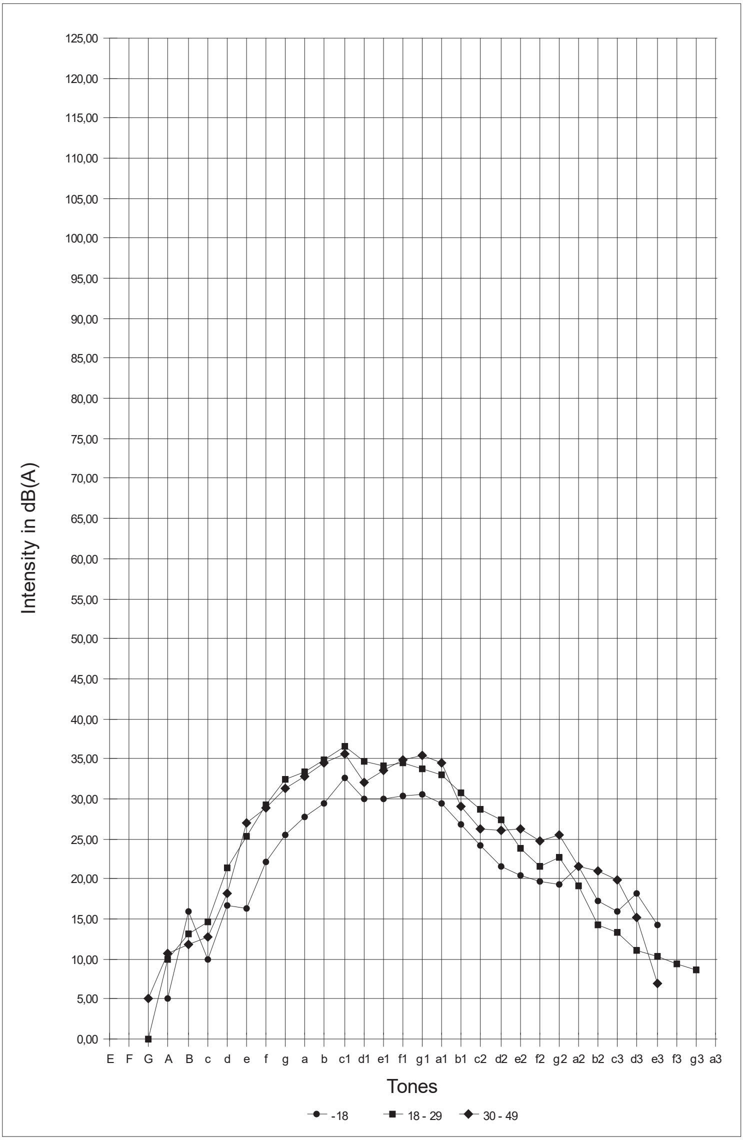


Figure 60: Comparison of average values of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range. (dynamic range) for different age-groups in females (N = 132).

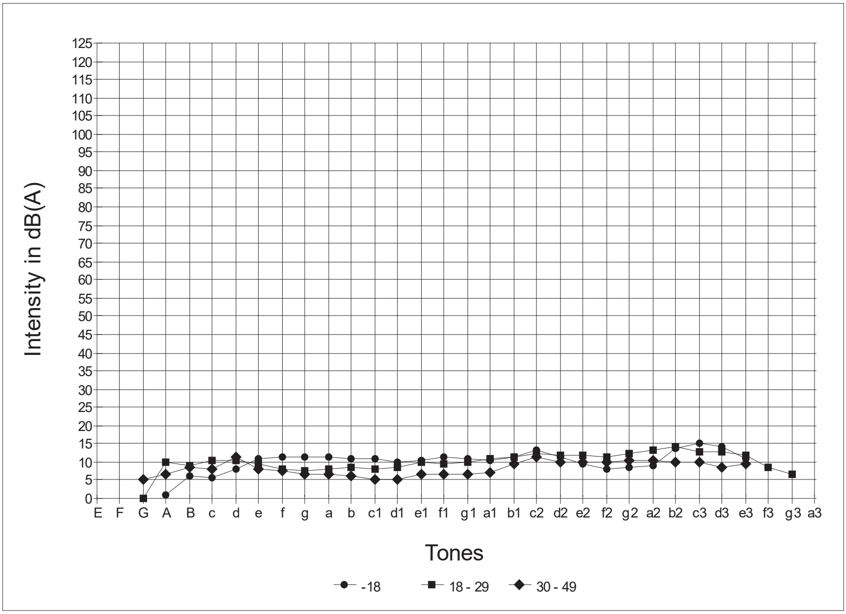


Figure 61: Comparison of standard deviation values of the differences between the maximum and the minimum intensity measurements of each tone of the vocal range. (dynamic range) for different age-groups in females (N = 132).

The next Figures 62, 63, 64, and 65 can be useful in clinical practice as a *pattern card of the human voice*. We divided our results of dynamic range measurements in *4 octave zones,* enabling clinicians to gather information on specific zones of the vocal range and to compare their results with ours.

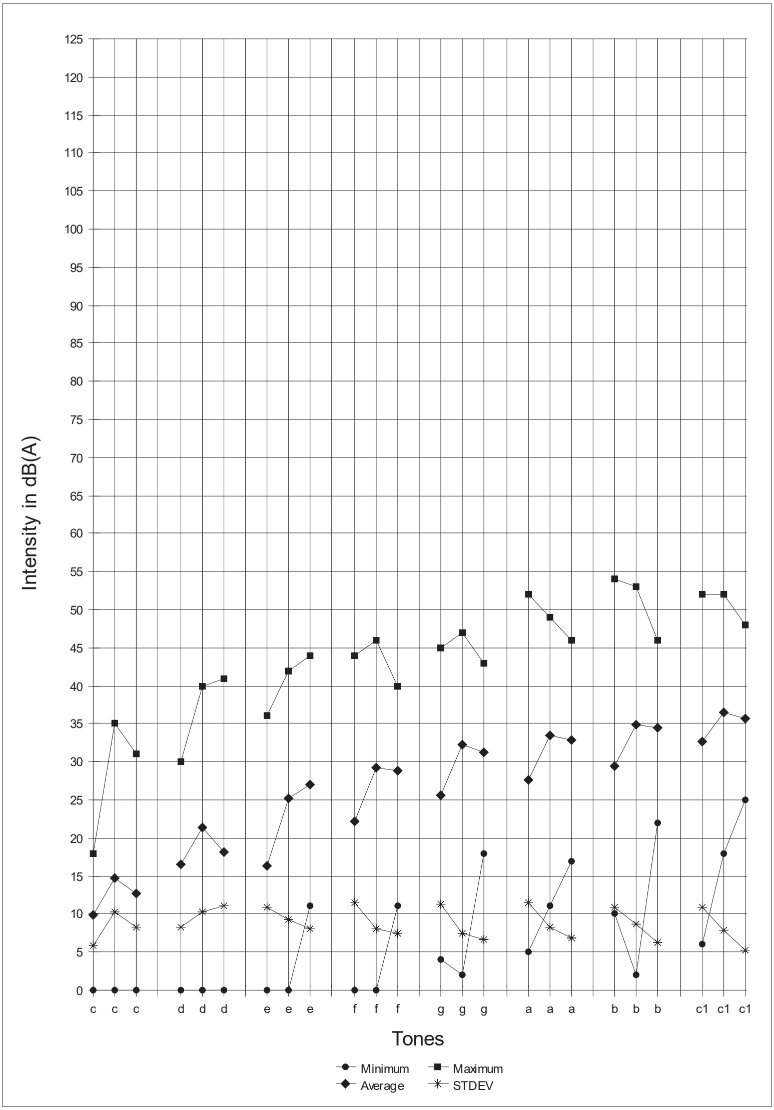


Figure 62: Results of variations of dynamic range measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c-c1. (N = 132).

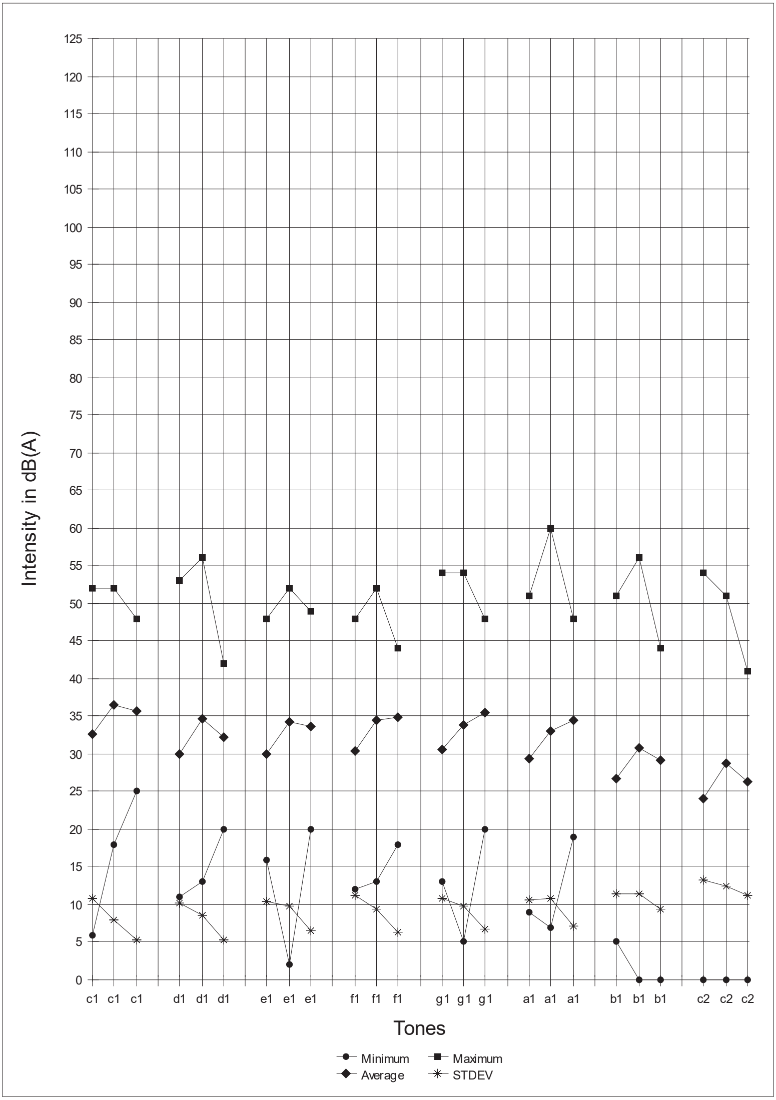


Figure 63: Results of variations of dynamic range measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c1-c2. (N = 132).

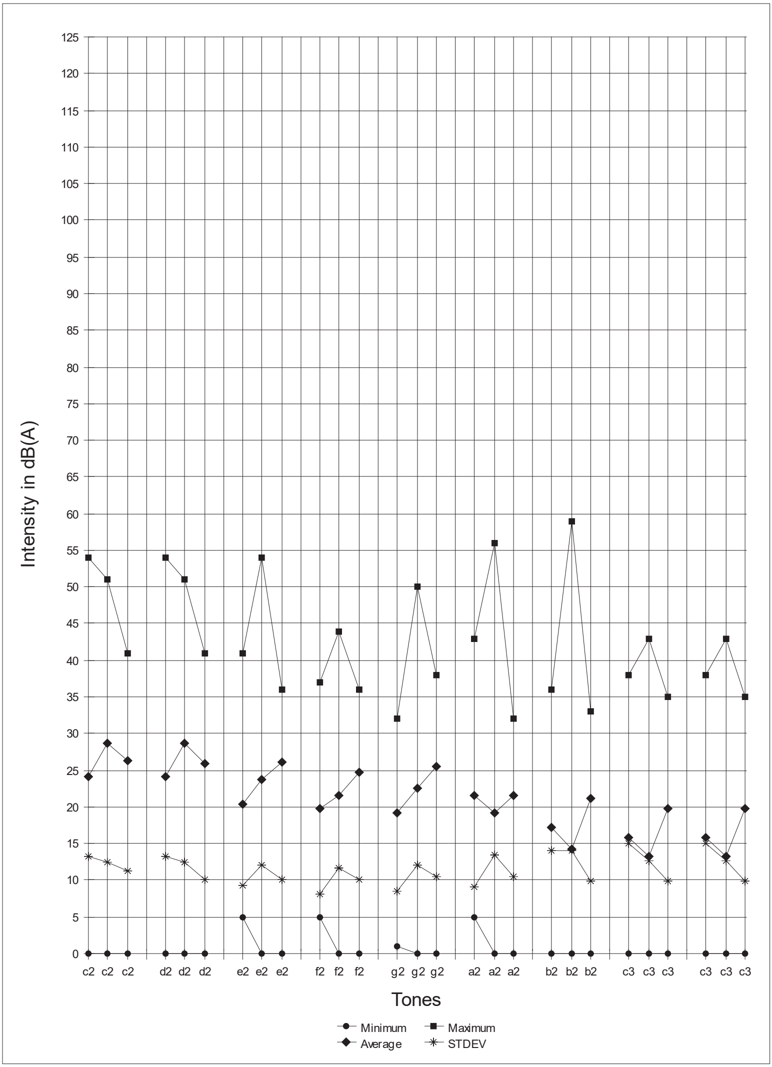


Figure 64: Results of variations of dynamic range measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c2-c3. (N = 132).

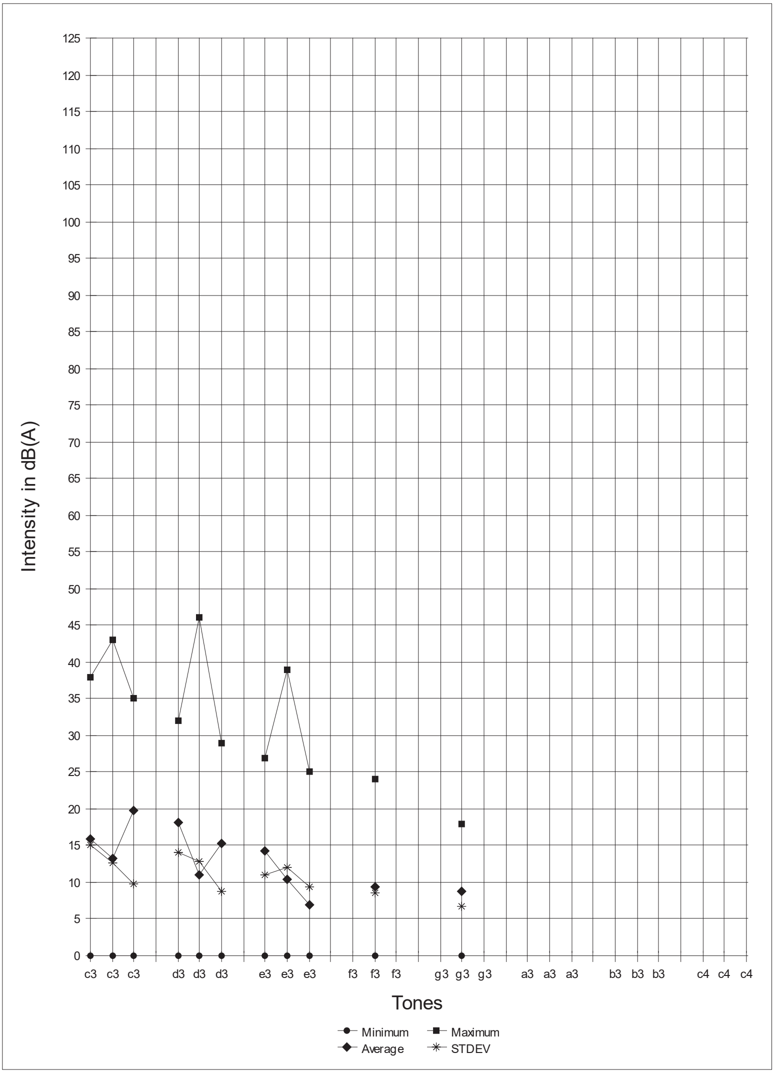


Figure 65: Results of variations of dynamic range measurements for each age group (the first notation relates to the age group under 18 years, the second to the age group of 18-29 years and the third to the age group of 30- 49 years) in the female voice range c3-c4. (N = 132).

As we mentioned above, the results of the differences between the maximum and minimum intensity measurements of each tone of the vocal range (**dynamic range**) are considered as an important parameter in the interpretation of the phonetogram. However, the possible relationship with voice classification is still not established. Let us look a little closer at the results of our own group of subjects.

Here again, we repeat our conviction that ALL frequencies must be analysed. Taking notice again of Table 6, indicating the limits of voice range / tessitura of the basic voice categories, we can say that the tones A and lower undoubtedly must correspond to a contralto voice, whatever their dynamic range might be. Higher pitches, however, can correspond to a higher voice category. That's why we think it is worthwhile to scrutinize the results of the variations of the **dynamic range** of our subjects within the range B – a as an illustration of how these ascending pitches and their corresponding variations in dynamic range in the lower part of the female voice range are connected to voice categories.

B	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	10	22	16,00	6,00000	10,00 - 22,00
18-29 years	0	28	13,07	8,91599	4,15 - 21,98
30-49 years	0	24	11,80	8,37616	3,42 - 20,17
c	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	0	18	9,88	5,90418	3,97 - 15,78
18-29 years	0	35	14,62	10,22329	4,39 - 24,84
30-49 years	0	31	12,75	8,23483	4,51 - 20,98
d	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	0	30	16,62	8,23257	8,38 - 24,85
18-29 years	0	40	21,35	10,18539	11,16 - 31,53
30-49 years	0	41	18,11	11,15491	6,95 - 29,26
e	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	0	36	16,23	10,79954	5,43 - 27,02
18-29 years	0	42	25,26	9,33955	15,92 - 34,59
30-49 years	11	44	27,00	7,98123	19,01 - 34,98
f	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	0	44	22,14	11,45464	10,68 - 33,59
18-29 years	0	46	29,27	7,99910	21,27 - 37,26
30-49 years	11	40	28,86	7,52321	21,33 - 36,38
g	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	4	45	25,57	11,38583	16,18 - 36,95
18-29 years	2	47	32,35	7,42445	24,92 - 39,77
30-49 years	18	43	31,29	6,64862	24,64 - 37,93
a	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	5	52	27,70	11,52855	16,17 - 39,22
18-29 years	11	49	33,40	8,25939	25,14 - 41,65
30-49 years	17	46	32,81	6,82864	25,98 - 39,63

Table 38: Variations in dynamic range measurements and differentiating ranges (= average maximum intensity +/- the standard deviations) of female voices.

These data could again give indications for specific voice categories: dynamic ranges below the lowest value of the differentiating range belong to a higher voice category, dynamic ranges above the highest value of the differentiating range belong to a lower voice category. Let us take again the tone e as an example:

e	Differentiating range	Alto	Soprano
< 18 years	5,43 - 27,02	> 27,02	< 5,43
18 - 29 years	15,92 - 34,59	> 34,59	< 15,92
30 - 49 years	19,01 - 34,98	> 34,98	< 19,01

Table 39: example of interpretation of the differentiating range between the values of minimum intensities in dB(A), specific for altos and sopranos (tone e).

The data provided for *each* tone, combined with the differentiating range, allow a gradual survey of how the minimum intensities of a given voice evolve within a specific voice category.

Again, the proposed method is to be interpreted as just one step in the step-to-step methodology of voice classification by phonetography.

8.5.2.4 Results of the differences between the minimum values of the maximum and the maximum values of the minimum intensity measurements of each tone of the vocal range

It could be interesting to compare these results, based on the Figures 36 and 44. As for male voices, the maximum values of the minimum intensity measurements of female voices of all ages are higher than the minimum values of the maximum intensity measurements.

The clinical aspects of these findings still must be studied.

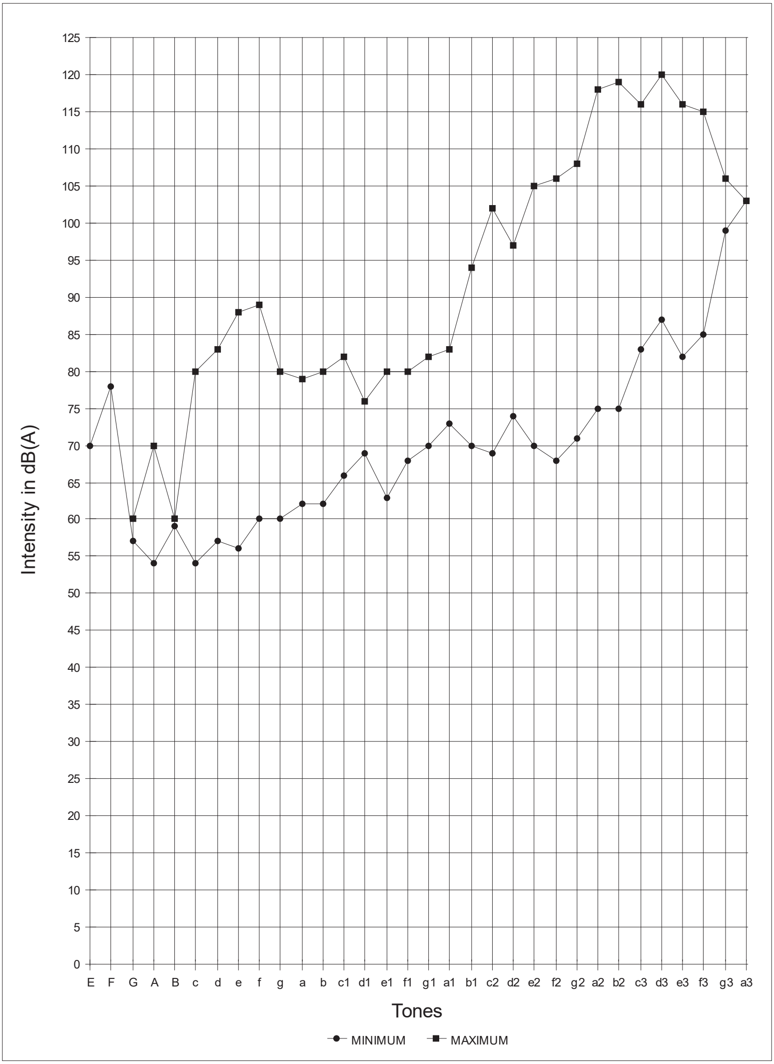


Fig. 66: Results of the differences between the minimum values of the maximum and the maximum values of the minimum intensity measurements of each tone of the vocal range in females of all ages. (N = 133).

8.5.3. Comparison between male and female voices

In the preceding pages, a complete survey was given of the results of different intensity measurements of male (ages 10-76 years) and female (ages 8-65 years) subjects. This mapping of different frequency and intensity capacities, tone by tone, provides a useful *clinical pattern card of the human voice*. Unfortunately, our results, completed by analysis and discussion, are not thoroughly comparable with those of other authors, because of different methodologies and lack of sufficient data.

As mentioned before, these different parameters, constituting the basic elements of a phonetogram, will be used later in our *step-by-step procedure of voice classification.*

Our analysis of the different parameters of intensity, revealed by VRP-analysis, not only demonstrated the *important influence of age* on the individual results, but also provided some hints about the *different results obtained by male and female subjects*.

To complete our study on voice intensity measurements, *we wondered what the differences would be between male and female subjects.* To this end we compared the maximum, minimum and dynamic range profiles of both genders by superposing them. *In a first effort, both profiles were mapped in the same Figure. In a second (adapted) Figure, the female profile was projected one octave lower (to fit the male profile).*

The *first method* is of interest for composers, musicians, (choir) conductors and other people involved in music performances, because *these graphs demonstrate the behaviour of mixed human voice categories of both genders, assembled in three age groups. This study of the minima, maxima and average intensity measurements at certain frequencies give an idea of what can be obtained by a group of different singers to interpret a given score. However, by superposing the profiles of both sexes, ignoring the one octave difference between both, the second method enables researchers and clinicians to compare the performances of male and female subjects in comparable conditions (the one octave difference between the genders is equalized).*

8.5.3.1. Comparison of maximum intensity measurements of each tone of the vocal range

As we stated before, our phonetographic results present a mixture of all kinds of voice categories, even in the so-called averaged or normalized phonetograms.

Nevertheless, it could be interesting to have a closer look at the *differences of the extreme and mean results of maximum intensity of both sexes.*

Musical scores do take notice of the octave difference between the genders. This means that, when both sexes sing an equal note, the male singer, for instance, sings c1 and the female singer c2. *In these unequal circumstances, we can see that the produced intensity is different too between the sexes.* We schematized the best results of the different age groups of both sexes in the next Table 40, according to both methods:

MAXIMUM		MINIMUM	MAXIMUM	AVERAGE
Under 18 years	1st method	Boys	Mixed	Boys
	2nd method	Mixed	Girls	Girls
18 - 29 years	1st method	Males	Males	Males
	2nd method	Males	Females	Females
30 - 49 years	1st method	Males	Mixed	Males
	2nd method	Mixed	Females	Females

Table 40: Comparison (*grosso modo*) of the best results of maximum intensity measurements of male and female subjects of different age categories.

As can be seen, according to the *first method*, and with exception of the highest frequencies, male subjects of all ages generally score best. Even when excluding the extremes of vocal range, a difference of as much as 20 dB(A) can be noted on e (*minimum value of maximum intensity*) and on B (*maximum value of maximum intensity*) between boys and girls under 18 years old.

The *second method*, however, offers quite another picture: only males in the age group of 18-29 years produce higher *minimum values of maximum intensity* than females of the same age group (up to 19 dB(A) on e). Female subjects of all ages, however, score better for *maximum and average values of maximum intensity*.

Sulter et al[1461,1462] reported that female subjects produced louder phonation at specific parts of their comparable (averaged) frequency ranges. They also concluded that "*the fact that specific differences in mean intensity levels between male and female subjects have been ascertained is an indication that male and female results might preferably be discussed separately in future studies.*

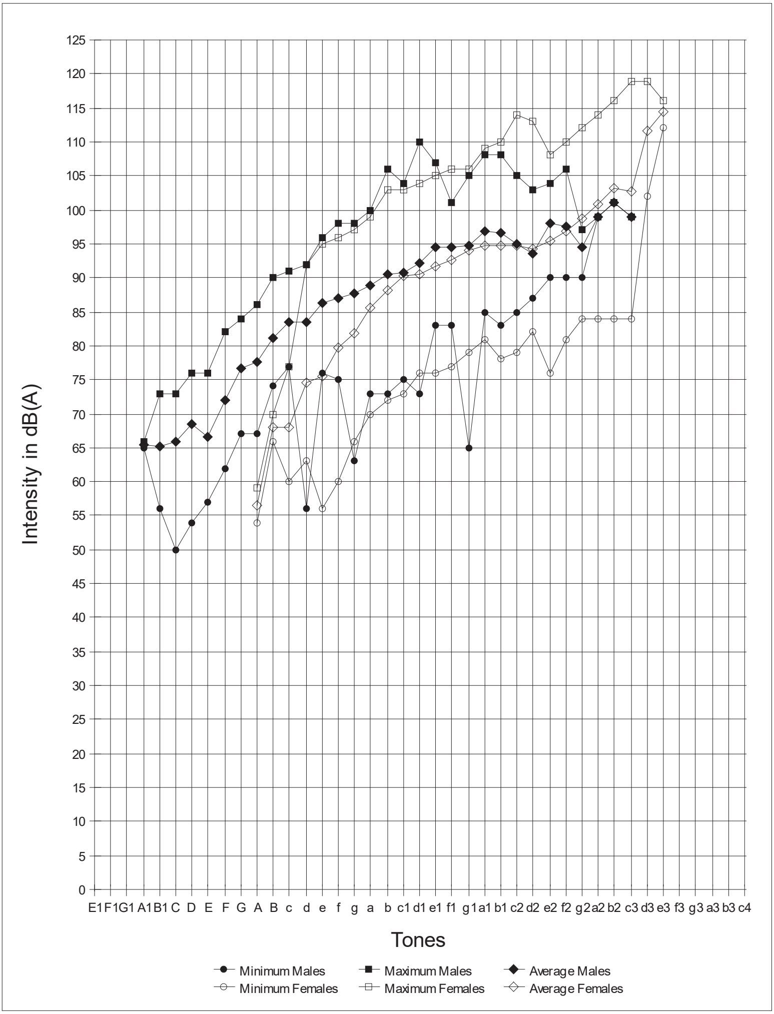
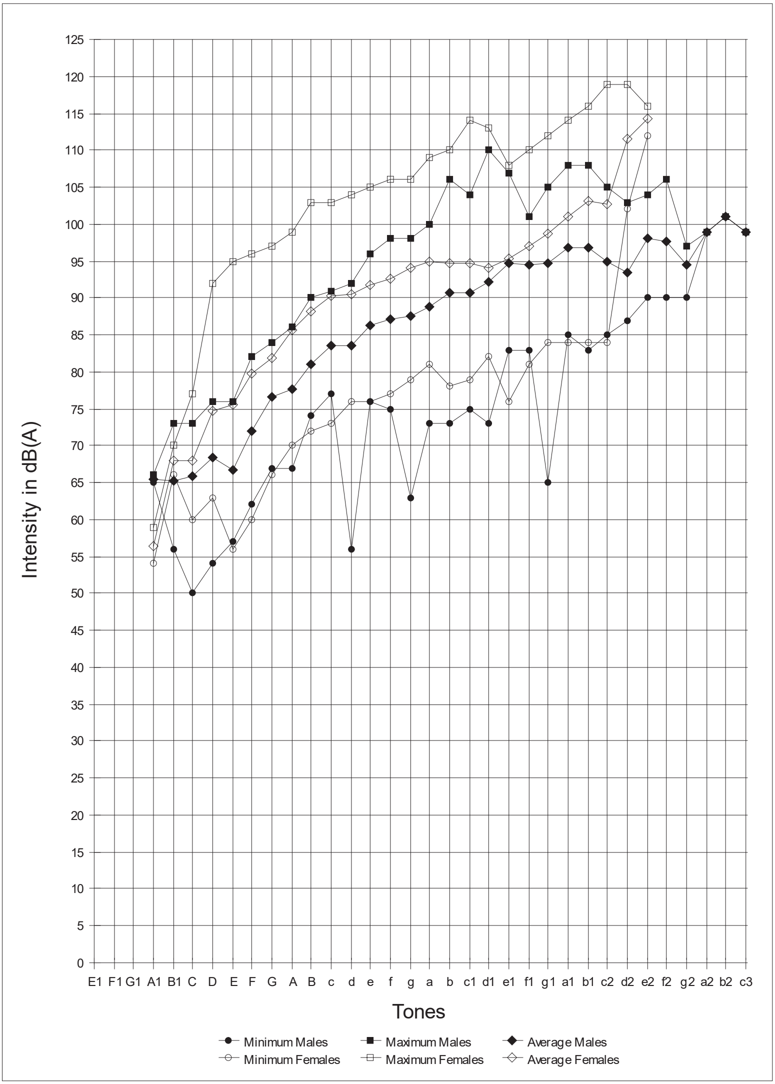


Figure 67: Comparison of maximum, minimum and average values of maximum intensity measurements between males and females under 18 years.



Adapted Figure 67: Comparison of maximum, minimum and average values of maximum intensity measurements between males and females under 18 years.

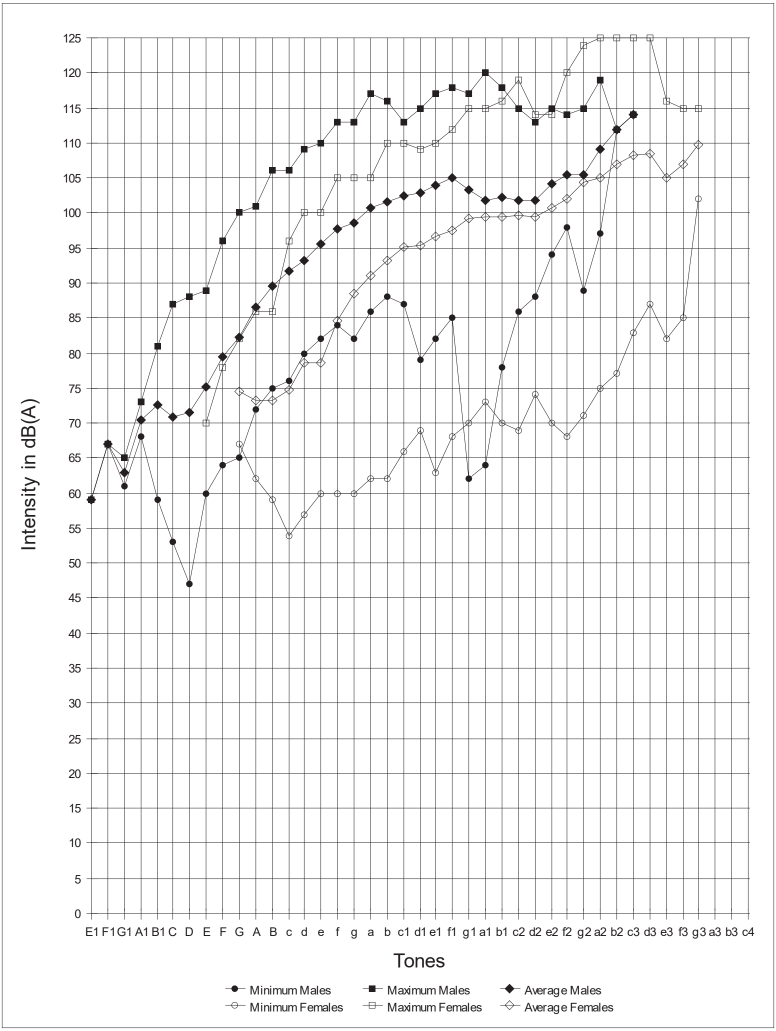
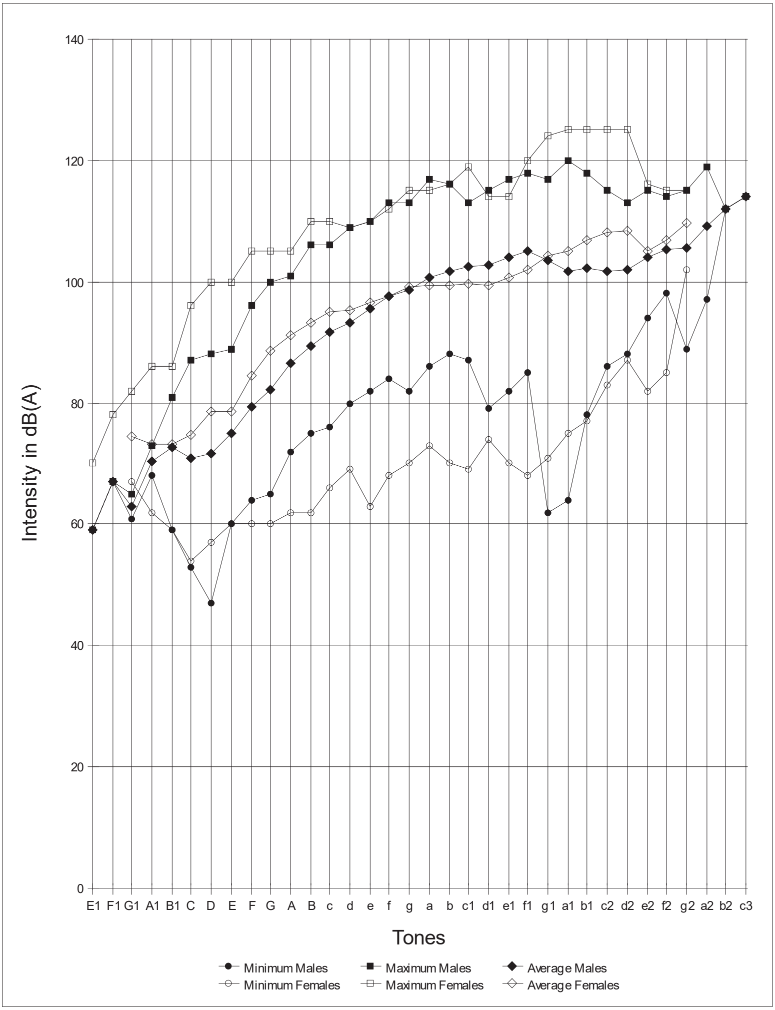


Figure 68: Comparison of maximum, minimum and average values of maximum intensity measurements between males and females (18-29 years).



Adapted Figure 68: Comparison of maximum, minimum and average values of maximum intensity measurements between males and females (18-29 years)

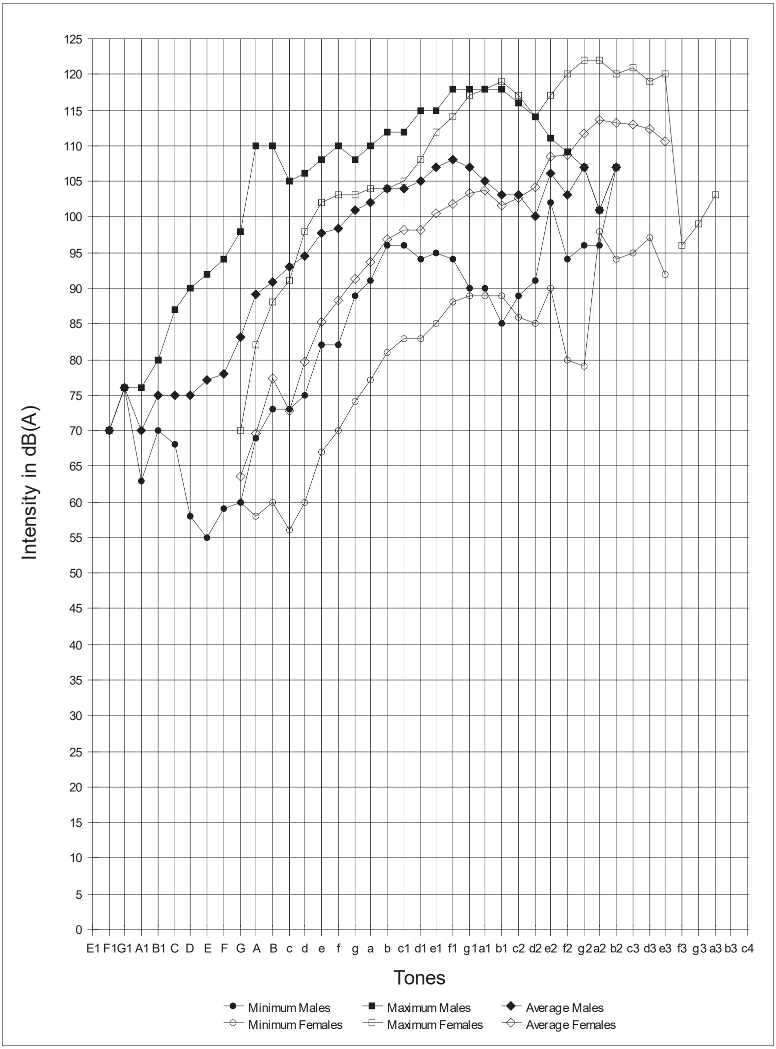
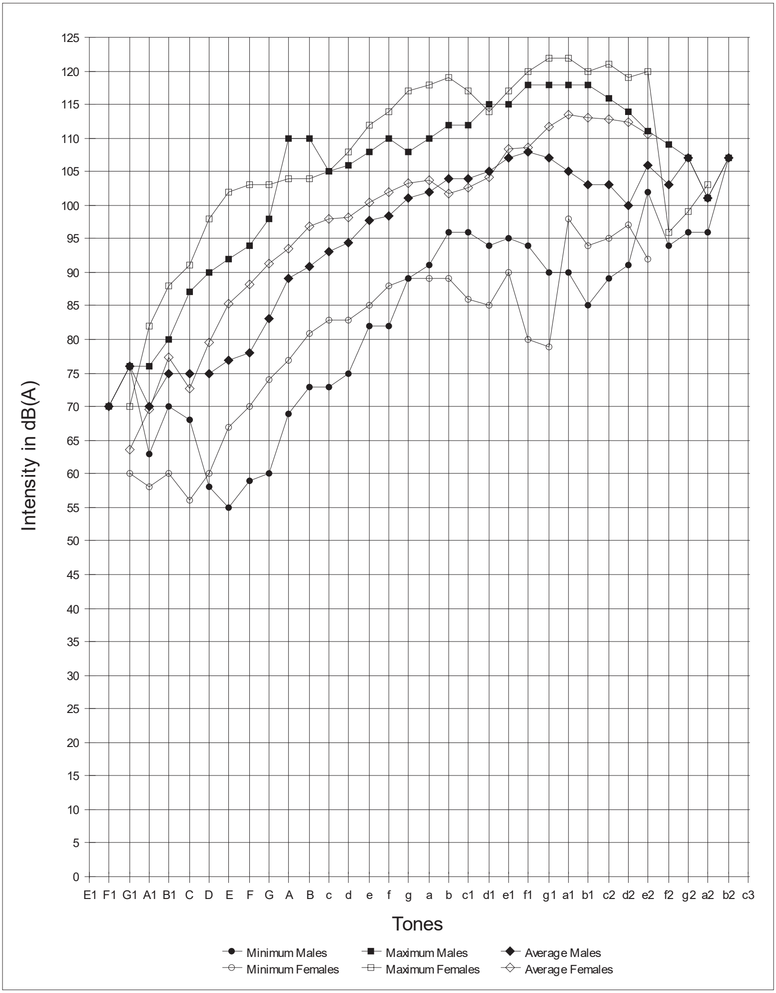


Figure 69: Comparison of maximum, minimum and average values of maximum intensity measurements between males and females (30-49 years).



Adapted Figure 69: Comparison of maximum, minimum and average values of maximum intensity measurements between males and females (30-49 years).

8.5.3.2. Comparison of minimum intensity measurements of each tone of the vocal range

Table 41 gives a *global* idea of the best results of minimum intensity measurements of male and female subjects of different age categories:

MINIMUM		MINIMUM	MAXIMUM	AVERAGE
Under 18 years	1st method	Girls	Mixed	Girls
	2nd method	Boys	Boys	Boys
18 - 29 years	1st method	Females	Mixed	Females
	2nd method	Females	Males	Males
30 - 49 years	1st method	Females	Mixed	Females
	2nd method	Males	Males	Males

Table 41: Comparison (*grosso modo*) of best results of minimum intensity measurements of male and female subjects of different age categories.

As can be seen, according to the *first method*, female subjects of all ages score best in producing the softest tones, with exception for the highest pitches. Even when excluding the extremes of vocal range, a difference of as much as 11 dB(A) can be noted on g1 (*minimum value of minimum intensity*) between boys and girls under 18 years old. There is also a difference up to 11 dB(A) on g1 and 13dB(A) on a1 between the *average values* of minimum intensity for both genders. For the average values of minimum intensity, females of all ages score better.

According to the *second method*, however, males in every age group produce lower *minimum values of minimum intensity* than females, with exception for the age-group 18-29 years. There is a difference up to 10 dB(A) on b and on d1 between boys and girls under 18 years. The *maximum value of the minimum intensity* can amount to 16 dB(A) difference (on d1). For the average values, males of all ages score better.

Sulter et al[1461] too, mention that male subjects can produce softer phonations.

Comparison of maximum, minimum and average values of minimum intensity measurements between males and females under 18 years.

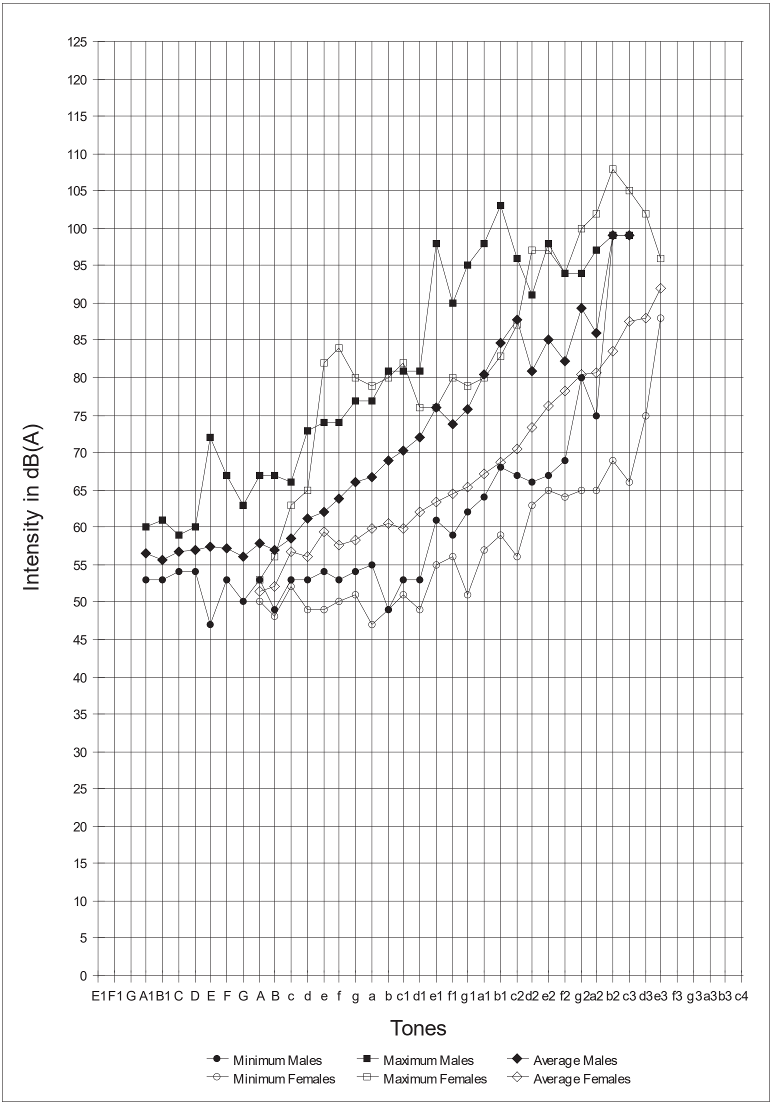
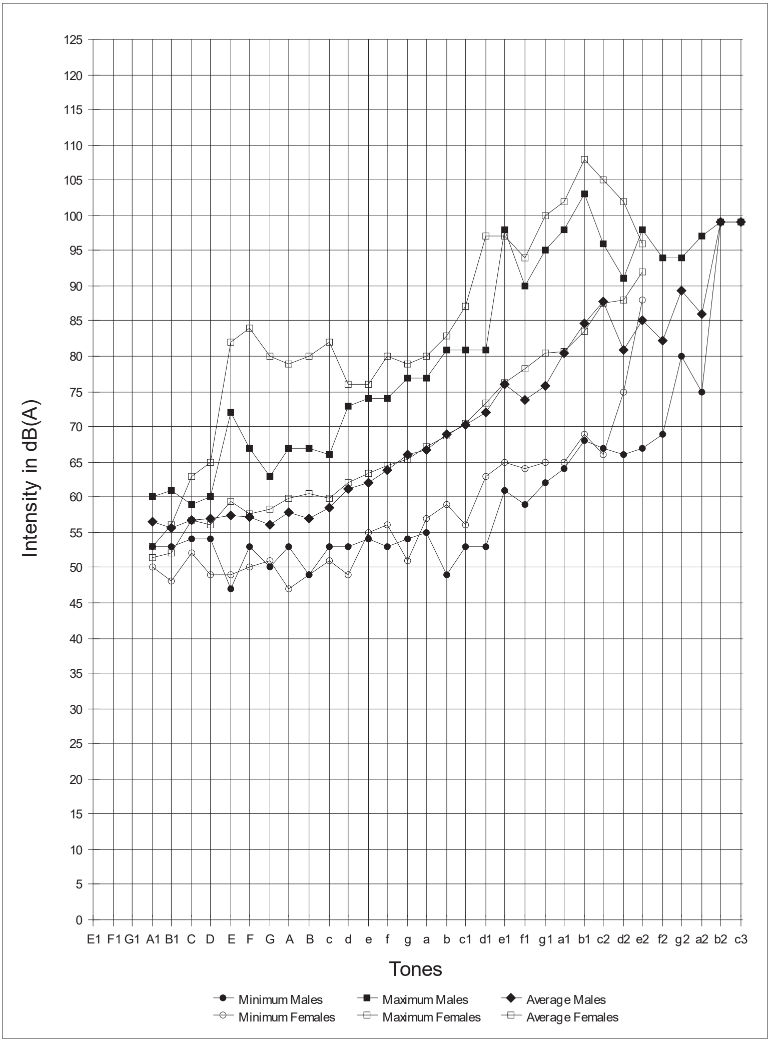


Figure 70: Comparison of maximum, minimum and average values of minimum intensity measurements between males and females under 18 years.



Adapted Figure 70: Comparison of maximum, minimum and average values of minimum intensity measurements between males and females under 18 years (adapted).

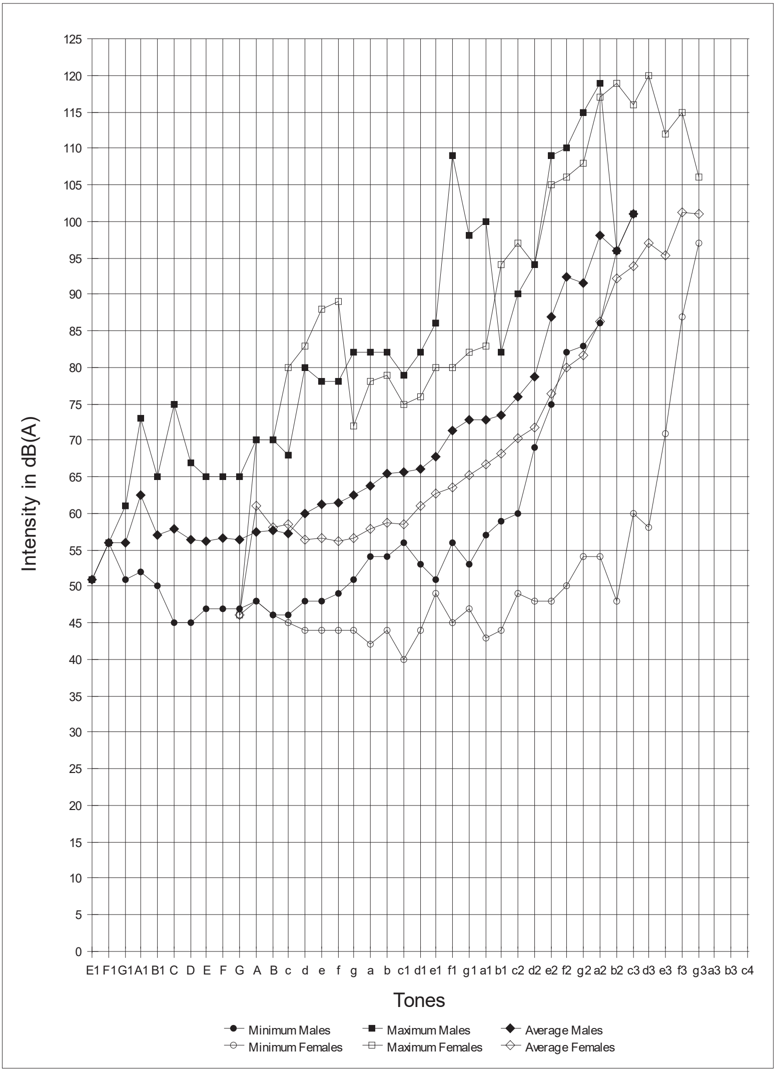
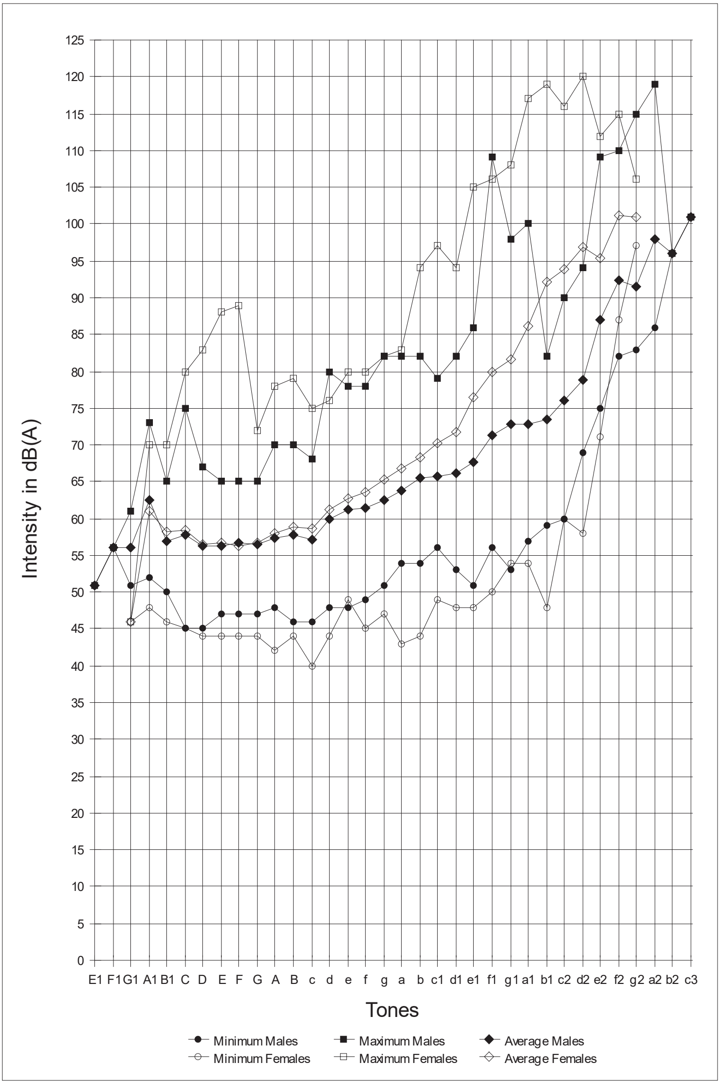


Figure 71: Comparison of maximum, minimum and average values of minimum intensity measurements between males and females (18-29 years).



Adapted Figure 71: frequencies of female subjects are projected one octave lower to fit the male frequencies (starting at E1 = E): adapted.

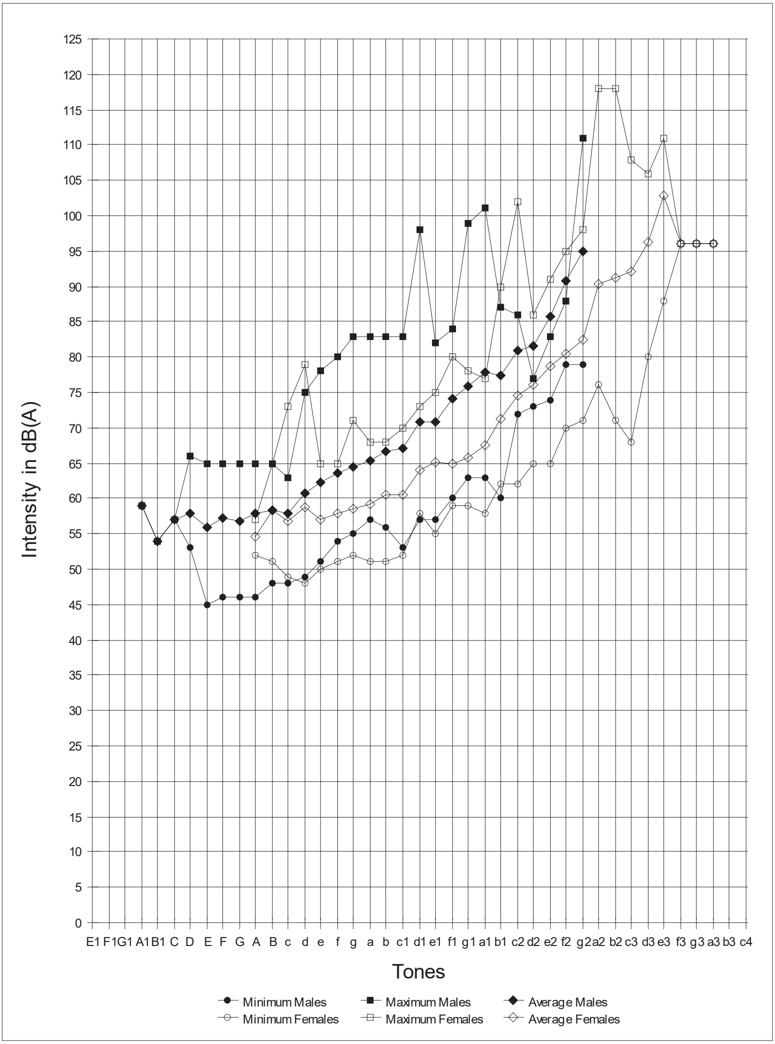
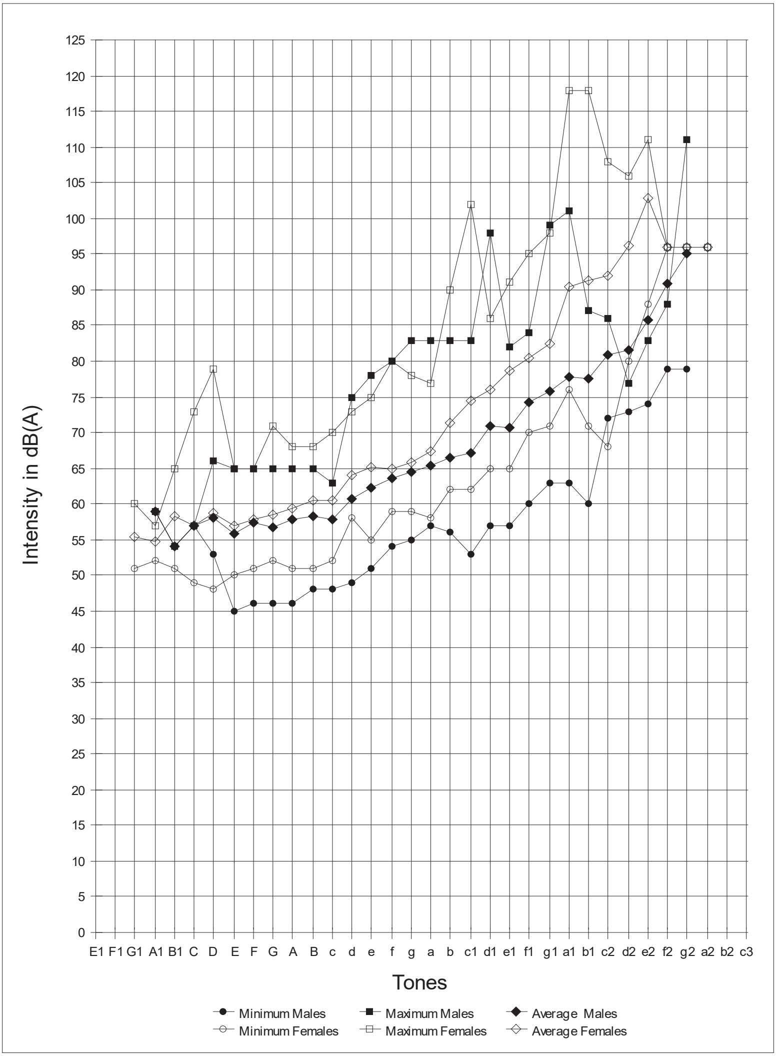


Figure 72: Comparison of maximum, minimum and average values of minimum intensity measurements between males and females (30-49 years).



Adapted Figure 72: frequencies of female subjects are projected one octave lower to fit the male frequencies (starting at E1 = E).

8.5.3.3. Comparison of dynamic range measurements of each tone of the vocal range

Next Table 42 still provides another picture of the complex relationship of intensity measurements between the two genders:

DYN. RANGE		MINIMUM	MAXIMUM	AVERAGE
Under 18 years	1st method	Boys	Mixed	Boys
	2nd method	Mixed	Girls	Girls
18 - 29 years	1st method	Males	Males	Males
	2nd method	Males	Females	Females
30 - 49 years	1st method	Males	Males	Males
	2nd method	Mixed	Females	Females

Table 42: Comparison (grosso modo) of best results of dynamic range measurements of male and female subjects of different age categories.

The results for all ages and genders are very divergent. Even *average differences* of dynamic range can exceed 30 dB (A), with *standard deviations* up to 13 dB(A).

Böhme and Stuchlick[1463] reported that the average intensity range of the boys is louder than the average range of the girls.

According to the *second method*, the results resemble those of the maximum intensity measurements. Female subjects generally show the largest dynamic range when frequencies are equalized.

Sulter et al.[1462] reported that their female *untrained* male subjects have a larger dynamic range (42,8 dB) than their *untrained* female subjects (39,1 dB) at the 40% frequency level of their averaged phonetograms. Their female *trained* subjects, however, have the largest dynamic range, but they stress the larger dynamic capacities of the group of *basses* and *baritones* at low-frequency levels, confirming our basic hypothesis and conclusions.

In Chapter 9 some interesting cases will be provided to demonstrate the great influence of logopedic voice training/therapy on the results of dynamic range measurements in both sexes.

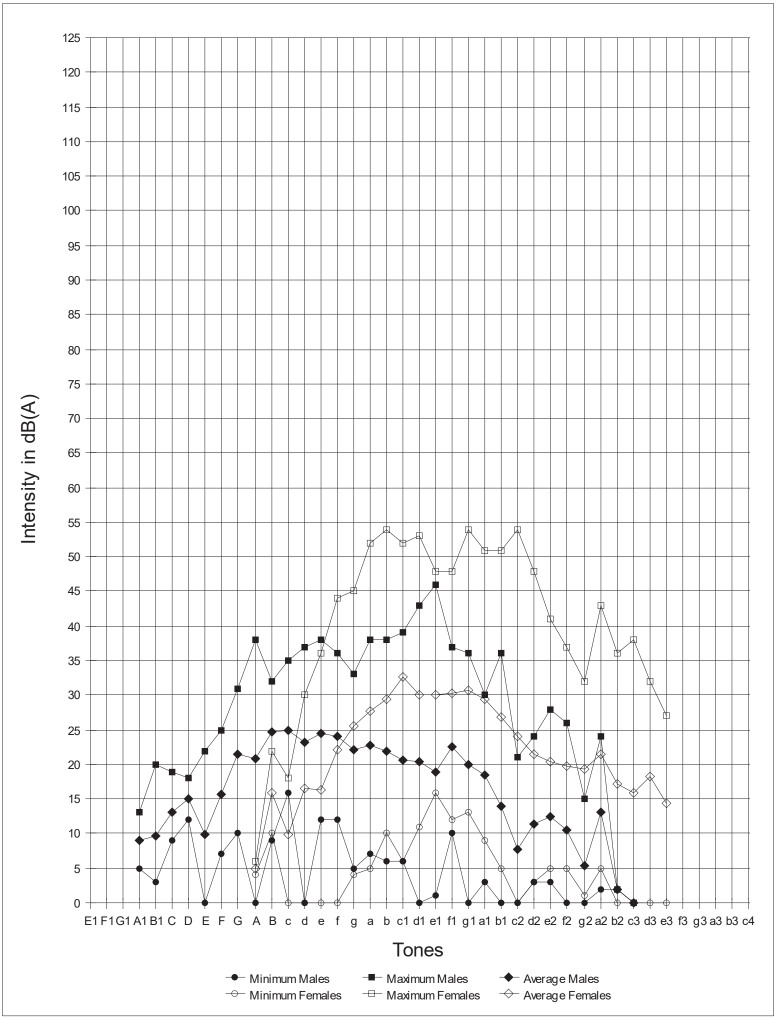
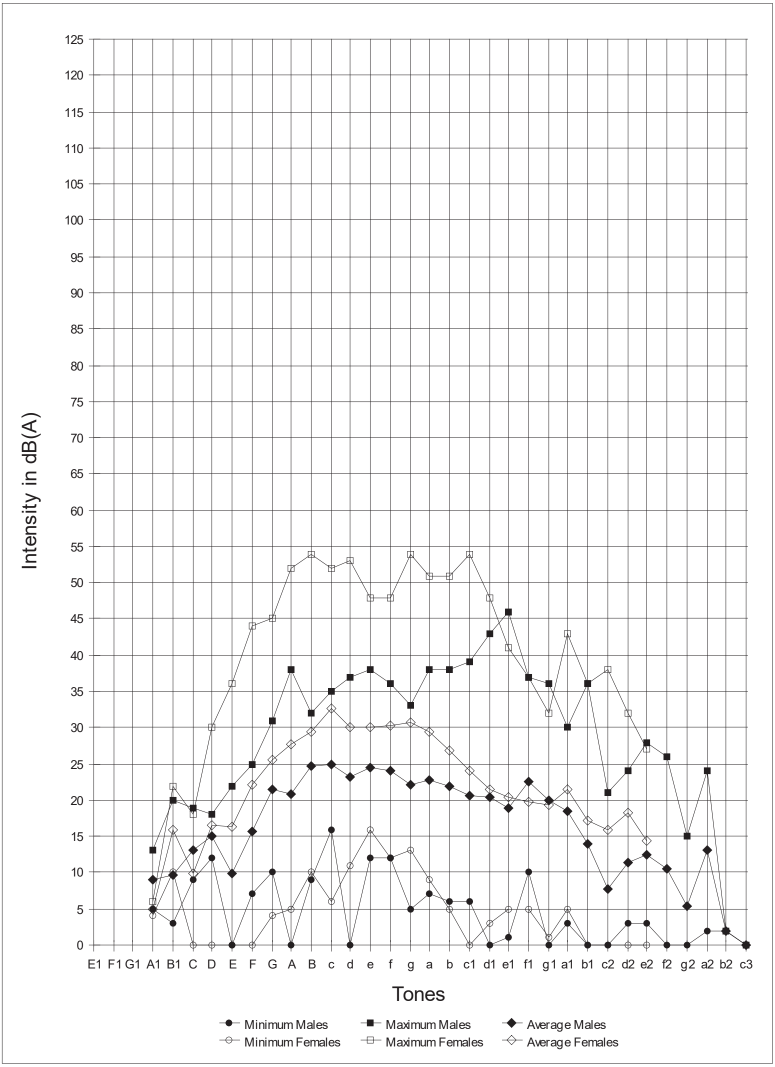


Figure 79: Comparison of maximum, minimum and average values of dynamic range measurements between males and females under 18 years.



Adapted Figure 79: frequencies of female subjects are projected one octave lower to fit the male frequencies (starting at E1 = E).

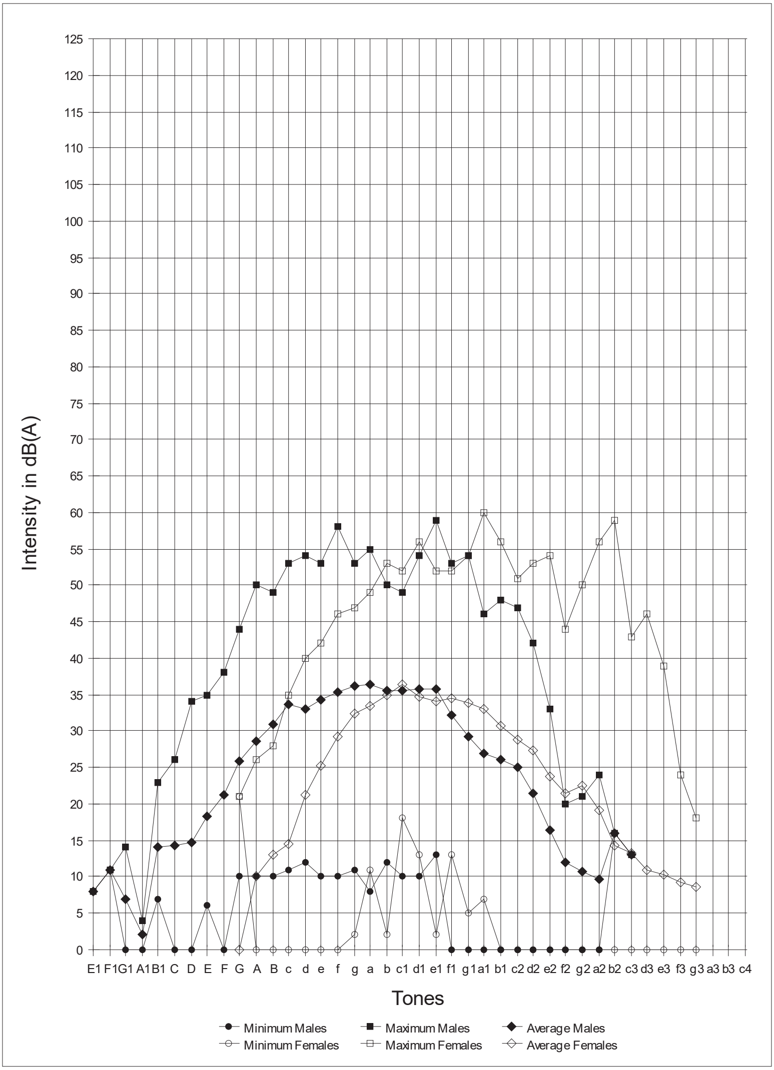
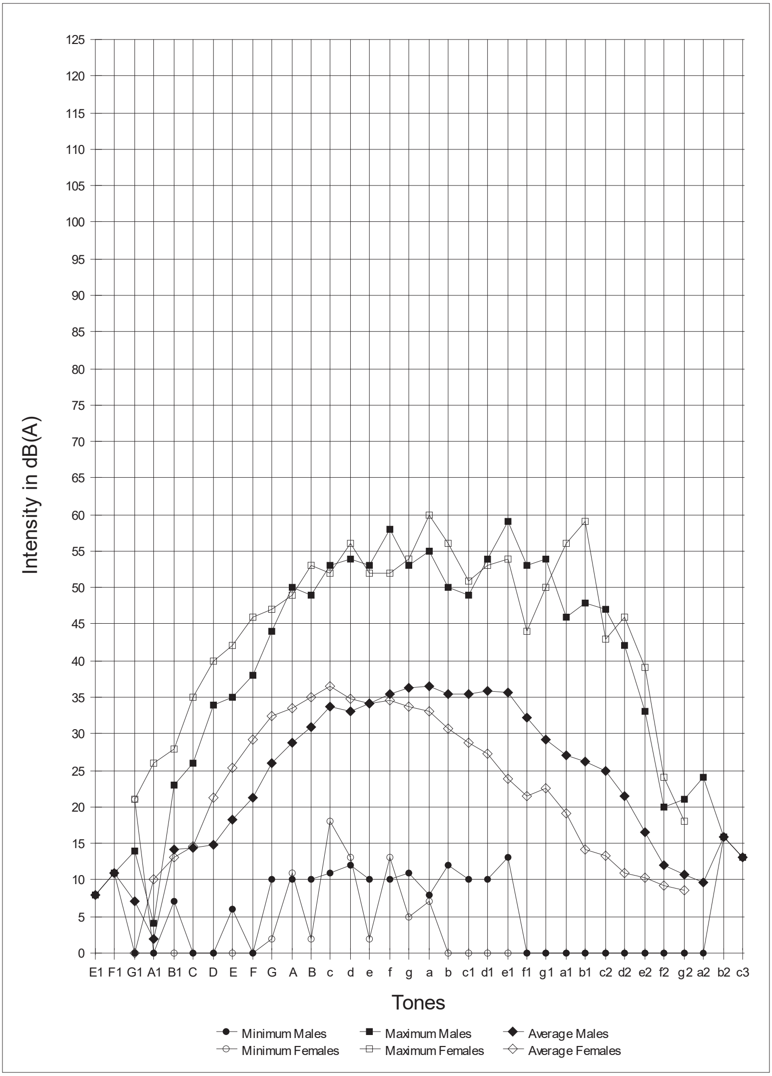


Figure 80: Comparison of maximum, minimum and average values of dynamic range measurements between males and females (18-29 years).



Adapted Figure 80: frequencies of female subjects are projected one octave lower to fit the male frequencies (starting at E1 = E).

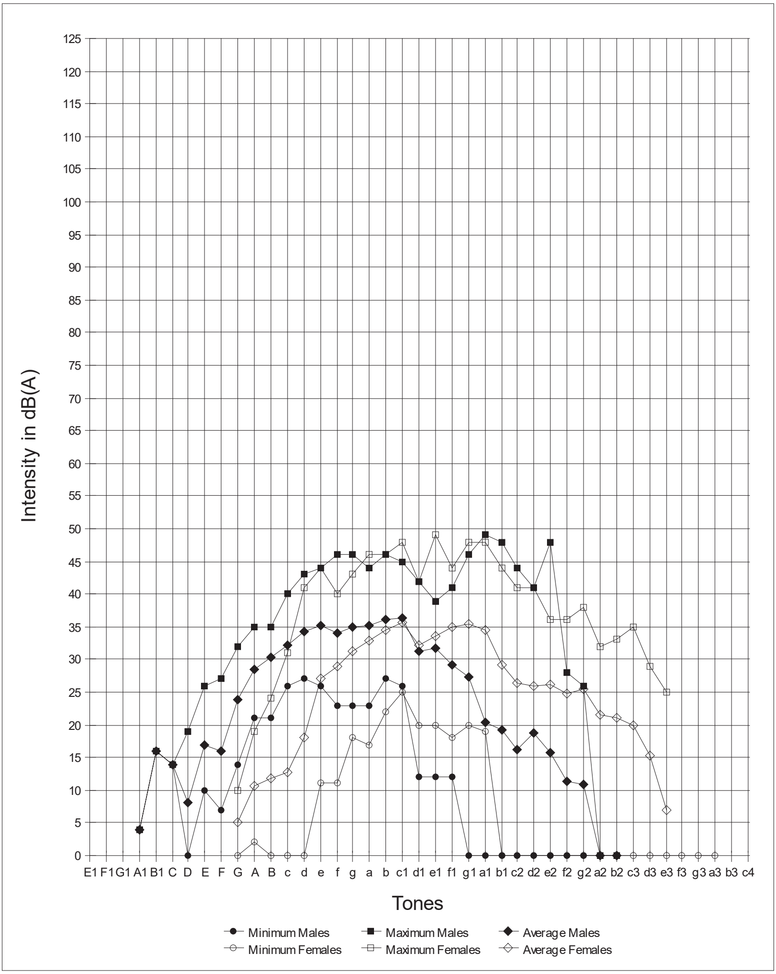
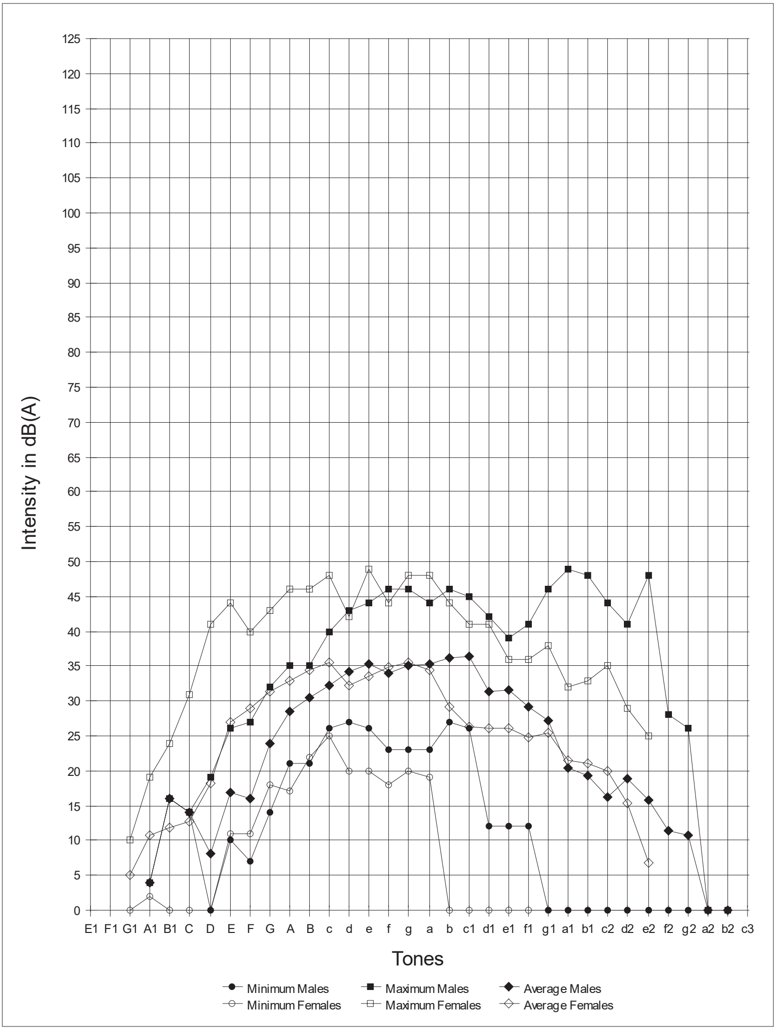


Figure 81: Comparison of maximum, minimum and average values of dynamic range measurements between males and females (30-49 years).



Adapted Figure 81: frequencies of female subjects are projected one octave lower to fit the male frequencies (starting at E1 = E).

8.6. Voice quality: Results and Discussion

8.6.1. Male voices

8.6.1.1. Results of maximum intensity measurements of the singing formant of each tone and of the vocal range

What is missing in the phonetogram is the quality aspect of the voice, Seidner[89] and Gramming[525] confirmed in their pioneering studies on phonetography. Anno 1993, Denk and Frank[83] too admitted that a qualitative assessment of the voice by phonetography was not yet possible, ignoring earlier publications on this matter and preferring sonographic analyses. However, as Miller and Schutte[572] already mentioned, the covariation of sub- and supraglottal formants is quite complex, defying attempts to provide adequate theoretical models.

Glaze et al.[1467] postulated that the direct relationship between loudness variation and vibratory characteristics of phonation accounts for the consistent finding of different acoustic measures (e.g. jitter, shimmer, and signal-to-noise ratio) under different loudness conditions. This also holds true for the clinical observation of a frequency and an intensity dependent grade of disturbance in disorders of the speaking and the singing voice.

A study by Huang et al.[1468] shows that jitter and shimmer decrease with increasing vocal effort. Having the same talker produce the same vowel at different levels of vocal effort can produce widely variant measures of jitter, shimmer, NNE (normalized noise energy), CQ (contact quotient) and CQP (contact quotient perturbation). Heinemann and Gabriel[1469] suggested to complement voice profile measurements with an auditive estimating and marking of a “hoarseness profile” into the voice profile. According to Wirth[1473], voice classification is not possible by spectral analysis; one can, however, determine if the voice is trained or untrained, low, and dark, or high and bright

Hülse[1474] only noted a better singer’s formant as a result of manual therapy in a female patient with cervical dysphonia.

As previously mentioned, (Chapter 6), several authors consider the singing formant as a quality and efficiency indicator of the singing and the speaking voice. Klingholz et al.[1470] express their doubts on this concept, arguing that, in general, there is an increase of the amplitudes of the high frequency harmonics with increasing intensity. They feel that measuring voice qualities at extreme intensities are usually worthless, while aesthetical sounds are excluded.

Seidner [1471,1472], however, considered the intensity of the singer's formant as an uncontested characteristic of vocal quality, expressed by more resonance and carrying power. With his collaborators he tried to differentiate by means of variant and discriminant analysis between singers, student singers and vocally healthy subjects. Female voices could better be differentiated by the measurement of the singing formant, while male voices were better differentiated by the difference between the maximum intensity measurement and the intensity of the singing formant. We will discuss both methods used in our own study of female and male subjects.

According to the Handbook of our WEVOSYS lingWaves Voice Diagnosic Center (VDC), which we have been using for many years to create a "Singing Profile", this real-time display of the singer's formant is invaluable in singing instruction. "To produce a strong singer's formant, it is essential to experiment with different vocal tract configurations and observe changes on the display." That is exactly what we have done for many decennia of voice testing, education, therapy, and research.

Our data have clinical value because they provide an *evaluation of vocal quality, expressed in a numeric value, easily comparable to other data.*

An analysis of the global results (for all ages) of the measurements of the singing formant (Figure 85) demonstrates how the singing formant evolves as frequency increases. We couldn't compare our results because of a lack of data in the research literature.

The first impression of Figure 85 is that of a F°-SPL Profile. As expected, the extreme lowest and highest pitches are of less resonant quality.

In fact, the *maximum values* of the singing formant also show a steep increase with frequency between the lowest tones and e1 (330 Hz) up to 115 dB(A). From then on, the maximum value of the singer's formant decreases gradually for the highest pitches but is still 106 dB(A) for a2 (880 Hz), an extremely high falsetto tone. Between a (220 Hz) and e1 (330 Hz), there is a typical dip, which certainly has to do with a register transition.

The *minimum values* of the singer's formant are very irregular, but still show a general increase with frequency. The lowest maximum value of the singer's formant is situated at g (196 Hz): 38 dB(A). Other highest minimum values, again, are situated at the highest pitches: up to 81 dB(A) on b2.

The *average values* of the singing formant show a more regular increase up to e1 (330 Hz) Then follows a dip, with a minimum value on a1 (440 Hz) and a maximum value on b2 (988 Hz). In the "speech zone" the average value of the singer's formant still varies between 57 dB(A) and 86 dB(A).

As can be expected, the *standard deviations* are very irregular, varying between 0 dB(A) and 15,47 dB(A) over the entire vocal range. It is obvious that vocal quality, as expressed by the value of the singer's formant, is very inconstant, *for each tone,* in different male subjects of different ages.

In Chapter 9 we will provide some case studies, demonstrating the clinical value of this parameter in diagnose, education and therapy of the voice.

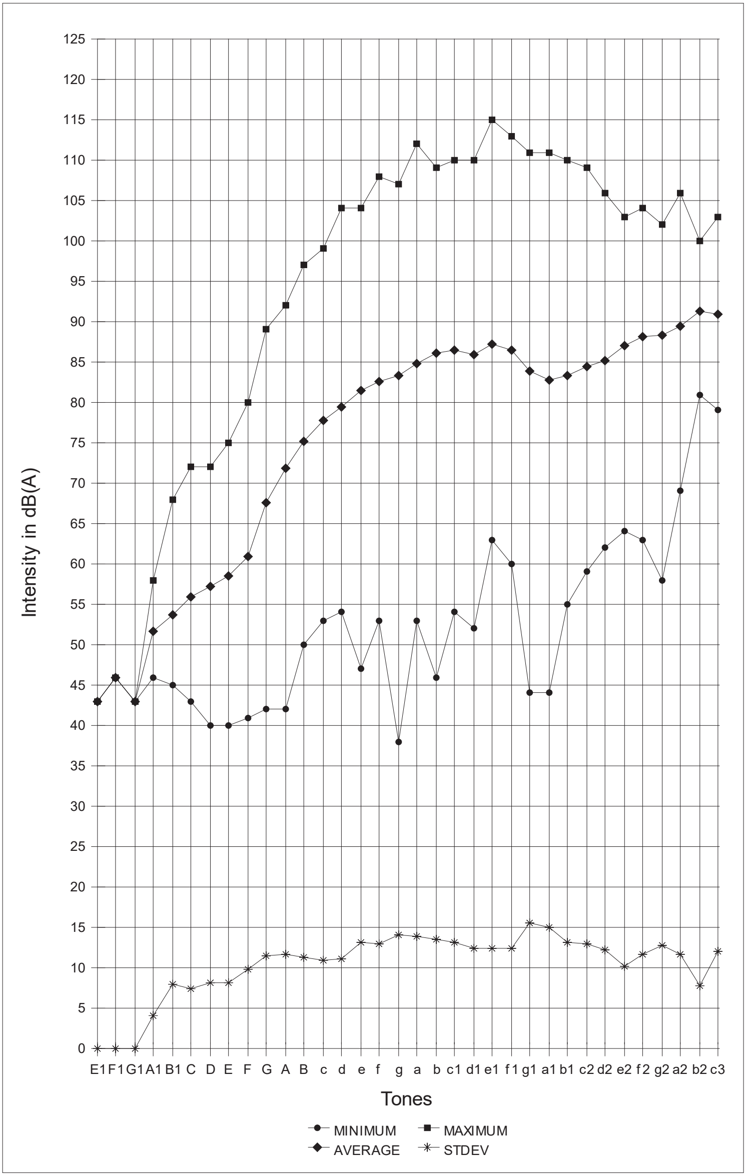

Intensity in dB(A)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
E1 F1 G1 A1 B1 C D E F G A B c d e f g a b c1 d1 e1 f1 g1 a1 b1 c2 d2 e2 f2 g2 a2 b2 c3
Tones
MINIMUM
MAXIMUM
AVERAGE
STDEV

Figure 85: Minimum, maximum, average and standard deviation of singing formant measurements of ALL tones in males of ages 10 – 52 years. (N = 57).

By dividing these global results in age-related results, we can see some important differences between the ages (Figures 86,87,88, and 89. The best results of vocal quality are obtained by the age group 18-29 years. These data are in contrast with the popular belief in the musical world that voices get better – “ripe” - during mature life and are more in accordance with gerontologists’ data on voice deterioration with age, beginning at age 30 and accelerating in later years.[1316]

Frank[1475] too, points at the decreasing intensity of the singer’s formant in elderly voices, resulting in a less carrying sound and Linville[1476] noted that elderly men as a group display higher jitter and shimmer values than do young men and this with considerably more variability than do young men. However, Sataloff et al.[1477] states: “the notion that this decline occurs gradually and progressively (linear senescence) is open to challenge”. Sataloff[1478] also believes that “with appropriate conditioning of the body and voice, many of the characteristics associated with vocal aging can be eliminated”.

As expected, the vocal quality of boys under 18 years is less good. The difference with the best group can amount to 15 dB(A) at c (speaking zone).

The *minimum values* of the singer’s formant vary a lot between the age groups of 18-29 and 30-49 years, and the age groups under 18 years, once again expressing the huge individual differences.

The best *average values* of the singer’s formant, again, are obtained in the age group above 18 years old.

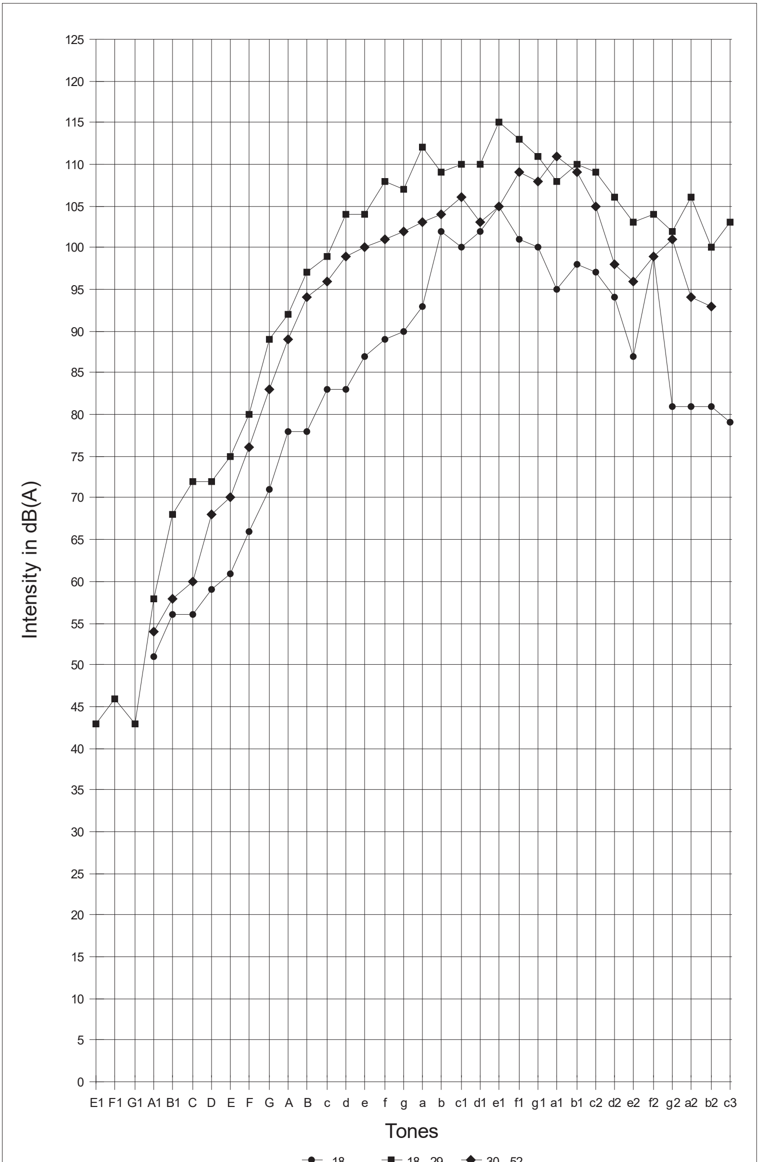


Figure 86: Comparison of maximum values of the singing formant curves for different age groups in males. (N = 57).

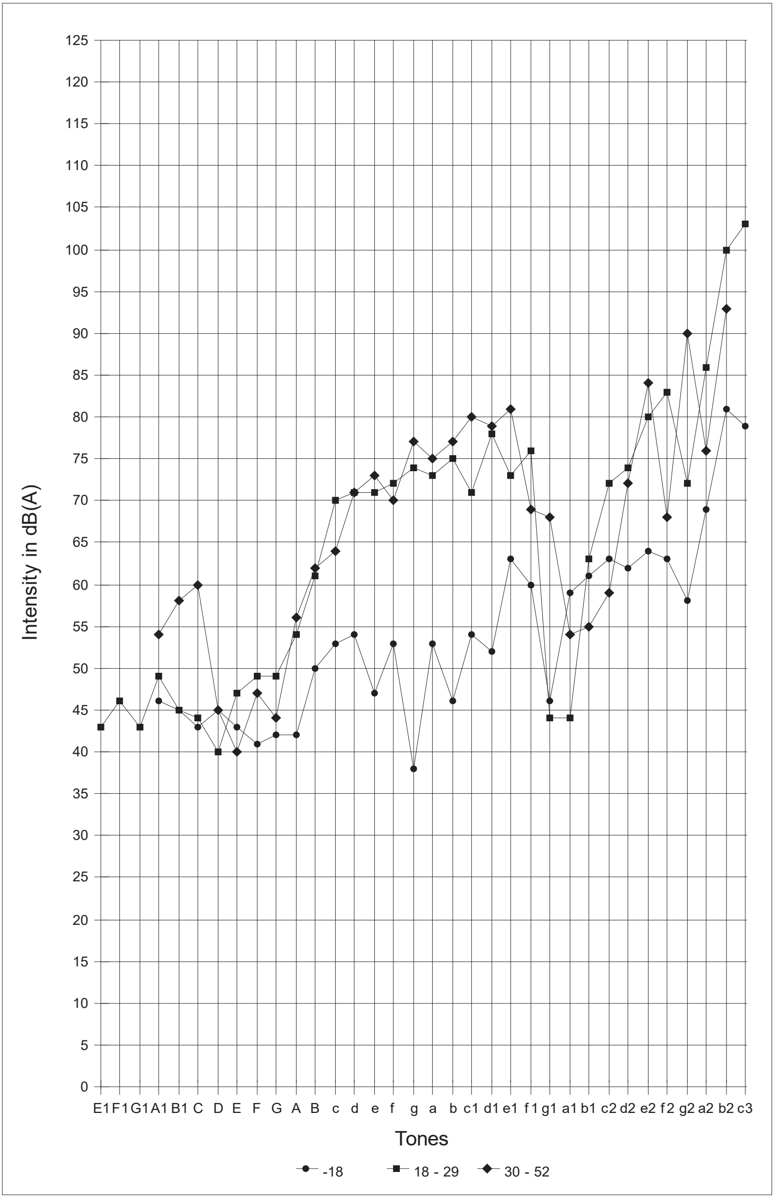


Figure 87: Comparison of minimum values of the singing formant curves for different age groups in males. (N = 57).

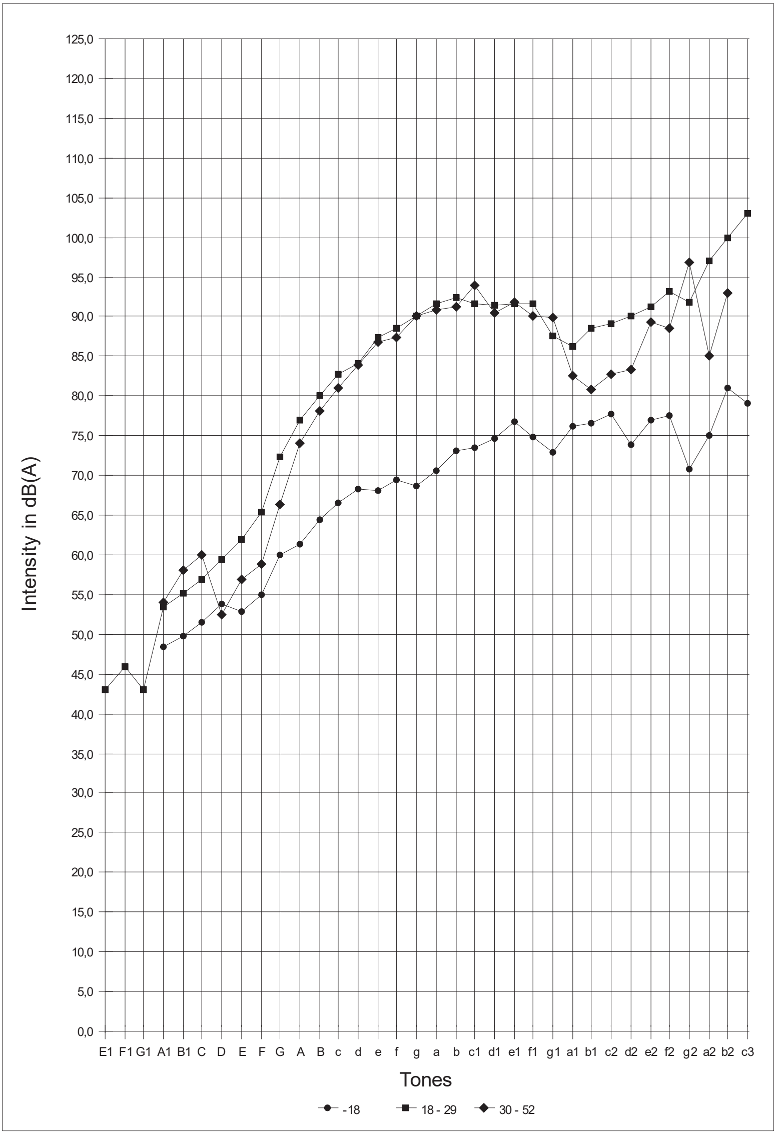


Figure 88: Comparison of average values of the singing formant curves for different age groups in males. (N = 57)

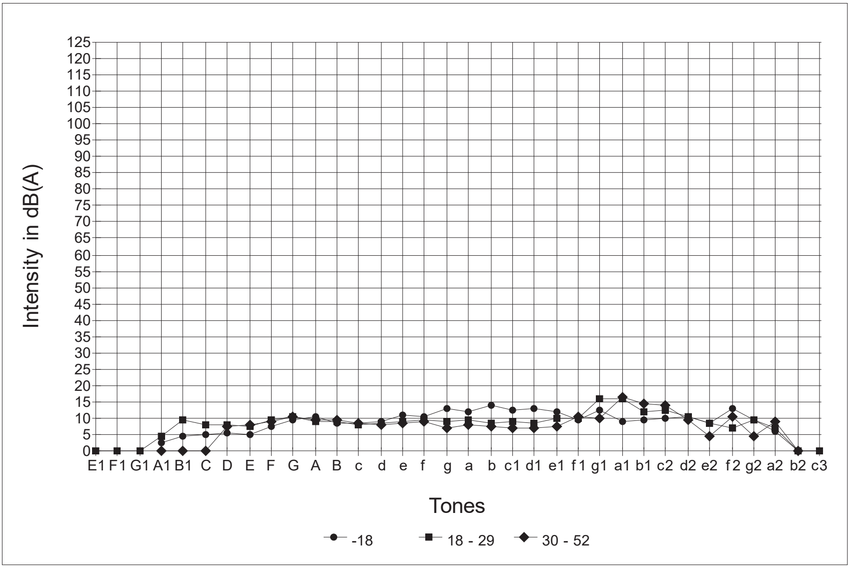


Figure 89: Comparison of STDEV values of the singing formant curves for different age groups in males. (N = 57)

To obtain further cues for voice classification one should scrutinize ALL pitches of a given voice range, if the quality of the voice, as expressed by the singing formant, could provide valid information. Following the same argumentation as with maximum intensity, minimum intensity and dynamic range data, the lowest pitches B1 to B could differ in quality, according to the voice type. So, let's look at the variations of the **singer's formant** in our male subjects:

B1	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	45	56	49,7	4,64	45,06 – 54,34
18 - 29 years	45	68	55,2	9,30	45,9 – 64,50
30 - 52 years	58	58	58,0	0,00	

C	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	43	56	51,5	5,12	46,38 – 56,62
18 - 29 years	44	72	56,9	7,81	49,09 – 64,71
30 - 52 years	60	60	60,0	0,00	

D	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	45	59	53,8	5,26	48,54 – 59,06
18 - 29 years	40	72	59,5	7,90	51,60 – 67,40
30 - 52 years	45	68	52,4	7,32	45,08 – 59,72

E	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	43	61	52,8	5,13	47,67 – 57,93
18 - 29 years	47	75	62,0	7,59	54,41 – 69,59
30 - 52 years	40	70	57,0	8,21	48,79 – 65,21

F	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	41	66	54,9	7,53	47,37 – 62,43
18 - 29 years	49	80	65,3	9,30	56,00 – 74,60
30 - 52 years	47	76	58,8	8,90	49,90 – 67,70

G	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	42	71	59,9	9,34	50,56 – 69,24
18 - 29 years	49	89	72,3	10,54	61,76 – 82,84
30 - 52 years	44	83	66,4	10,45	55,95 – 76,85

A	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	42	78	61,3	10,57	50,73 – 71,87
18 - 29 years	54	92	76,9	8,81	68,09 – 85,71
30 - 52 years	56	89	74,0	9,60	64,40 – 83,60

B	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	50	78	64,5	8,44	56,06 – 72,94
18 - 29 years	61	97	80,0	8,84	71,16 – 88,84
30 - 52 years	62	94	78,2	9,52	68,68 – 87,72

Table 43: Variations in the singing formant and differentiating ranges (= average minimum intensity +/- the standard deviations).

The combination of Table 6 with Table 43 could provide indications for specific voice categories: values of the singing formant below the lowest value of the differentiating range belong to a higher voice category; values of the singer's formant above the highest value of the differentiating range belong to a lower voice category. For instance, for the tone E:

E	**Differentiating range**	**Bass**	**Tenor**
< 18 years	47,67 – 57,93	> 57,93	< 47,67
18 - 29 years	54,41 – 69,59	> 69,59	< 54,41
30 - 52 years	48,79 – 65,21	> 65,21	< 48,79

Table 44: Example for differentiating between the values of the singing formant, specific for basses and tenors (tone E).

The data provided for each tone in Table 43 allow a gradual survey of how the values of the singing formant of a given voice evolve within a specific voice category.

Again, the proposed method is to be interpreted as just one step in the step-to-step methodology of voice classification by phonetography.

8.6.1.2. Results of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant of each tone of the vocal range in males

To test the carrying power ("Tragfähigkeit") one measures the differences between the maximum intensity of the voice signal and the measurement of the energy in the region of 3 kHz with a selective filter[1479-1483].

According to Seidner (et) [1479,1480] male voices are better differentiated by the measurement of the difference between the maximum intensity and the intensity of the singing formant, while female voices could better be differentiated by the measurement of the singing formant alone.

In general, (the pitch) of the singer's formant lies close to the maximum intensity in trained singers and is situated much lower in untrained singers.[1480,1484]

An analysis of the global results (*for all ages*) of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant (Figure 90) shows some interesting features.

Maximum values of this parameter are situated between 16 and 34 dB(A) and the average values between 13 and 21 dB(A).

The *minimum values* of this parameter vary between 0 and 21 dB(A); the phonetometer once even measured a negative difference (-1 dB(A) on e!).

The *average values* of the differences between the maximum intensity measurements and the maximum intensity measurements and the maximum intensity measurements of the singing formant are situated around 13 dB(A).

Standard deviations are around 6 dB(A).

We couldn't compare our results with those of other authors because of lack of data in the research literature.

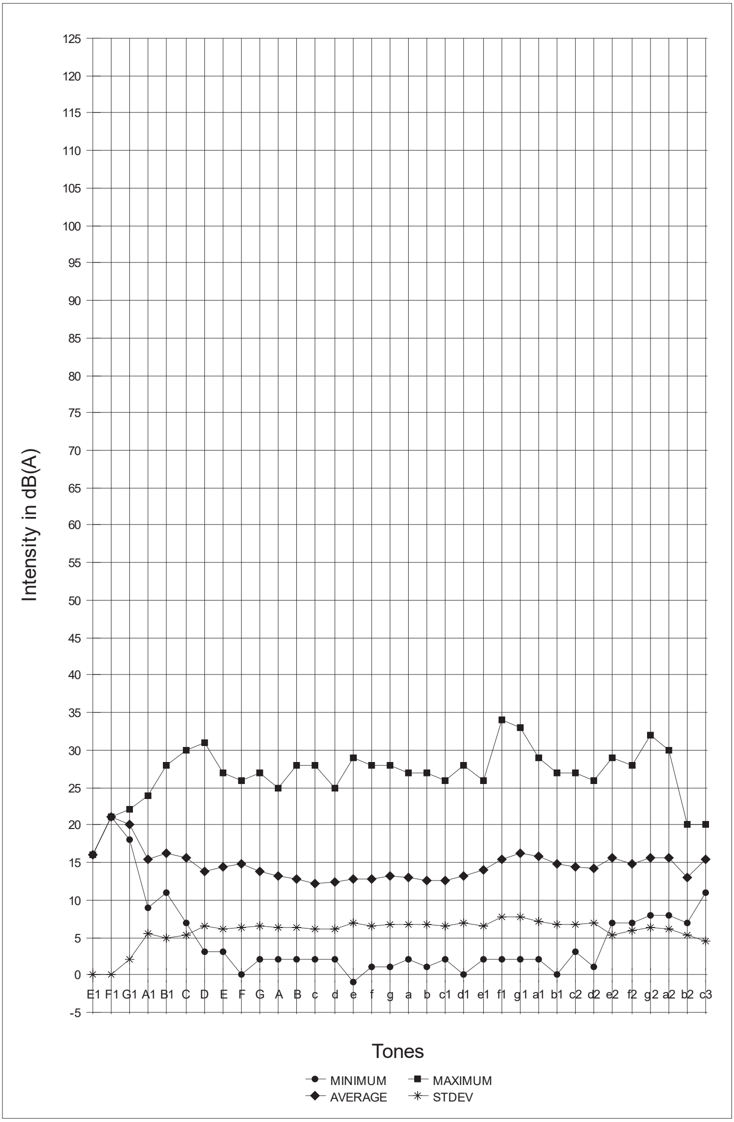


Figure 90: Minimum, maximum, average, and standard deviation of the differences between the maximum intensity measurements and the maximum intensity

measurements of the singing formant of ALL tones in males of ages 10 – 52 years. (N = 57)

By dividing the global results in age-related results, we can find some differences between the ages (Figures 91,92,93, and 94):

Concerning the *minimum values* of this parameter, the age group 18-29 years scores best, followed by the age group 30-49 years. The latter group scores best for the *maximum values* of the parameter.

The best *average values* of the differences between the maximum intensity measurements and the maximum intensity measurements of the singer's formant are found in the age groups 18-29 and 30-49 years, depending on the frequency zones: the eldest group scores best in the speaking zone.

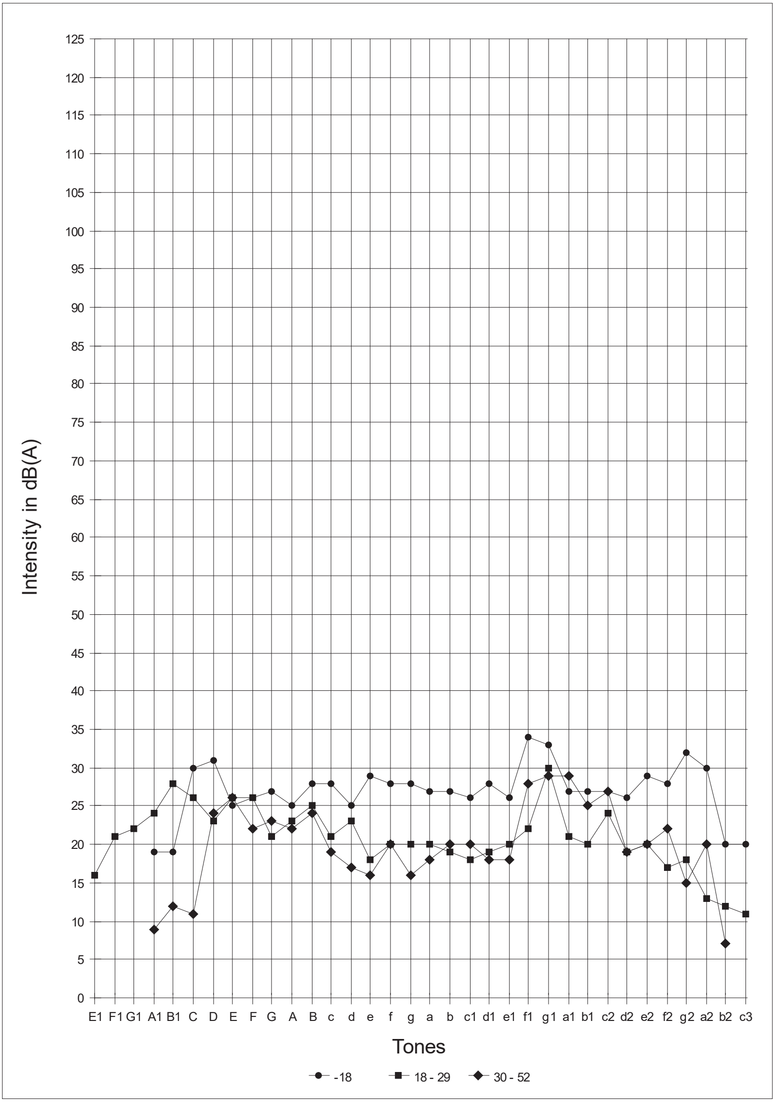


Figure 91: Comparison of maximum values of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant curves for different age groups in males. (N = 57).

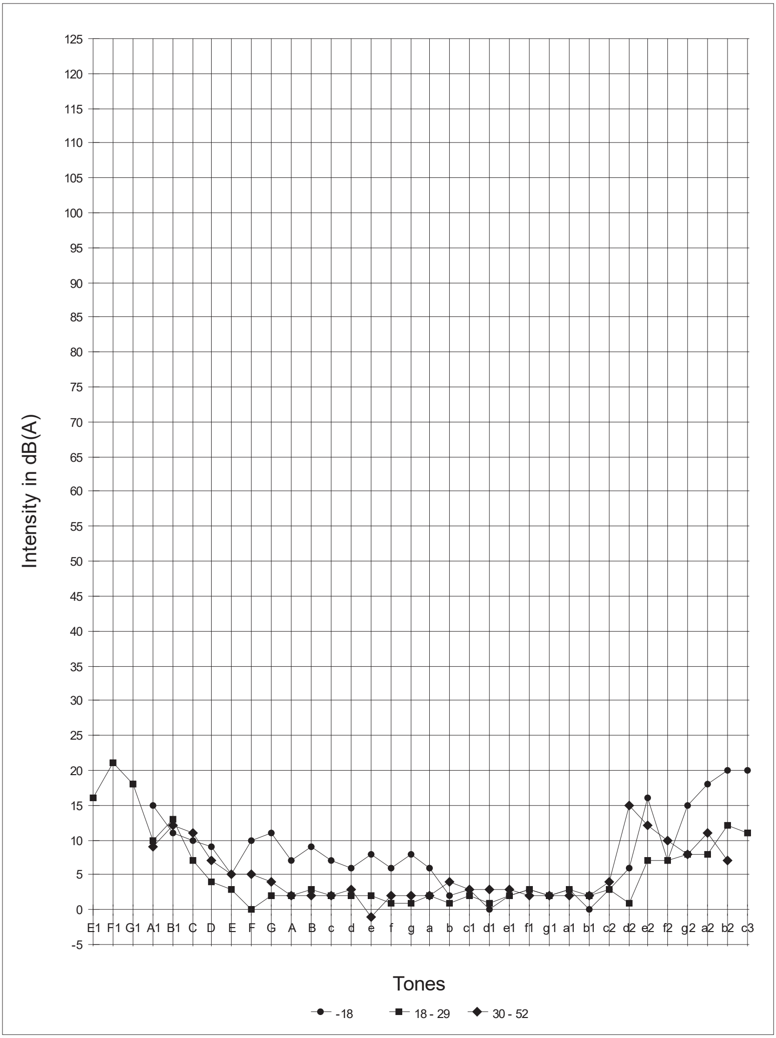


Figure 92: Comparison of minimum values of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant curves for different age groups in males. (N = 57)

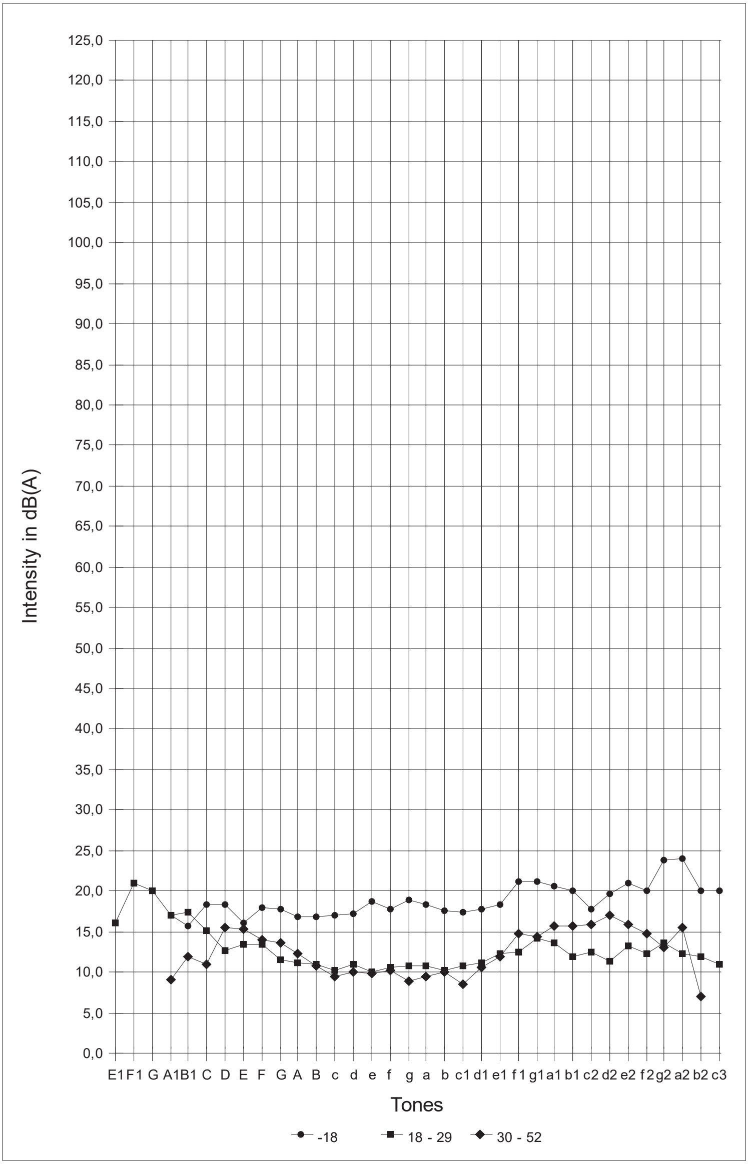


Figure 93: Comparison of the average values of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant curves for different age groups in males. (N = 57)

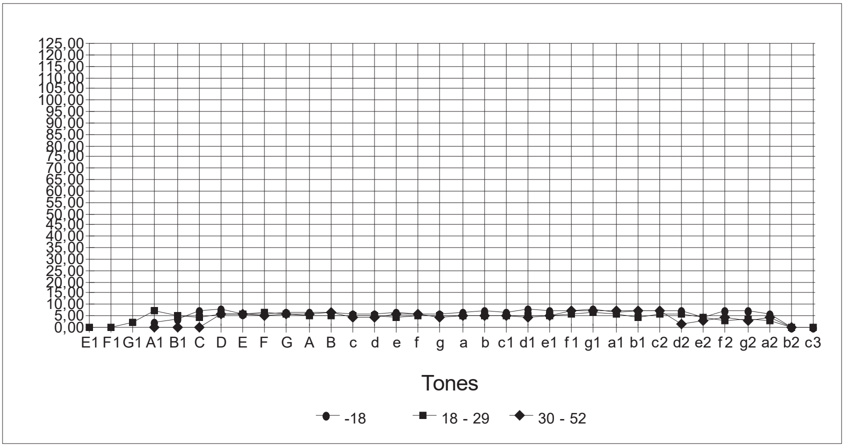


Figure 94: Comparison of the standard deviation values of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant curves for different age groups in males. (N = 57)

To obtain further cues for voice classification it is advisable to inspect ALL pitches of a given voice range, assuming that the quality of the voice, as expressed by the measured differences between the maximum intensity and the singing formant, could provide valid information. Assumedly, the lowest pitches B1 to B could differ in quality, according to the voice type:

B1	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	11	19	15,7	3,40	12,3 – 19,1
18 - 29 years	13	28	17,4	5,46	11,94 – 22,86
30 - 52 years	12	12	12,0	0,00	

C	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	10	30	18,3	7,29	11,01 – 25,59
18 - 29 years	7	26	15,1	4,47	10,63 – 19,57
30 - 52 years	11	11	11,0	0,00	

D	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	9	31	18,3	7,98	10,32 – 26,28
18 - 29 years	4	23	12,7	5,85	6,85 – 18,55
30 - 52 years	7	24	15,6	6,18	9,78 – 21,78

E	MINIMUM	MAXIMUM	AVERAGE	STDEV	Differentiating range
< 18 years	5	25	16,0	5,79	10,21 – 21,79
18 - 29 years	3	26	13,5	6,03	7,47 – 19,53
30 - 52 years	5	26	15,3	5,67	9,63 – 20,97

F	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	10	26	17,9	5,55	12,35 – 23,45
18 - 29 years	0	26	13,4	6,53	6,87 – 19,93
30 - 52 years	5	22	14,0	5,01	8,99 – 19,01

G	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
<18 years	11	27	17,7	6,31	11,39 – 24,01
18 - 29 years	2	21	11,6	5,78	5,82 – 17,38
30 - 52 years	4	23	13,7	5,72	7,98 – 19,42

A	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	7	25	16,8	6,78	10,02 – 23,58
18 - 29 years	2	23	11,2	5,15	6,05 – 16,35
30 - 52 years	2	22	12,3	5,82	6,48 – 18,12

B	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	9	28	16,9	6,22	10,68 – 23,12
18 - 29 years	3	25	11,0	4,92	6,08 – 15,92
30 - 52 years	2	24	10,7	6,50	4,20 – 17,20

Table 45: Variations in the differences between the maximum intensity and the singing formant and differentiating ranges (= average minimum intensity +/- the standard deviations).

The combination of Table 6 with Table 45 could provide indications for specific voice categories: values of the differences between the maximum intensity and the singing formant below the lowest value of the differentiating range belong to a lower voice category; values of the differences between the maximum intensity and the singer's formant above the highest value of the differentiating range belong to a higher voice category. For instance, for the tone E:

E	Differentiating range	Bass	Tenor
< 18 years	10,21 – 21,79	< 10,21	> 21,79
18 - 29 years	7,47 – 19,53	< 7,47	> 19,53
30 - 52 years	9,63 – 20,97	< 9,63	> 20,97

Table 46: Example for differentiating between the differences between the maximum intensity and the singing formant, specific for basses and tenors (tone E).

The data provided for each tone in Figures 91,92, 93 and 94, could allow a gradual survey of how the values of the differences between the maximum intensity and the singing formant of a given voice evolve within a specific voice category.

Again, the proposed method is to be interpreted as just one step in the step-to-step methodology of voice classification by phonetography.

8.6.2. Female voices

8.6.2.1. Results of maximum intensity measurements of the singing formant of each tone of the vocal range

An analysis of the global results of female voices *(of all ages*) of the measurements of the singing formant (Figure 95), demonstrates how the singing formant evolves as frequency increases. We couldn't compare our results because of lack of data in the research literature.

The first impression of Figure 95 is that of a F°-SPL Profile. The *maximum values* of the singer's formant increase with frequency. First, there is a steep increase with frequency up to f1 (349 Hz), followed by a kind of plateau between f1 and a2 (880 Hz) Then again, a steep increase up to c3 (1047 Hz), followed by a quick decrease. The maximum value of the S.F. is 118 dB(A) at c3.

The *minimum curve* of the values of the S.F. is much more irregular, with dips on c, f, e1, c2, and, curiously, f2.

The much more regular curve of *mean values* of the singing formant also demonstrates a plateau between a1 (440 Hz) and g2 (784 Hz).

It is obvious to find out from the 3 curves of the values of the singer's formant, that the large zone of register transition - for all ages and, for all kinds of voices -, i.e., from b1 (494 Hz) to a2 (880 Hz) is a zone of much less vocal quality and carrying power.

As can be expected, *standard deviations* are quite high, up to 12 dB(A).

The quality of the voice, as expressed by the value of the singing formant, varies strongly, not only for every individual subject, but also for every pitch of the vocal range.

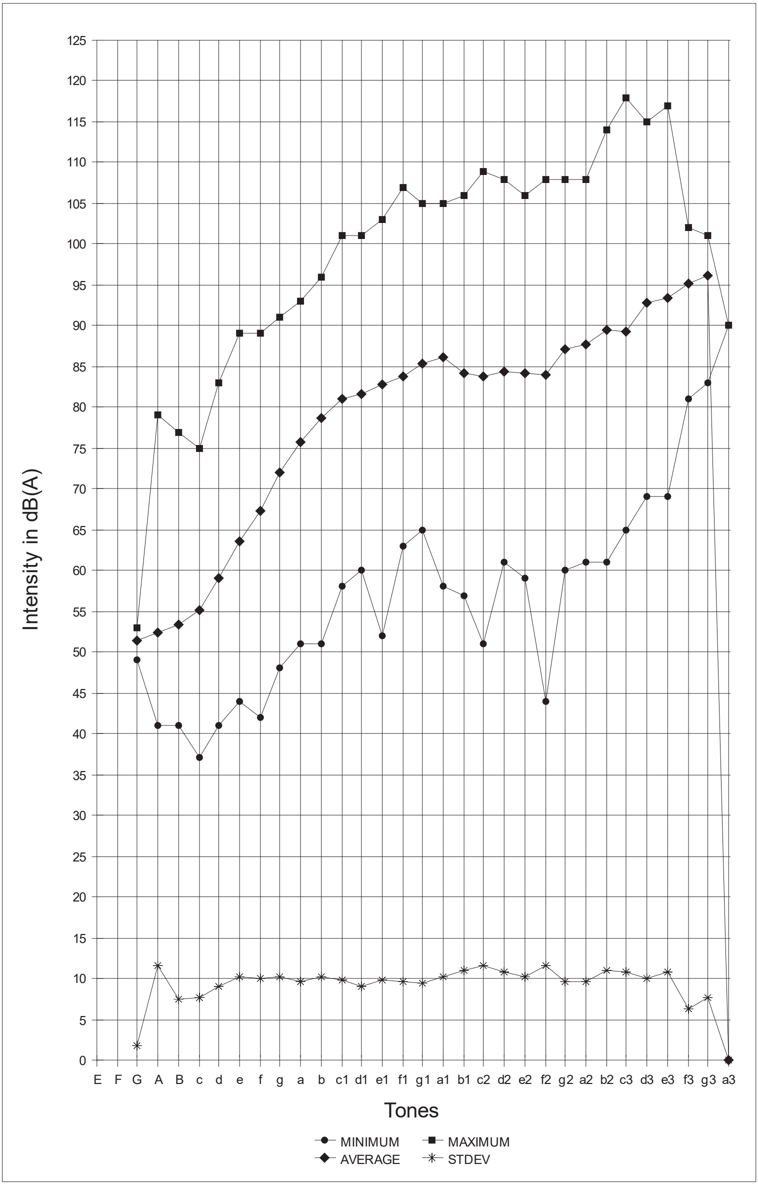


Figure 95: Minimum, maximum, average, and standard deviation of singing formant measurements of ALL tones in females of ages 8-59 years. (N = 118).

By dividing the global results in age-related results (Figures 96 to 99), we can see some important differences between the ages.

Maximum, minimum, and average values of the singer's formant increase with age in female subjects. Only the *maximum values* of the S.F. in the range c1 – e2 are higher in the age group 18-29 years, but the highest pitches of women in the age group 30-49 years have much better quality and carrying power. Could this be the "ripening" of the voice?

Minimum curves are very irregular for all ages.

The huge difference between the age groups 30-49 years and the two other age groups are very distinct in the *mean curve* of the S.F. in the range a1 – c3; which is the most important area for all female singing voices!

Standard deviations are situated around 10 dB(A).

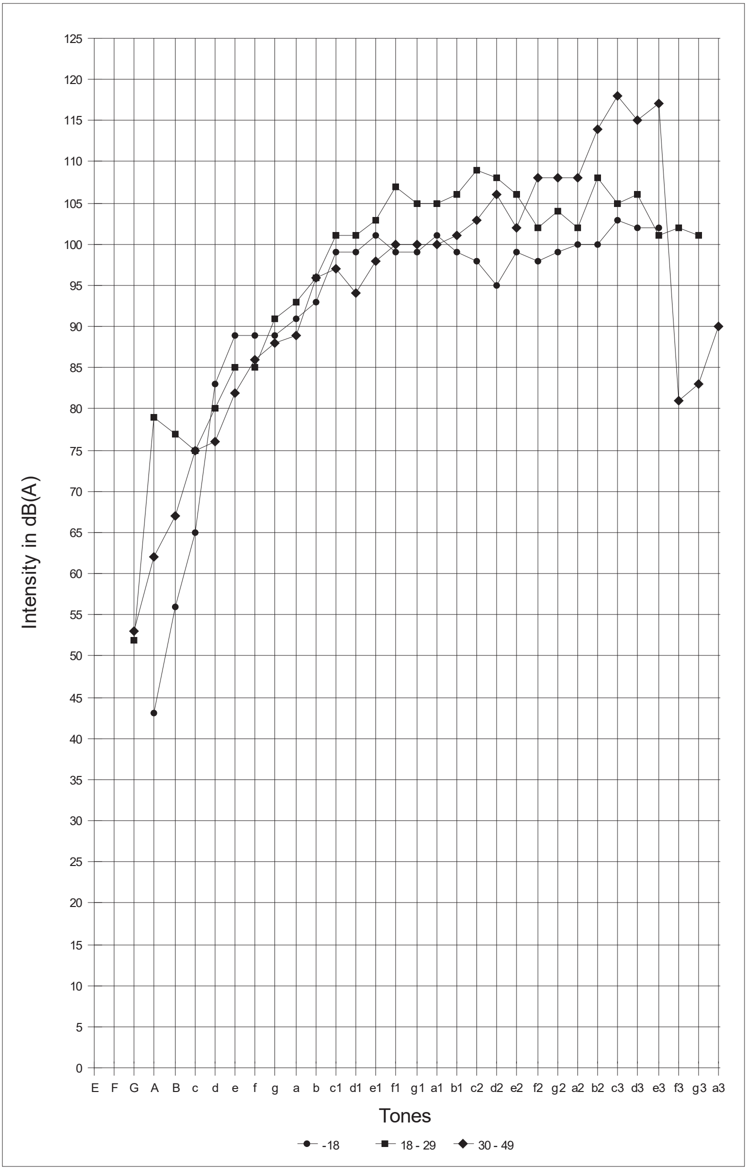


Figure 96: Comparison of maximum values of the singing formant curves for different age groups in females. (N = 117).

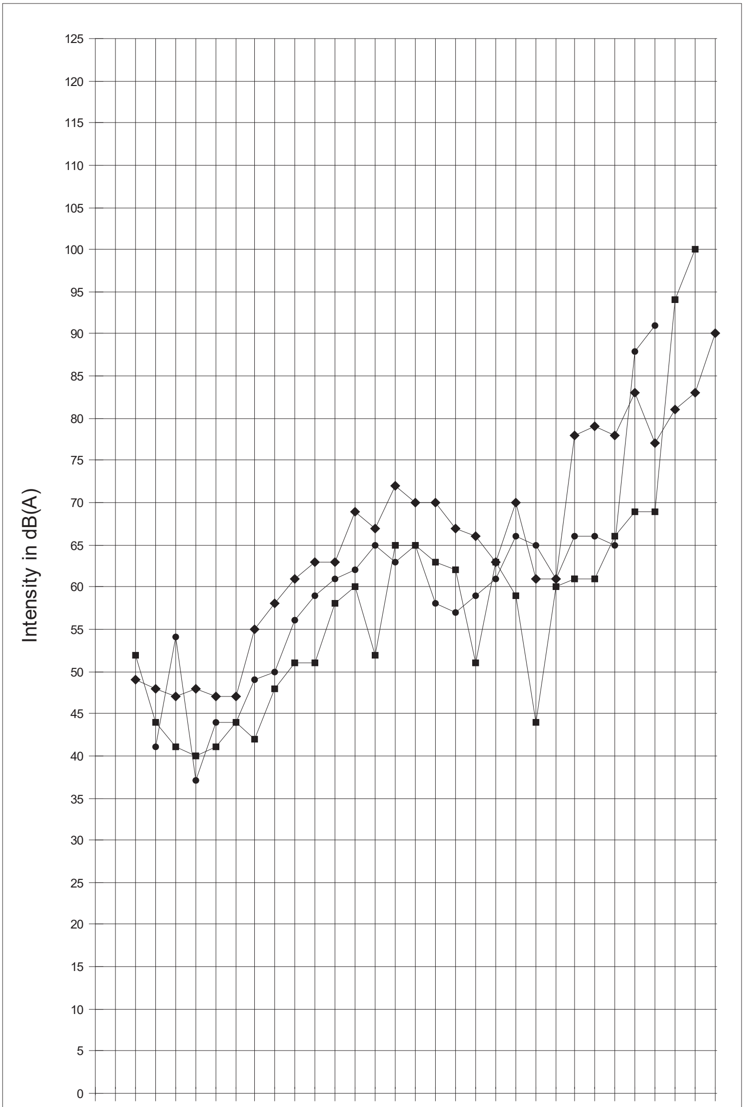


Figure 97: Comparison of minimum values of the singing formant curves for different age groups in females. (N = 117).

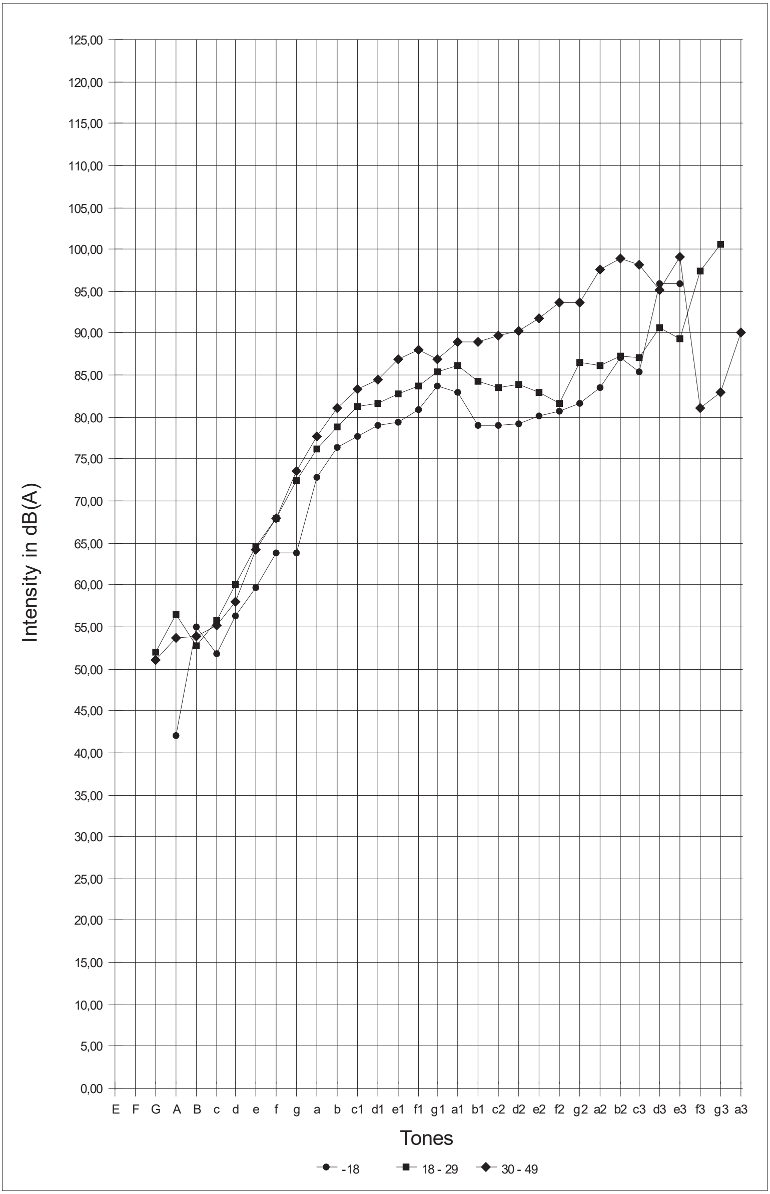


Figure 98: Comparison of average values of the singing formant curves for different age groups in females. (N = 117).

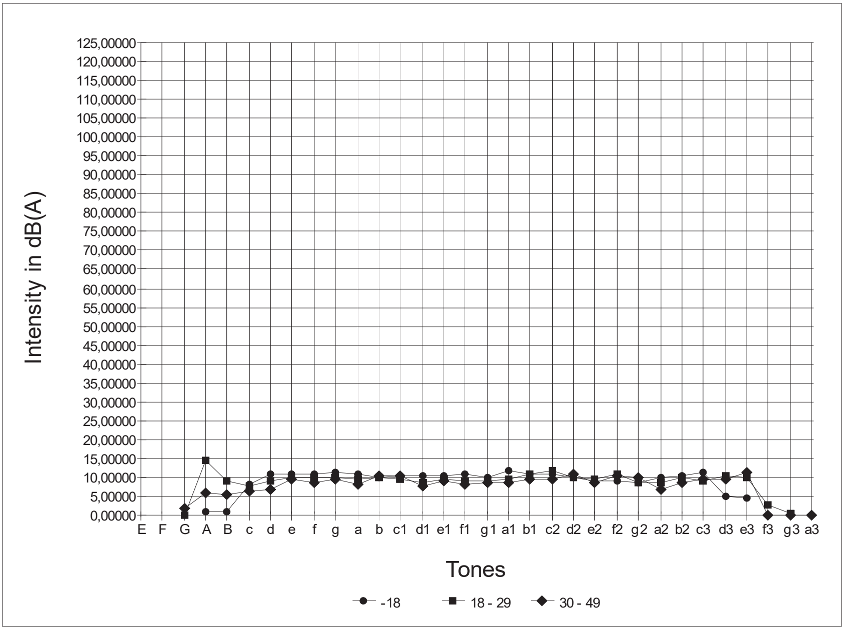


Figure 99: Comparison of STDEV values of the singing formant curves for different age groups in females. (N = 117).

To obtain further cues for voice classification *one should scrutinize ALL pitches of a given voice range*, if the quality of the voice, as expressed by the singing formant, could provide valid information.

Following the same reasoning as with maximum intensity, minimum intensity, and dynamic range data, we hypothesised that the *lowest pitches B to a* could differ in quality, according to the voice type. So, let's have a look at the **variations of the singer's formant** in our female subjects:

B	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	54	56	55	1	54 – 56
18 - 29 years	41	77	52,75	9,00116	43,749 – 61,751
30 - 49 years	47	67	53,89	5,54666	48,343 – 59,437

c	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	37	65	51,88	8,23768	43,642 – 60,118
18 - 29 years	40	75	55,77	7,77670	47,993 – 63,547
30 -49 years	48	75	55,2	6,50333	48,697 – 61,703

d	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	44	83	56,25	10,93256	45,317 – 67,183
18 - 29 years	41	80	60,05	8,98100	51,069 – 69,031
30 - 49 years	47	76	58	8,77311	49,227 – 66,773

e	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	44	89	59,7	10,86324	48,837 – 70,563
18 - 29 years	44	85	64,6	9,99675	54,603 – 74,597
30 -492 years	47	82	64,12	9,40514	54,715 – 73,525

f	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	49	89	63,8	10,97543	52,825 – 74,775
18 - 29 years	42	85	68,03	9,92433	58,106 – 77,954
30 - 49 years	55	86	68	8,73689	59,263 – 76,737

g	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	50	89	63,8	11,14611	52,654 – 74,946
18 - 29 years	48	91	72,41	9,73910	62,671 – 82,149
30 - 49 years	58	88	73,5	9,32887	64,171 – 82,829

a	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	56	91	72,9	10,89666	62,003 – 83,797
18 - 29 years	51	93	76,23	9,60097	66,629 – 85,831
30 - 49 years	61	89	77,61	8,35423	69,256 – 85,964

Table 47: Variations in the singing formant and differentiating ranges (= average minimum intensity +/- the standard deviations).

The combination of Table 6 with Table 47 should provide indications for specific voice categories: values of the singing formant below the lowest value of the differentiating range belong to a higher voice category; values of the singer's formant above the highest value of the differentiating range belong to a lower voice category. For instance, for the tone e:

e	Differentiating range	Alto		Soprano
< 18 years	48,837 – 70,563	> 70,563		< 48,837
18 - 29 years	54,603 – 74,597	> 74,597		< 54,603
30 - 52 years	54,715 – 73,525	> 73,525		< 54,715

Table 48: Example for differentiating between the values of the singing formant, specific for altos and sopranos (tone e).

The data provided for *each* tone, combined with the differentiating range, allow a gradual survey the values of the singing formant for a given female voice evolve within a specific voice category.

Again, the proposed method is to be interpreted as just one step in the step-to-step methodology of voice classification by phonetography.

8.6.2.2. Results of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant of each tone of the vocal range in females.

An analysis of the global results (for all ages) of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant in females (Figure 100), shows some interesting features.

At first sight, the three curves of maximum, minimum and mean difference between the maximum intensity and the maximum intensity of the singer's formant are quite different from those of the values of the singer's formant. (Figure 95)

The *maximum value* of the difference between the maximum intensity and the intensity of the S.F. is 33 dB(A) on e2 (659 Hz), while *minimum values* are very low. In four subjects the device noted negative differences, which we cannot explain.

Interesting to note is that the *mean differences* between the maximum intensity and the maximum intensity of the S.F. fluctuate around 15 dB(A).

Standard deviations are around 6 dB(A).

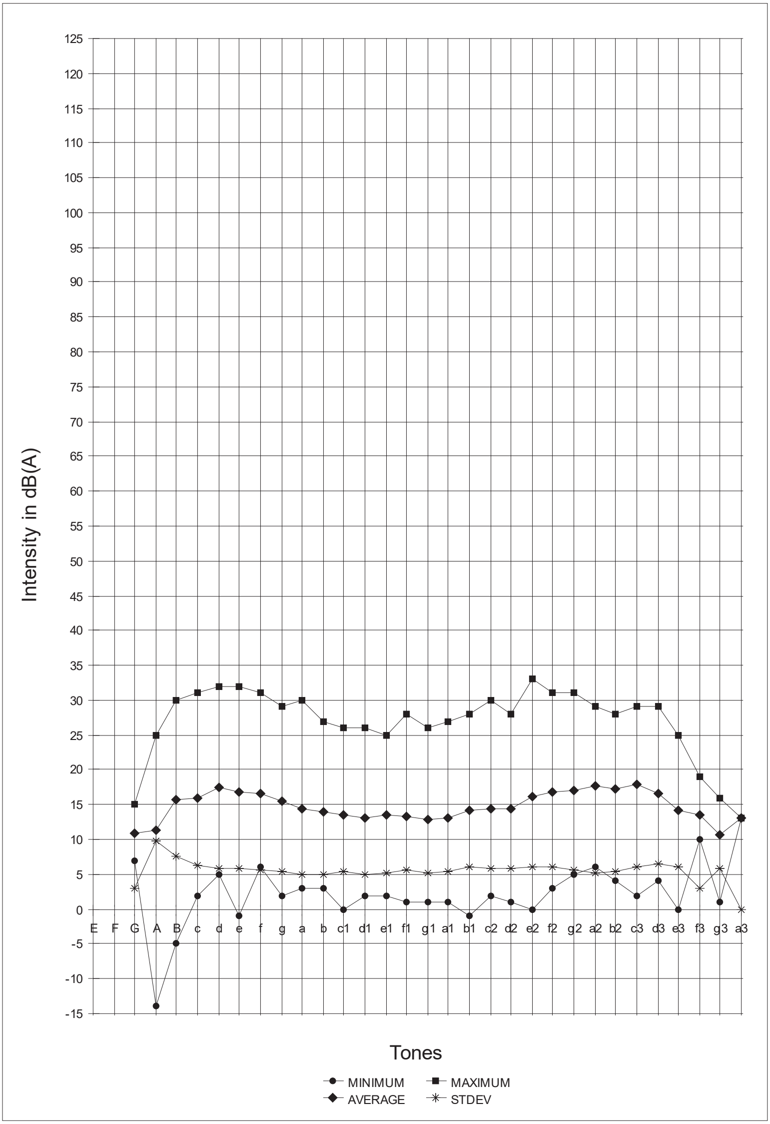


Figure 100: Minimum, maximum, average, and standard deviation of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant of ALL tones in females of ages 8 – 59 years (N = 113).

By dividing the global results in age-related results, we can find many differences between the ages (Figures 101 to 104), but we found these differences to divergent to interpret.

In general, the age-group 18-29 years features the best *minimum values*.

Standard deviations are consistently around 5 dB(A).

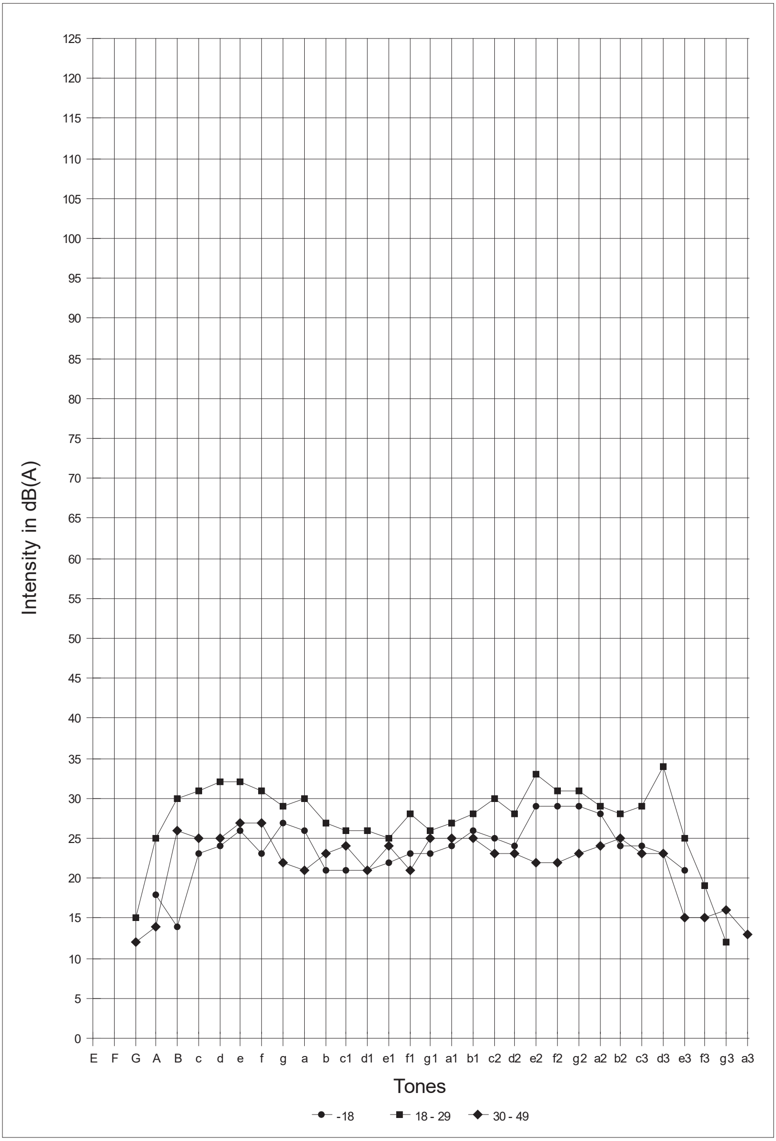


Figure 101: Comparison of maximum values of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant curves for different age groups in females (N = 112).

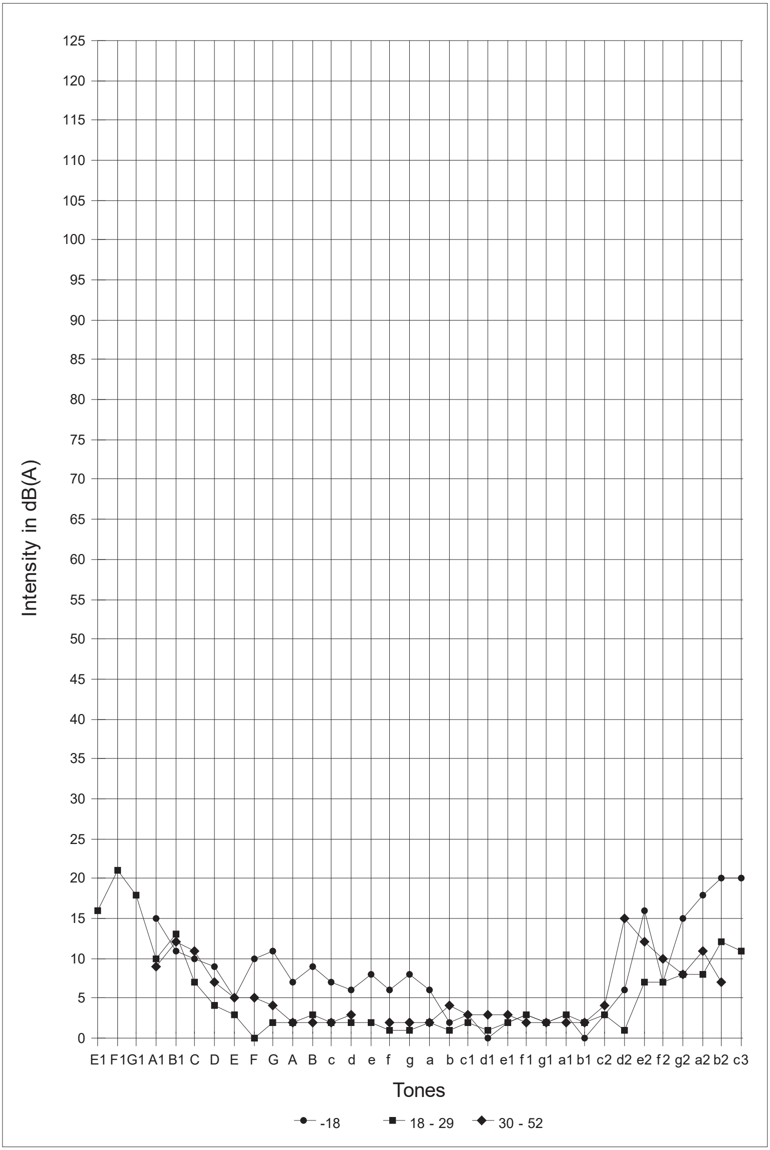


Figure 102: Comparison of minimum values of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant curves for different age groups in females (N = 112).

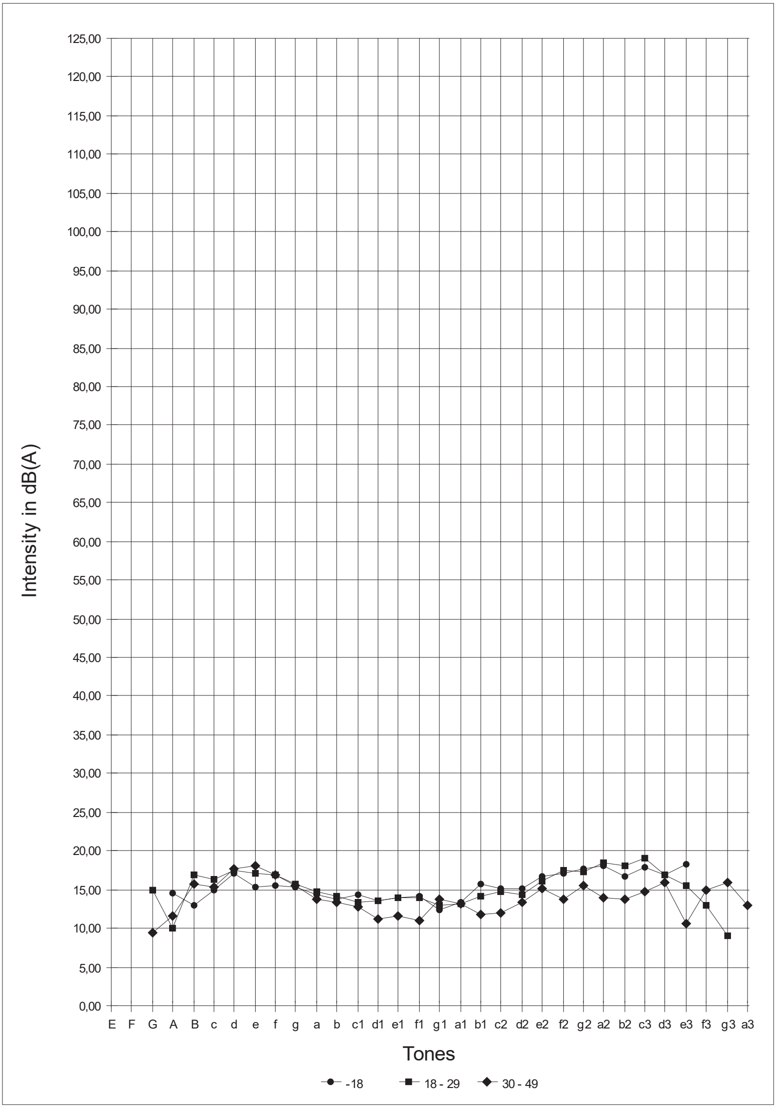


Figure 103: Comparison of the average values of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant curves for different age groups in females (N = 112).

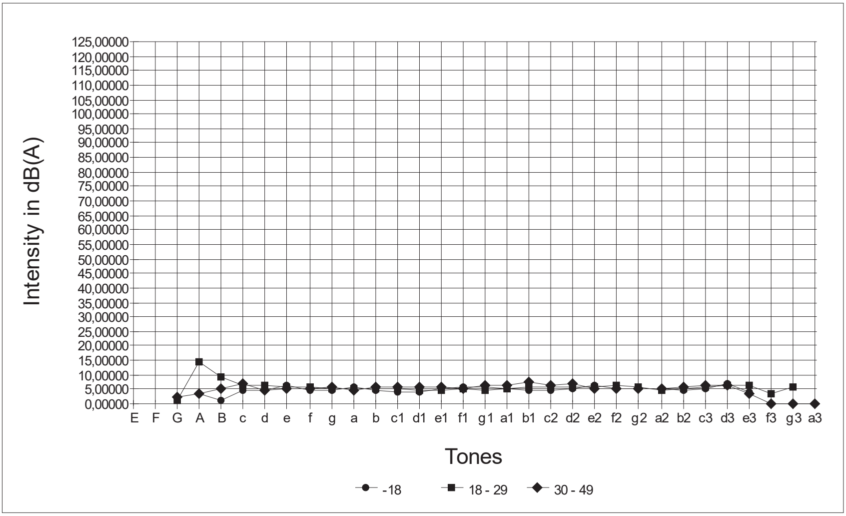


Figure 104: Comparison of the standard deviation values of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant curves for different age groups in females (N = 112).

To obtain further cues for voice classification it is advisable to inspect ALL pitches of a given voice range, if the quality of the voice, as expressed by the measured differences between the maximum intensity and the singing formant, could provide valid information.

For instance, the lowest pitches B to a could differ in quality, according to the voice type:

B	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	12	14	13	1	12 – 14
18 - 29 years	-5	30	16,83	9,46778	7,36 – 26,298
30 - 52 years	8	26	15,78	5,41146	10,37 – 21,19

c	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	9	23	14,88	4,67540	10,20 – 19,56
18 - 29 years	2	31	16,4	6,09729	10,30 – 22,5
30 - 49 years	2	25	15,4	7,20925	8,19 – 22,61

d	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	9	24	17,17	4,70520	12,46 – 21,88
18 - 29 years	5	32	17,49	6,39749	11,09 – 23,89
30 - 49 years	11	25	17,75	4,39460	13,36 – 22,14

e	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	-1	26	15,25	6,41775	8,83 – 21,67
18 - 29 years	5	32	17,04	5,84389	11,2 – 22,88
30 - 49 years	11	27	18,12	4,94538	13,17 – 23,07

f	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	7	23	15,6	4,37493	11,23 – 19,98
18 - 29 years	6	31	16,82	6,03039	10,79 – 22,85
30 - 49 years	8	27	16,94	5,06044	11,88 – 22

g	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	5	27	15,29	4,74234	10,55 – 20,03
18 - 29 years	2	29	15,87	5,45983	10,41 – 21,33
30 - 49 years	7	22	15,61	5,51905	10,09 – 21,39

a	**MINIMUM**	**MAXIMUM**	**AVERAGE**	**STDEV**	**Differentiating range**
< 18 years	3	26	14,29	5,53898	8,75 – 19,83
18 - 29 years	5	30	14,68	5,04467	9,64 – 19,72
30 - 49 years	6	21	13,83	4,37480	9,46 – 18,2

Table 49: Variations in the differences between the maximum intensity and the singing formant and differentiating ranges (= average minimum intensity +/- the standard deviations).

The combination of Table 6 with Table 47 could provide indications for specific voice categories: values of the differences between the maximum intensity and the singing formant below the lowest value of the differentiating range belong to a lower voice category; values of the differences between the maximum intensity and the singer's formant above the highest value of the differentiating range belong to a higher voice category. For instance, for the tone e:

e	**Differentiating range**	**Alto**	**Soprano**
< 18 years	8,83 – 21,67	< 8,83	> 21,67
18 - 29 years	11,2 – 22,88	< 11,2	> 22,88
30 - 49 years	13,17 – 23,07	< 13,17	> 23,07

Table 50: Example for differentiating between the differences between the maximum intensity and the singing formant, specific for altos and sopranos (tone e).

The data provided for each tone allow a gradual survey of how the values of the differences between the maximum intensity and the singing formant of a given voice evolve within a specific voice category.

Again, the proposed method is to be interpreted as just one step in the step-to-step methodology of voice classification by phonetography.

In the preceding pages we tried to demonstrate how the measurement of the singer's formant and the measurement of the difference between the maximum intensity and the singer's formant of the *lowest* pitches of the human vocal range can provide supplementary clues for voice classification. Of course, this methodology should be extended to the *whole vocal range*. Our experience, however, is limited to the lower vocal range, because we hypothesized that the results in this particular area should be quite obvious.

But there is more. As we know, neither the exact value of the maximum and minimum intensities of a given pitch, nor the dynamic range of a voice can directly be estimated by the human ear. Although voice quality is extremely difficult to evaluate, a lot of authors still conceive our ears to be the best instrument for that purpose. As mentioned before, a simple indication of voice quality within the traditional F° SPL measurement, could help a lot both therapist and voice patient in everyday practice. That is why we learned to appreciate the diagnostic value of the measurement of the singer's formant, in addition to the common F°-SPL measurement.

In the melting pot of all kinds of voices, we learned to distinguish – tone by tone – the different qualities of a given voice, as expressed by only one number, i.e., the value of the singer's formant and the value of the difference between the maximum intensity measurement and the maximum intensity measurement of the singing formant. Comparing this simple number with our supposed experienced appreciation by ear, opened a rich world of enlarged experience.

Let us just consider, for instance, the huge differences between the statistics of the maximum and the minimum values of the singer's formant for both sexes in two very important regions of the vocal range: the region of the *habitual pitch* and the region of the *register change*:

	MINIMUM	MAXIMUM	DIFFERENCE
G	42	89	47
A	42	92	50
B	50	97	47
c	53	99	46
d	54	104	50

Table 50: Differences in dB(A) between the maximum and the minimum values of the singer's formant in the region of the *habitual pitch* of male voices of all ages.

	MINIMUM	MAXIMUM	DIFFERENCE
a	53	112	59
b	46	109	63
c1	54	110	56
d1	52	110	58
e1	63	115	52
f1	60	113	53
g1	44	111	67

Table 51: Differences in dB(A) between the maximum and the minimum values of the singer's formant in the region of *register change* of male voices of all ages.

	MINIMUM	MAXIMUM	DIFFERENCE
g	48	91	43
a	51	93	42
b	51	96	45
c1	58	101	43
d1	60	101	41

Table 52: Differences in dB(A) between the maximum and the minimum values of the singer's formant in the region of the *habitual pitch* of female voices of all ages.

	MINIMUM	MAXIMUM	DIFFERENCE
a1	58	105	47
b1	57	106	49
c2	51	109	58
d2	61	108	47
e2	59	106	47
f2	44	108	64
g2	60	108	48

Table 53: Differences in dB(A) between the maximum and the minimum values of the singer's formant in the region of *register change* of female voices of all ages.

The same observations can be made regarding the huge differences in dB(A) between the maximum and minimum values of the differences between the maximum intensities and the values of the singer's formant in both sexes:

	MINIMUM	MAXIMUM	DIFFERENCE
G	2	27	25
A	2	25	23
B	2	28	26
c	2	28	26
d	2	25	23

Table 54: Differences in dB(A) between the maximum and minimum values of the differences in dB(A) between the maximum intensities and the values of the singer's formant in the region of the *habitual pitch* in males of all ages.

	MINIMUM	MAXIMUM	DIFFERENCE
a	2	27	25
b	1	27	26
c1	2	26	24
d1	0	28	28
e1	2	26	24
f1	2	34	32
g1	2	33	31

Table 55: Differences in dB(A) between the maximum and minimum values of the differences between the maximum intensities and the values of the singer's formant in the region of *register change* in males of all ages.

	MINIMUM	MAXIMUM	DIFFERENCE
g	2	29	27
a	3	30	27
b	3	27	24
c1	0	26	26
d1	2	26	24

Table 56: Differences in dB(A) between the maximum and minimum values of the differences between the maximum intensities and the values of the singer's formant in the region of the *habitual pitch* in females of all ages.

	MINIMUM	MAXIMUM	DIFFERENCE
a1	1	27	26
b1	-1	28	29
c2	2	30	28
d2	1	28	27
e2	0	33	33
f2	3	31	28
g2	5	31	26

Table 57: Differences in dB(A) between the maximum and minimum values of the differences between the maximum intensities and the values of the singer's formant in the region of *register change* in females of all ages.

Anno 1952, Heinemann and Gabriel[1486], complementing their voice profile measurements by an *auditive estimation* of the voice quality ("*hoarseness profile*"), already remarked a *frequency- and intensity dependency* of vocal quality in *voice patients*.

Our results clearly show that the same remarks hold true for *every voice*. The given examples of two important zones (habitual pitch and register transition) demonstrate, *for each pitch*, enormous differences: between 41 – 50 dB(A) and 47 – 67 dB(A) for the singer's formant in the zones of the habitual pitch resp. register change of both genders. In the same zones, the differences between the maximum intensity and the maximum intensity of the S.F., in the zones of habitual pitch and register change, for both genders, can attain 23 – 27 dB(A) resp. 24 – 33 dB(A).

These two zones have much clinical importance as they provide clues in our step-by-step procedure of voice classification. Besides, by using our Figures and, of course, also the Figures corresponding to other pitches of the total vocal range, *the clinician has an indication by a simple number of the voice quality of a given subject at a given moment, but also of what could be expected by further training or therapy*.

8.6.3. Comparison between male and female voices

8.6.3.1. Results of maximum intensity measurements of the singing formant of each tone of the vocal range.

In the preceding pages (Chapter 8.6), a complete survey was given of the results of different quality measurements of our male (ages 10-76 years) and female (ages 8-65 years) subjects. This mapping of different vocal qualities, expressed by het measurement of the singer's formant, and/of the difference of the maximum intensity measurements and the value of the singer's formant, provides, tone by tone, a useful *clinical pattern card of the human voice.* Unfortunately, our results, completed by analysis and discussion, are not comparable with those of other authors, because of different methodologies and lack of sufficient data.

As mentioned before, this vocal parameter, constituting an important complementary element of a phonetogram, will be used later in our step-by-step procedure of voice classification (see Chapter 9).

Linville[1487] reported altered glottal configurations across phonatory conditions in female speakers after a period of loud reading.

Södersten et al.[1488] found a high incidence of incomplete vocal fold closure in both young and elderly women, while Sulter et al.[1489] saw more horizontal phase differences in female subjects, and more vertical phase differences in male subjects. Men, however, have a more complete glottal closure than women do[1489].

Mendoza et al.[1490,1491] stated that only very few attempts were made to classify differences in voice quality between men and women by means of objective acoustic measures.

To complete our study on voice quality measurements, we wondered what the differences would be between male and female subjects. To this end we compared the quality profiles of both genders by superposing them.

In a first effort, both profiles were mapped in the same Figure. In the second (adapted) Figure, the female profile was projected one octave lower (to fit the male profile). The first method is of interest for composers, musicians, (choir) conductors and other people involved in music performances, because these graphs demonstrate the *characteristics of mixed human voice categories of both genders, assembled in three age groups.* The study of the quality measurements at certain frequencies gives an idea of the *actual vocal capacities presented by an amalgam of different singers to interpret a given score.* However, by superposing the profiles of both sexes, ignoring the one octave difference between both, *the second method enables researchers and clinicians to compare the performances of male and female subjects in comparable conditions (the one octave difference between the genders is equalized).*

By using the averaging Long-Term Average Spectrum (LTAS) method, Mendoza et al.[1490] looked for differences in voice quality between 24 men and 31 women whose ages ranged from 20 to 50 years (with an average of 28 and 30 years, respectively). Their results showed a significant difference between genders, as well as an interaction of gender and frequency level, taken from voice samples. Aspiration noise in the region of the third formant leads to a “breathier” quality of the female voice.[1490]

Let us have a look now at our own results, obtained by another methodology.

The many differing values of the singing formant give ample proof of the *huge inter- and intrasubject differences in voice quality.*

Let us explore some possible differences of the extreme and mean results of quality measurements between the genders. We schematized the best results of the different age groups of both sexes in the next Table 58, according to both cited methods:

Singer's form.		**MINIMUM**	**MAXIMUM**	**AVERAGE**
Under 18 years	1st method	Girls	Mixed	Girls
	2nd method	Girls	Girls	Girls
18 - 29 years	1st method	Males	Males	Males
	2nd method	Males	Males	Males
30 - 49 years	1st method	Males	Males	Males
	2nd method	Males	Males	Males

Table 58: Comparison (grosso modo) of best values of the singer's formant of male and female subjects of different age categories.

In age-groups 18 -- 49, males obtain the best results, according to both methods. (Figures 105 to 110).

In comparable conditions (Figures 106,108, and 110), when the one octave difference between the sexes is equalized, the results of the girls under 18 years are far much better than the results of the young boys. In the lower part of the vocal range, for instance, differences in maximum value of the S.F. are as big as 28 dB(A) on E.

The *minimum values* of the singing formant – in both methods- are extremely low and irregular in females in all age groups. (Figures 107 to 110).

The *average values* of the singing formant are very divergent for all genders of all ages, and thus provide useful information for individual voice education and therapy.

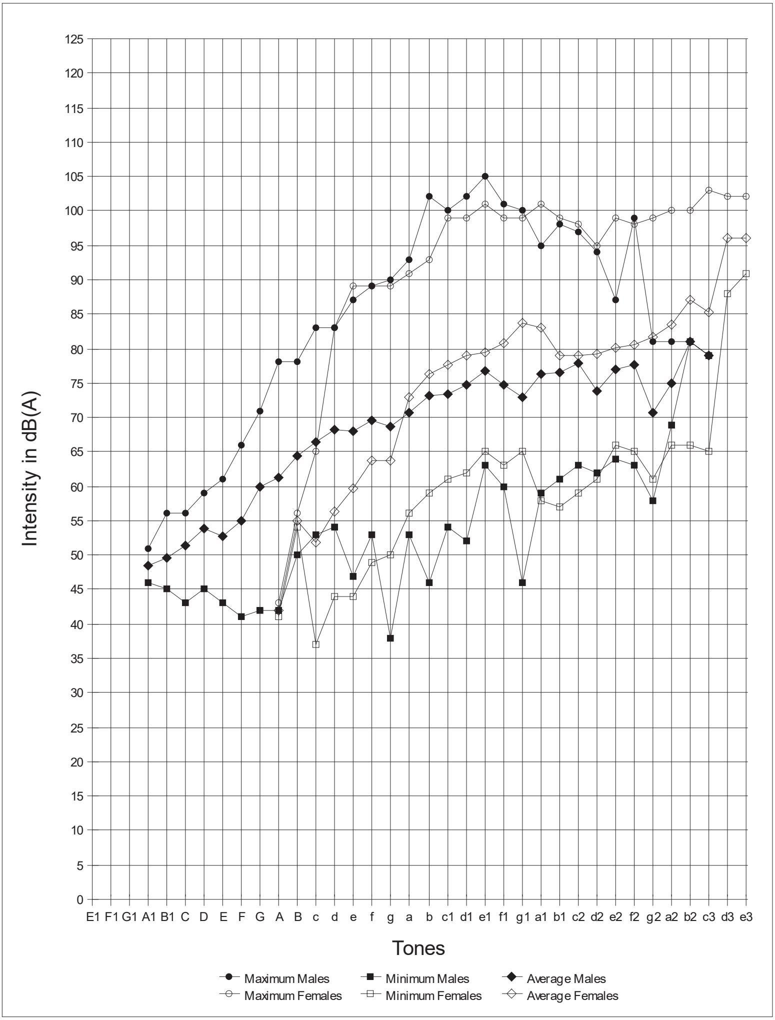
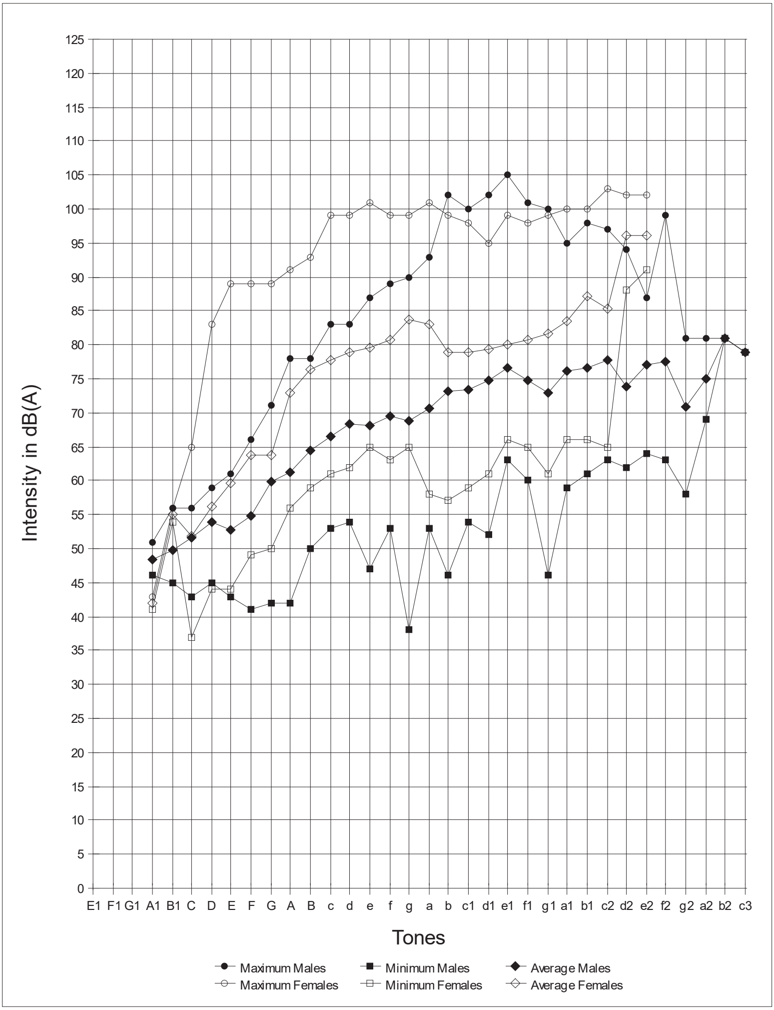


Figure 105: Comparison of maximum, minimum, and average values of the singer's formant between males and females under 18 years.



Adapted Figure 105: Comparison of maximum, minimum, and average values of the singer's formant between males and females under 18 years.

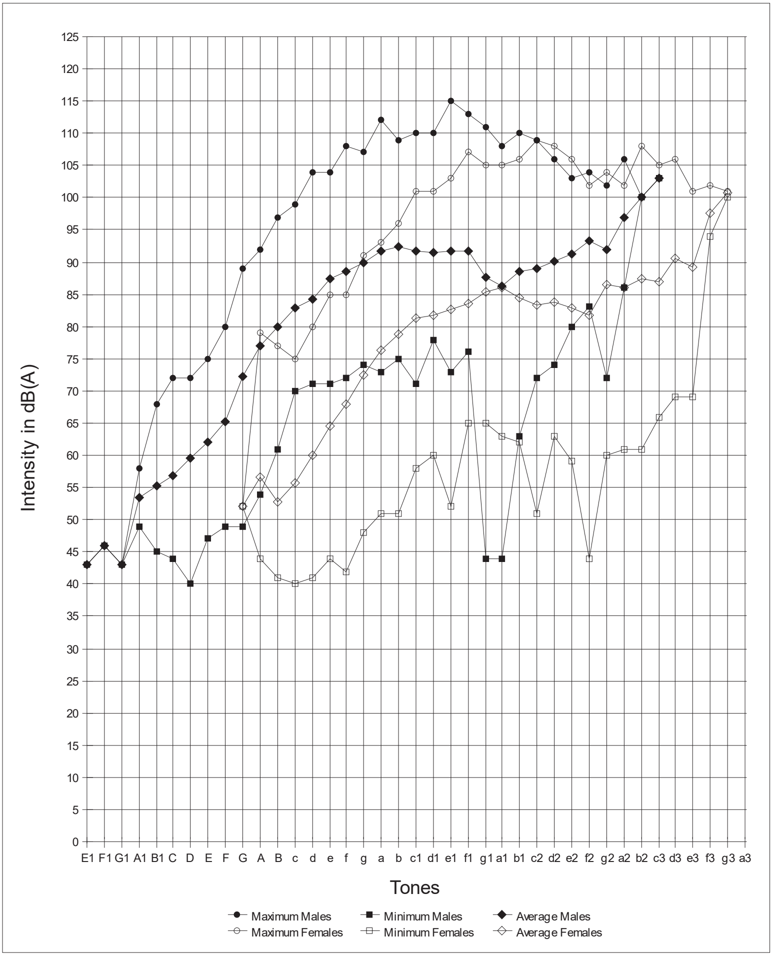
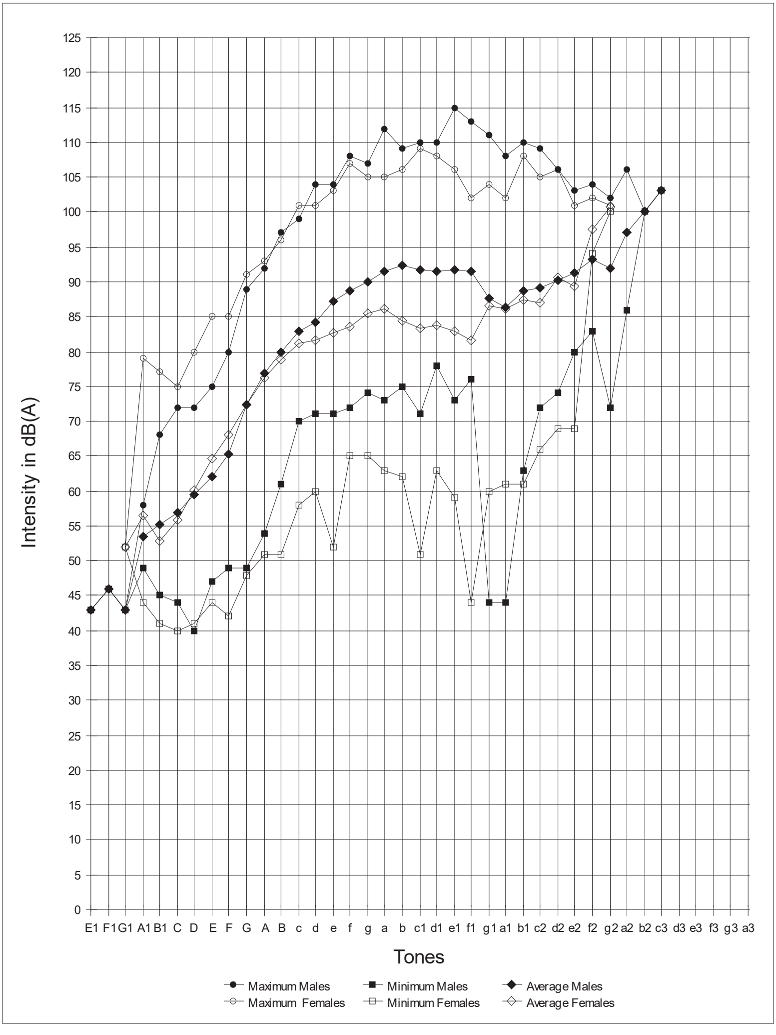


Figure 106: Comparison of maximum, minimum, and average values of the singer's formant between males and females (18 – 29 years).



Adapted Figure 106: Comparison of maximum, minimum, and mean values of the singer's formant between males and females (18 – 29 years)

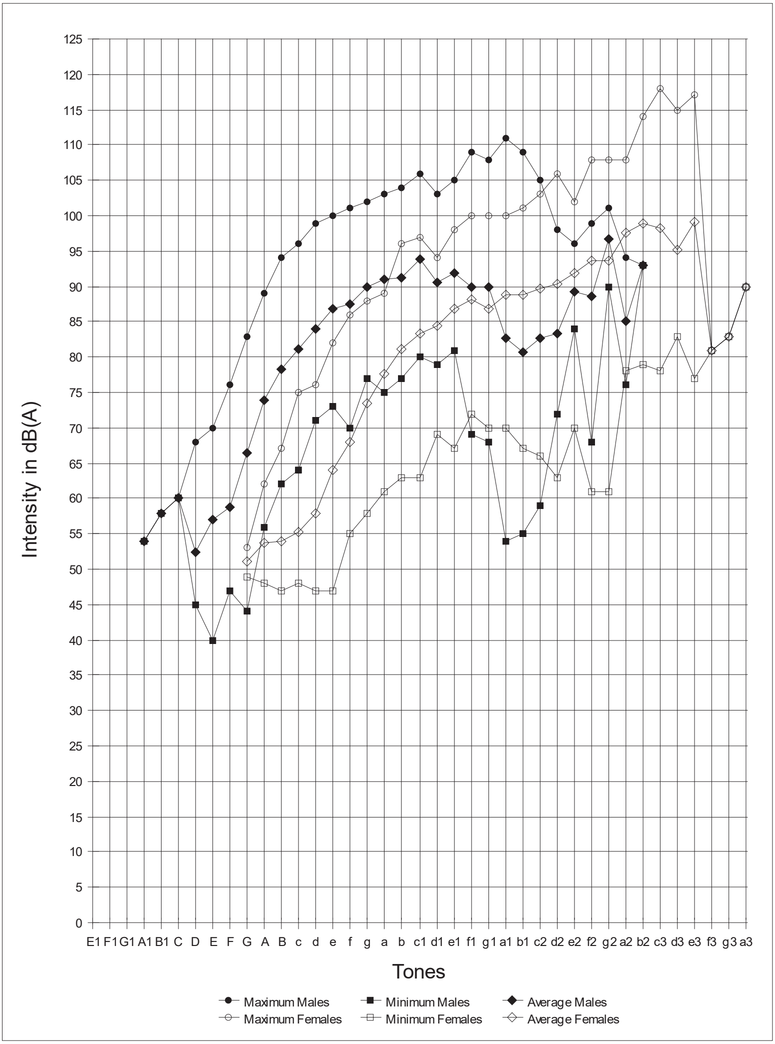
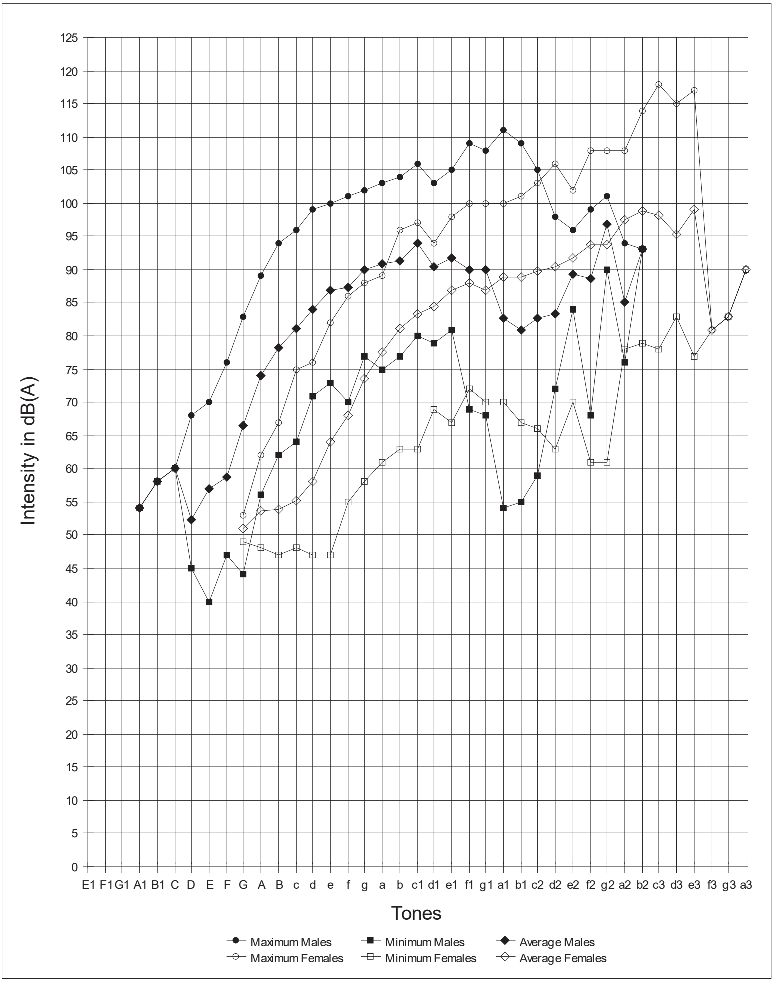


Figure 107: Comparison of maximum, minimum, and average values of the singer's formant between males and females (30 – 49 years).



Adapted Figure 107: Comparison of maximum, minimum, and mean values of the singer's formant between males and females (30 – 49 years)

8.6.3.2. Results of the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant of each tone of the vocal range.

In order to compare the differences between the maximum intensity measurements and the maximum intensity measurements of the singing formant, the quality profiles of both genders were again superposed. First, both profiles were mapped in the same Figure. In the second (adapted) figure the female profile was projected one octave lower (to fit the male profile).

The best results of the different age groups of both sexes are schematized in Table 59, according to both cited methods:

Max. I. - S.F.		**MINIMUM**	**MAXIMUM**	**AVERAGE**
Under 18 years	1st method	Girls	Boys	Girls
	2nd method	Girls	Girls	Girls
18 - 29 years	1st method	Males	Males	Males
	2nd method	Mixed	Males	Males
30 - 49 years	1st method	Males	Males	Males
	2nd method	Males	Males	Males

Table 59: Comparison (grosso modo) of best values of the differences between the maximum intensity measurements and the maximum intensity measurement of the singing formant of male and female subjects of different age categories.

Girls under 18 years show the best results. In all other age-groups, however, males produce, in general, much better voice qualities.

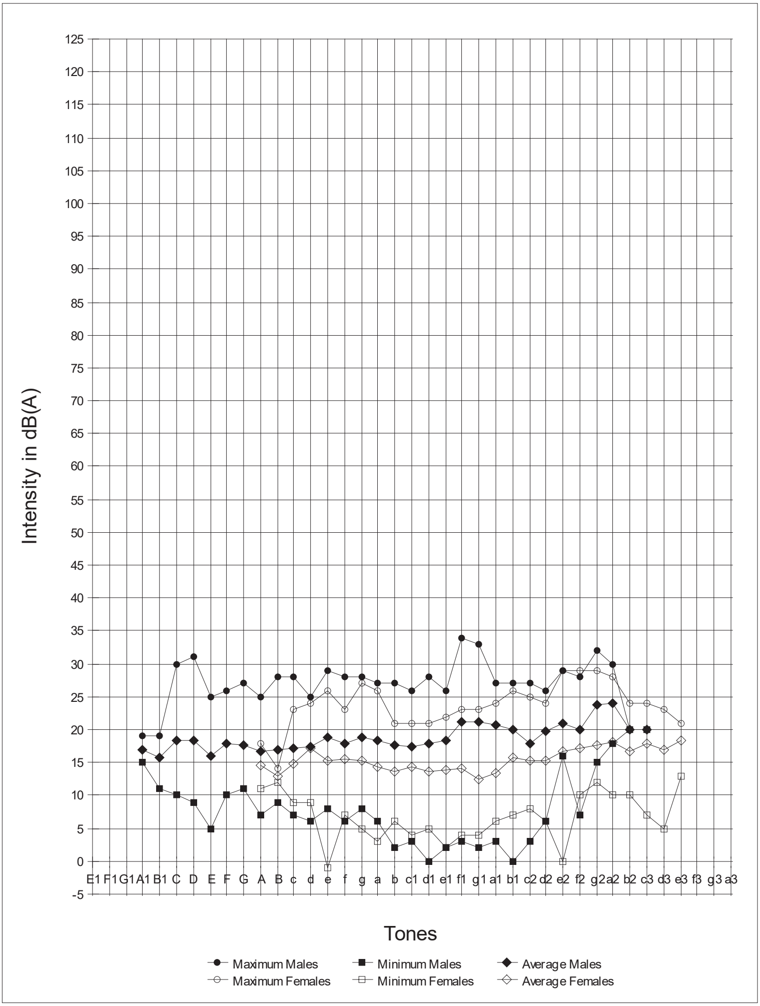
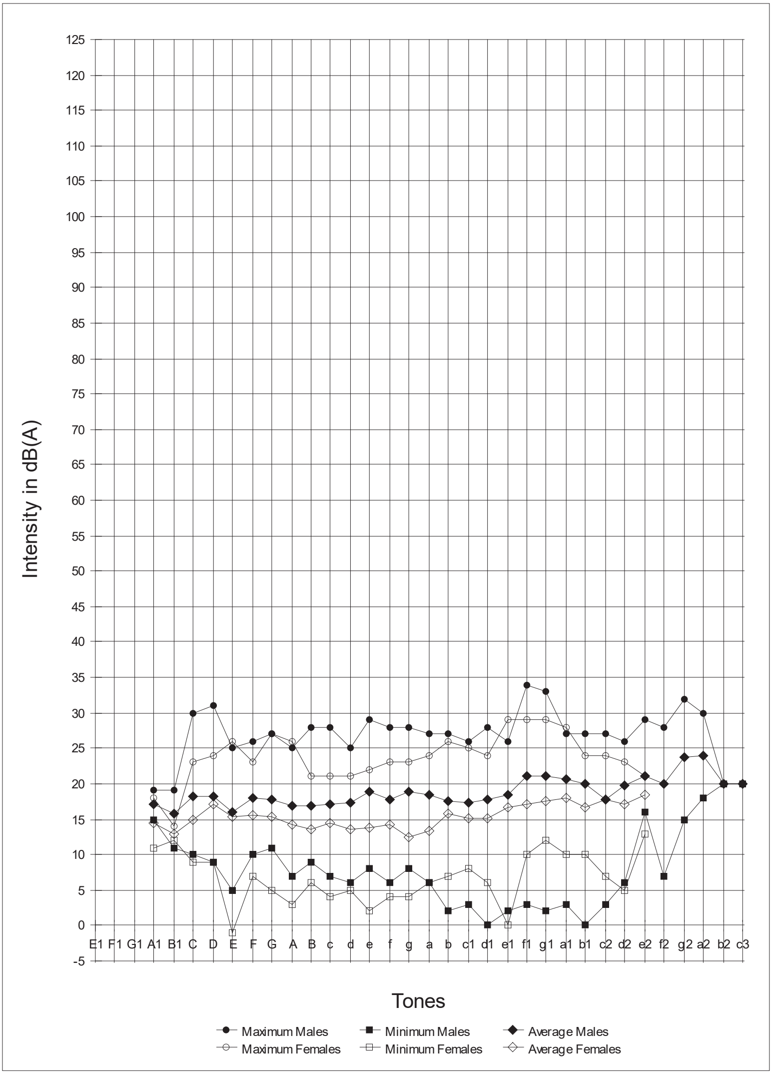


Figure 111: Comparison of the differences between the values of the maximum intensity measurements and the values of the maximum intensity measurements of the singing formant between males and females under 18 years.



Adapted Figure 111: Comparison of the differences between the values of the maximum intensity measurements and the values of the maximum intensity measurements of the singing formant between males and females under 18 years.

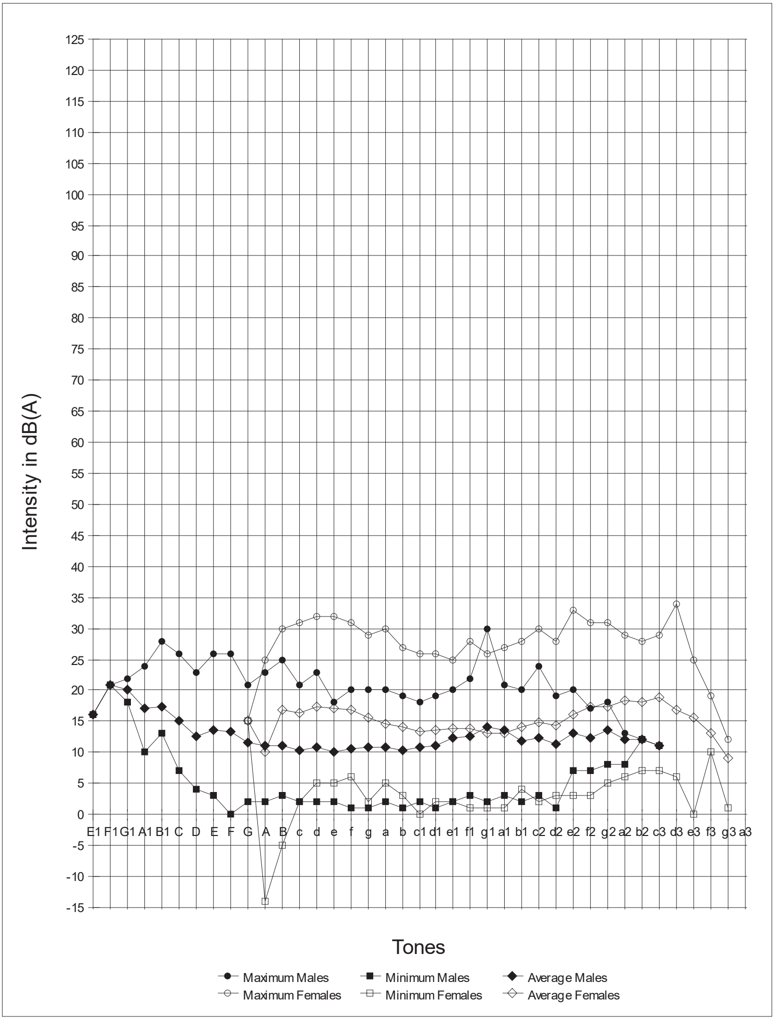
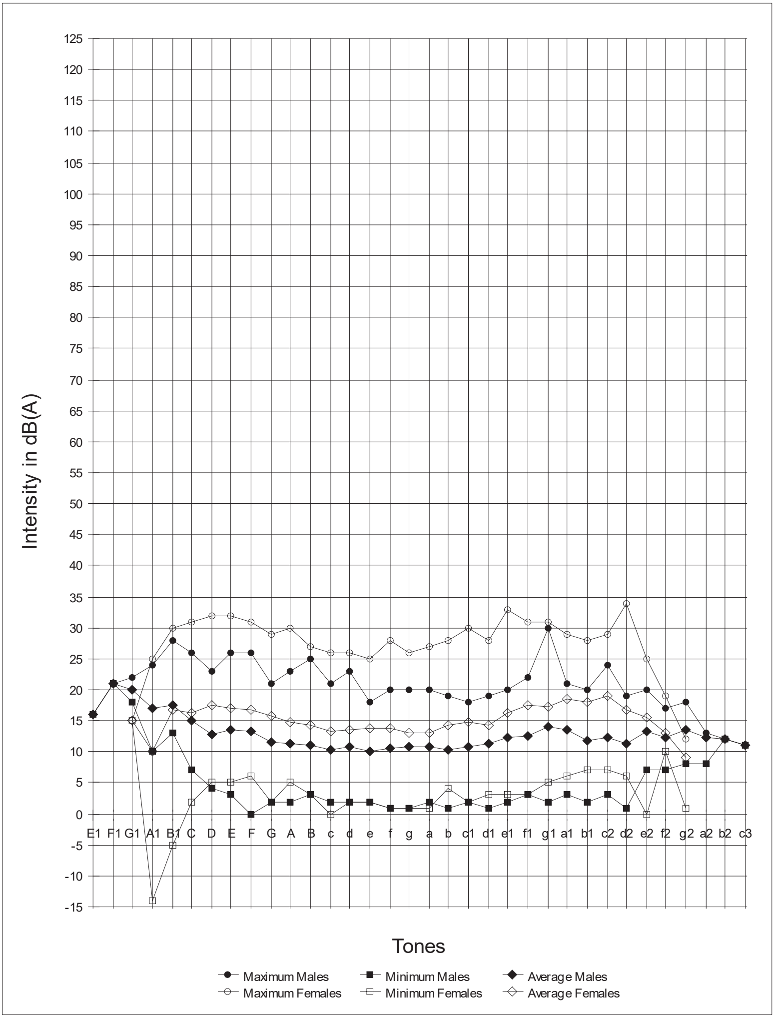


Figure 112: Comparison of the differences between the values of the maximum intensity measurements and the values of the maximum intensity measurements of the singing formant between males and females (18 – 29 years).



Adapted Figure 112: Comparison of the differences between the values of the maximum intensity measurements and the values of the maximum intensity measurements of the singing formant between males and females (18 – 29 years). (adapted Figure).

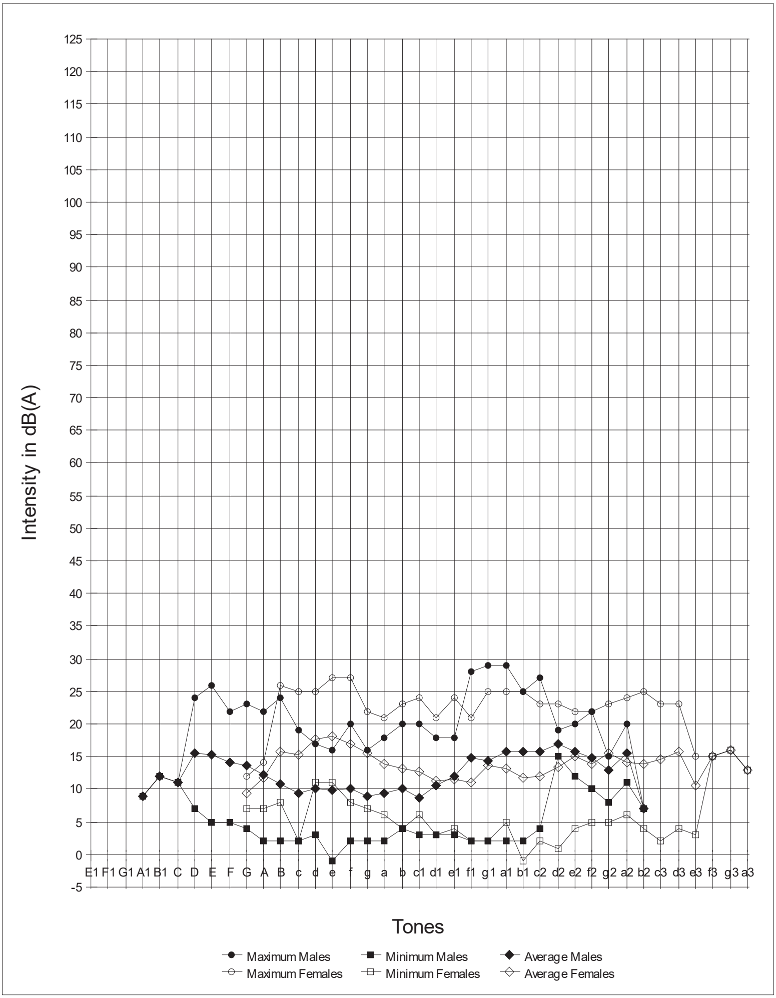


Figure 113: Comparison of the differences between the values of the maximum intensity measurements and the values of the maximum intensity measurements of the singing formant between males and females (30 - 49).

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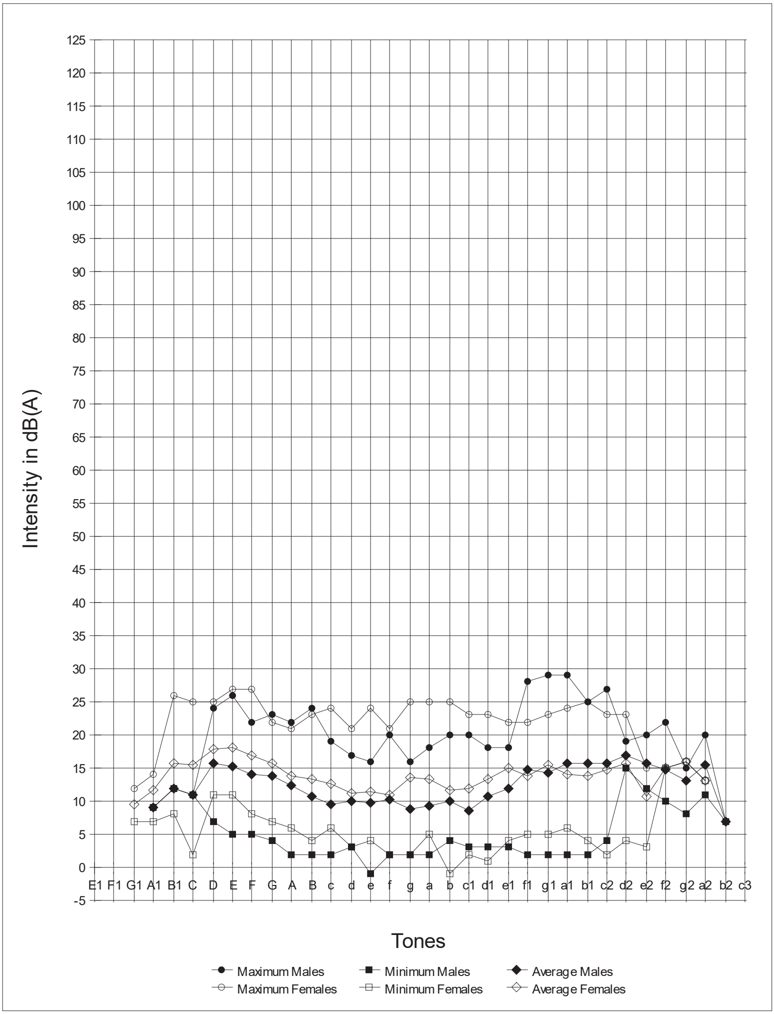


Adapted Figure 113: Comparison of the differences between the values of the maximum intensity measurements and the values of the maximum intensity measurements of the singing formant between males and females (30 - 49) (adapted Figure).

8.7. Register location

A direct approach to voice classification could consist of looking at the location of the registers in a person's voice. In Chapter 6.4. on vocal registers, we tried to summarize the many conflicting opinions on this subject up to now. We retained, however, that *register, pitch, and intensity are dependent parameters*[892] thus giving a hint that phonetography could be useful to analyse the relationship between these parameters. Moreover, there may be a *continuum* of blended interactions of acoustic and myoelastic influences on register transitions[898], and finally, there is an *influence of training and technique* (open voice, covered voice, mixed voice, forcing …), allowing the singers to use the voice registers ad libitum, but retaining their original set of registers[588,944,956,969,1059], even when these registers and passagios sometimes seem to disappear[891,1326] after some kind of singing training. All these influences imply that we rather should speak about a *region*[588] or zone in which register transitions can be shifted in pitch.[18,158,944,1007,1081,]

In our study, we held on to the more practical theory of only three major registers[944], thereby even omitting the location of the pulse register. The location of the transition between modal and loft register seems to be sufficient to give a hint for voice classification.

With a few exceptions, NO authors mention the methodology employed to assess the register transitions. According to Klingholz et al.[179,974] only the acoustic methods provide a reliable and objective access to the registers. Unfortunately, in most phonetograms providing relatively few measuring points, subtle or even eye casting register transitions are therefore seldom visible.[1028,1062]

We choose phonetography as a convenient method of assessing register transitions, as illustrated by the common parameters of voice: pitch, intensity, and vocal quality. Airainer and Klingholz[1037] refer to a set of *reference register transitions* "because the transitions can be hard to find".

Considering the many differing zones of register transition, found in the literature, we choose to analyse by phonetography *an as much possible large zone of pitches in which the transition between modal (chest) and loft (falsetto, head) is supposed to take place*. This zone is situated *between a and a1 for males, and one octave higher, between a1 and a2, for the female subjects*. This large zone of one octave must be thoroughly scrutinized, to find typical clues, indicating the important register transition. To that end we decided, experimentally, to take a closer look at:

- the register range, i.e., the zone from the last ascending maximum intensity points to the next maximum ascending intensity point.
- the maximum intensity of the register dip.
- the minimum intensity of the register dip.
- the difference between the maximum and the minimum intensity of the register dip.
- the evolution of the maximum intensities of the singer's formant in the register range.
- the value of the singer's formant in the register dip.
- the difference between the maximum intensity and the value of the singer's formant in the register dip.

These different data were compared to the concise information on register transitions, related to *voice categories*, as found in the literature, and listed in our step-by-step procedure of voice classification.

Many examples of our (tentative) interpretation can be found in our case studies.

As we could not find data on register location by F°-SPL measurement, we could not compare our own results with those of other studies. (Chapter 9).

The results of our PhD study, however, have clearly demonstrated *the huge importance of the localisation and interpretation of the register change zone for objective voice classification.* (Chapter 10).

8.8. Voice classification by phonetography: a step- by- step procedure

8.8.1. Male voices: Results and Discussion

We already mentioned that F°-SPL measurement can be considered as a simple, yet practical instrument by which somebody's voice category can be determined. However, data on voice classification by phonetography are extremely scarce.

Seidner et al.[1485] obtained spectral voice area measurements of 90 subjects (30 professional singers, 30 singing students and 30 non-singers).

According to these researchers, non-singers were difficult to classify or could not be classified at all! We certainly do not agree with this.

Klingholz et al.[1028] classified 50 choir-boys voices by phonetograhy and compared his results with those obtained from choir directors.

The results of the different items in our step-by-step procedure, mentioned above, will eventually lead to the establishment of the voice category of the subject.

Next to our step-by-step diagnosis we will mention *every opinion* we could gather on the (possible) voice classification of our subjects.

To demonstrate and test the different steps of our voice classification procedure, we analysed *116 measurements of male subjects*. We analysed not only F°-SPL-measurements, inclusive the singer's formant, but also all kinds of "incomplete" measurements. In fact, the complete procedure is not always necessary. With some experience, a lot of phonetograms can be quickly interpreted *de visu*, by controlling just a few steps of the procedure. Longitudinal phonetograms, over a long period of time, offer an excellent opportunity to control the initial diagnosis. *In any case, we found that the initial voice classification remained the same, whatever other parameters changed over time.*

Our extensive examples (see our **selected Case Studies of all kinds of male and female subjects of different ages (**See Chapter 9) provide an overview of the interpretations of our phonetographic results in our step-by-step procedure of voice classification. Each of the 8 different items is interpreted according to the method explained in previous chapters. These 8 items of a *consecutive tentative classification* are:

- 1. lowest tone.
- 2. highest tone.
- 3. maximum intensity of each tone.
- 4. minimum intensity of each tone.
- 5. dynamic range.
- 6. value of the singer's formants.
- 7. value of the difference between the maximum intensities and the value of the singer's formants.
- 8. register location.

Voice classification by only noting the lowest and the highest tone of the vocal range, is not at all sufficient. In fact, in most cases, this limited procedure proves to be deceptive, because the vocal range of many voices is forced or reduced one way or another. Our final diagnosis was only made at the end of the 6 supplementary steps (maximum intensity, minimum intensity, dynamic range, singer's formant, difference between maximum intensity and intensity of the singing formant, and register location) as obtained by phonetography, and after carefully balancing the value of the different items, Remarks and other opinions about the voice category or vocal status of the subject are also noted.

As we mentioned before, young adult people – with or without voice and/or singing training, many of them with vocal complaints – occupied the major portion of the subjects of our study.

Curiously, 63,4 % of our male subjects were not aware of their own voice category. Only 18,3 % of other opinions concerning their voice classification was in consensus with our diagnosis, while the same percentage (18,3 %) was found to be incorrect. Consequently, one can only guess what the real impact of this ignorance on the vocal health of a lot of "normal" people could be…

According to our methodology, the results showed that +/- 71 % of our male population were baritones, while only 15,65 % were tenors and only 13,04 % were real basses.

In the world of singing, male voices of extreme ranges are considered as exceptional, but we think that this is also the case in the daily world of ordinary people. The great majority of male voice types are situated in the medium range.

In a study on "normal classically trained singers", Carroll et al.[1512] reported that 60% of the singers classified themselves as baritones, 25 % classified themselves as tenors and 15 % found they were basses.

One must consider that the population in our study was extremely diverse. (e.g., more than 20 % of our subjects had a serious voice disorder). Nevertheless, in 75,8 % of the cases, 5 to 6 of the 6 supplementary items of our step-by-step procedure were in concordance. In only 20,6 % of the cases, 2 to 3 items were concordant, and 3,4 % were predominantly divergent.

Classification, however, is not always easy. For instance, according to the Table 6, providing a synopsis of the extreme limits of voice ranges / tessitura, as suggested by 38 authors with different backgrounds, tones beneath B1 do belong to basses. However, we found one subject, producing a G1 and we classified him as a baritone, while his singing teacher even thought he was a "high" baritone!

Possible controversial results between the different items, can be explained by the clinical interpretation of the complete vocal picture. For instance, suppose the maximum intensity and the maximum value of the singer's formant of the lowest pitches are situated within the range of a baritone voice. Some higher pitches, however, are produced at a higher maximum intensity level, thus suggesting a bass voice. It is obvious that the better results at some higher pitches do not indicate another voice type but do reveal a well-trained voice of superior quality. Vice versa, for voices of lesser quality or disturbed voices. Divergent values can also be checked by controlling the differences between two items (e.g., dynamic range, difference between maximum intensity and intensity of singer's formant).

Nevertheless, we understand that the global "differing ranges" we proposed, must be checked further on and completed by many more subjects.

8.8.2. Female voices: Results and Discussion

We analysed *251 measurements of female voices* according to the methodology described above.

As with male subjects, most subjects were not aware of their own voice category. Astonishingly, not less than 68 % of our female subjects, who were, after all, interested in (vocal) performing, declared never been told which voice they had, nor had any idea themselves about what type of voice they could have. Only 8,4 % of other opinions concerning their voice classification was in consensus with our diagnosis, while 24,3 % was found to be incorrect or at least uncertain.

In a study on "normal classically trained singers", Carroll et al.[1512] found that only 25 % of the singers classified themselves as mezzos and 75 % classified themselves as sopranos! Apparently, there were no contraltos…

According to our methodology, however, the results showed that almost 80 % of our female population were mezzos, while only 12 % were contraltos and only 8 % were real sopranos. *Female voices of extreme ranges are exceptional*. The great majority of voice female types are situated in the medium range. Could these results explain the many errors in voice classification? Is it acceptable that female subjects who took singing lessons never heard about voice classification, even after more than 5 years of taking classes? Could these results also explain why *49,4 % of our female subjects suffered one kind or another of (functional) voice disorder*? However, this percentage is still small in comparison to the 69 – 70 % of vocal disability in singers and student-singers, reported by other authors.[1493,1494]

Anyway, in almost 80 % of the cases, 5 to 6 of the 6 supplementary items of our step-by-step procedure were in concordance and thus plainly sufficient for an adequate voice classification. In 20 % of the cases there was only a consensus of 3 to 4 items, as revealed by phonetographic analysis.

8.8.3. Case studies

As can be learned from the results of the step-by-step analysis of our male and female subjects,75,8 % to 80 % of voice classification is supported by 5 to 6 concordant supplementary items, featured by phonetographic analysis.

Our *extremely diverse population* over the years (male and female untrained subjects, classically trained singers, actors, dancers, acting – singing - dancing students and voice patients of all ages, allows, of course, for many divergent results and some extreme cases.

Out of more than 1.000 phonetograms, we made a choice to illustrate our methodology, and we will analyse *some instructive phonetograms, insisting on atypical and even aberrant cases.*

As a rule of thumb, training should (normally) result in higher maximum intensity, lower minimum intensity, higher dynamic range, higher singer's formant, and lower difference between maximum intensity and singer's formant.

Regarding voice classification, however, some measurements of "*well-trained voices"* sometimes suggest a *lower* voice category, while some measurements of "*bad or pathological voices"* suggest a *higher* voice category. In such case, our subjective impression of voice quality is adequately completed by the measurement of the singer's formant.

LEGEND:

Nr.: number of male / female subject.
Y.: age in years.
M.: months.
1: lowest tone.
2: highest tone.
3: maximum intensity.
4: minimum intensity.
5: dynamic range.
6: singer's formant.
7: maximum intensity – singer's formant.
8: register location.
9: diagnosis.
10: remarks: voice status; other opinions on voice classification.
?: voice classification unknown.
B: bass voice.
b: baritone voice.
T: tenor voice.
C: contralto voice.
M: mezzo voice.
S: soprano voice

1). Figure 117 (nr. 47).

Untrained female subject.

Age: 18 years, 1 month.

Functional voice disorder.

Nr.	Y.	M.	1	2	3	4	5	6	7	8	9	10
47	18	01	**d**	**e3**								Functional voice disorder
			C-M-S	**C-M-S**	M	M	M	M	M	M	**M**	?

Table 60: Synthetic Figure of voice classification steps in Case Nr. 47.

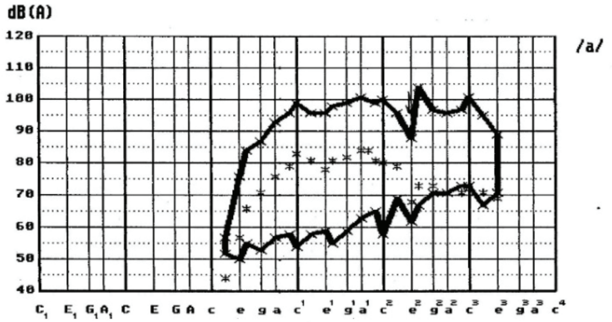
This 18-years old girl took dance lessons since she was 5-years old, but never had singing lessons. According to her singing range (1) (2), which is quite large (d-e3), she could be a contralto, or a mezzo, or a soprano (C-M-S). All phonetographic measurements of her lowest pitches, however, clearly indicate a mezzo voice (M).

In the next Figure 117 we can see from measurements (3), (5), and (6) of her lowest pitch d, that this tone is very weak. The maximum intensity (3) on d is hardly 57 dB(A) and the dynamic range (5) is only 5 dB(A). There is also a steep increase of maximum intensity from 57 dB(A) to 76 dB(A) between d and e.

From c1 on, the maximum intensity hardly increases from 99 dB(A) to 104 dB(A) on f2.

The register transition (8) is situated between c2 and f2, with a great dip on e2, and is typical for a mezzo voice. Remark a little parallel dip between c1 and f1, with a lowered singer's formant of 78 dB(A) on e1 and a very low singer's formant of 68 dB(A) on e2. The bad quality of the voice is clearly demonstrated by the low singing formants (6) over her entire vocal range. The functional voice disorder, however, is more pronounced on the highest pitches and is clearly visualised by the extremely low values of the singer's formant in that region.

Voice Research Laboratory Groningen, Ing. J.H. van Dijk



Frekwenties : 23
dB waarden : 46

Toon	Frekw.	Max	Min	dBz
d	147	57	52	44
e	165	76	50	57
f	175	84	55	66
g	196	87	53	71
a	220	93	57	76
b	247	96	58	79
c 1	262	99	54	83
d 1	294	96	58	81
e 1	330	96	59	78
f 1	349	98	55	81
g 1	392	99	59	82
a 1	440	101	63	84
b 1	494	99	65	81
c 2	523	100	58	80
d 2	587	96	69	79
e 2	659	88	62	68
f 2	698	104	67	73
g 2	784	97	71	73
a 2	880	96	71	71
b 2	988	97	73	71
c 3	1047	101	73	72
d 3	1175	95	67	71
e 3	1319	89	71	69

	3	Differentiating range	Indication
B			
c			
d	57	70,83 - 86,42	S
e	76	70,34 - 86,91	M
f	84	76,63 - 92,50	M
g	87	80,91 - 96,18	M
a	93	83,97 - 98,24	M
	4	Differentiating range	Indication
B			
c			
d	52	48,15 - 64,84	M
e	50	49,62 - 63,73	M
f	55	50,05 - 62,30	M
g	53	51,80 - 61,50	M
a	57	52,18 - 63,65	M
	5	Differentiating range	Indication
B			
c			
d	5	11,16 - 31,53	S
e	26	15,92 - 34,59	M
f	29	21,27 - 37,26	M
g	34	24,92 - 39,77	M
a	36	25,14 - 41,65	M
	6	Differentiating range	Indication
B			
c			
d	44	51,069 - 69,031	S
e	57	54,603 - 74,597	M
f	66	58,106 - 77,954	M
g	71	62,671 - 82,149	M
a	76	66,629 - 85,831	M
	7	Differentiating range	Indication
B			
c			
d	13	11,09 - 23,89	M
e	19	11,2 - 22,88	M
f	18	10,79 - 22,85	M
g	16	10,41 - 21,33	M
a	17	9,64 - 19,72	M

Table 61: Step-by-step analysis of Case Nr. 47.

2). Figure 118 (nr. 109).

Untrained female subject.

Age: 19 years, 6 months.

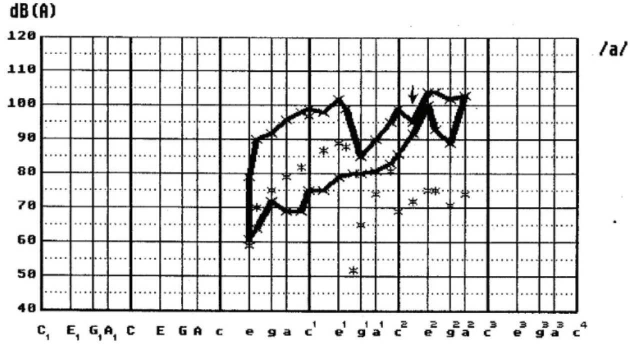
(Severe) functional voice disorder.

Nr.	Y.	M.	1	2	3	4	5	6	7	8	9	10
109	19	06	**e**	**a2**								Functional voice disorder
			C-M-S	**C-M-S**	M	S	M	M	M	M	**M**	?

Table 62: Synthetic Figure of voice classification steps in Case Nr. 109.

This 19 1/2 years-old dance girl never had voice or singing lessons but is in desperate need of voice therapy. According to her singing range (e – a2), she too could be a contralto, or a mezzo, or a soprano. Her shrunk phonetogram clearly shows the severe voice problems, especially in her middle and high register. While the lower part of her voice sounds dysphonic, tones from f1 on are completely hoarse, as can be seen from the extreme low singing formants in that region. The two register dips (g1) and d2 also demonstrate the specific difficulties of the register transitions of a mezzo, spread over the middle and upper register.

The severe dysphonic voice pathology explains why some measurements of maximum intensity (f, g, and a), and their dynamic range could give the impression of a *higher* voice type (soprano). As stated before, the *complete vocal image* must be seen and heard.



Frekwenties : 19
dB waarden : 35

Toon	Frekw.	Max	Min	dBz
e	165	79	61	59
f	175	90	64	70
g	196	92	72	75
a	220	96	69	79
b	247	98	69	82
c 1	262	99	75	97
d 1	294	98	75	87
e 1	330	102	79	89
f 1	349	99	0	88
f#1	370	0	80	52
g 1	392	85	80	65
a 1	440	90	81	74
b 1	494	95	83	81
c 2	523	99	86	69
d 2	587	95	92	72
e 2	659	104	100	75
f 2	698	104	93	75
g 2	784	102	89	71
a 2	880	103	0	74

	3	Differentiating range	Indication
B			
c			
d			
e	79	70,34 - 86,91	M
f	90	76,63 - 92,50	M
g	92	80,91 - 96,18	M
a	96	83,97 - 98,24	M
	4	Differentiating range	Indication
B			
c			
d			
e	61	49,62 - 63,73	M
f	64	50,05 - 62,30	S
g	72	51,80 - 61,50	S
a	69	52,18 - 63,65	S
	5	Differentiating range	Indication
B			
c			
d			
e	18	15,92 - 34,59	M
f	26	21,27 - 37,26	M
g	20	24,92 - 39,77	S
a	27	25,14 - 41,65	M
	6	Differentiating range	Indication
B			
c			
d			
e	59	54,603 - 74,597	M
f	70	58,106 - 77,954	M
g	75	62,671 - 82,149	M
a	79	66,629 - 85,831	M
	7	Differentiating range	Indication
B			
c			
d			
e	20	11,2 - 22,88	M
f	20	10,79 - 22,85	M
g	17	10,41 - 21,33	M
a	17	9,64 - 19,72	M

Table 63: Step-by-step analysis of Case Nr. 109.

3). Figure 119: Comparison of nr. 47 and nr.109.

Phonetograms must be thoroughly analysed, tone by tone. At first sight, the first phonetogram (Case Nr. 47) looks better than the second one (Case Nr. 109):

- a greater vocal range: d – e3 vs. e – a2.
- a much bigger surface.
- less pronounced register transition dips.
- much lower minimum intensities.

However, the pitches in the lower range of the second phonetogram (e – f1) showing better results for maximum intensity and singer's formant measurements, could provide an *interesting starting-point for voice therapy*.

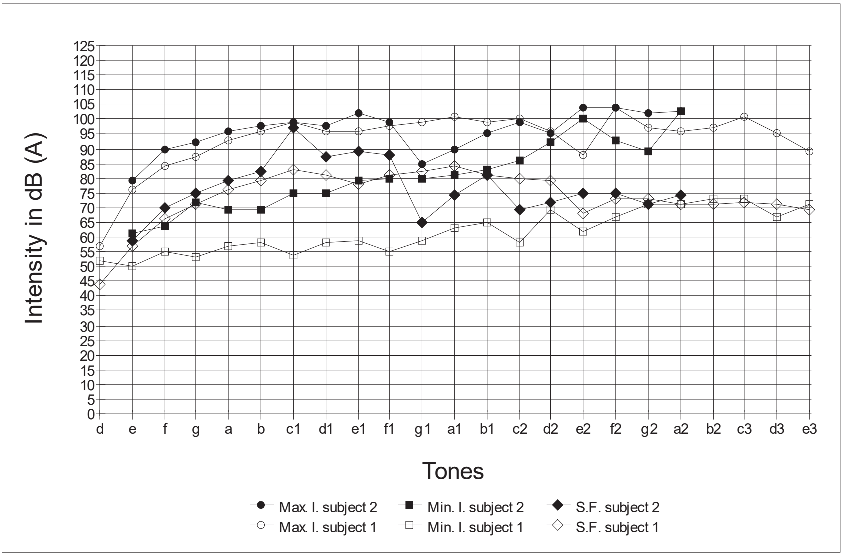


Figure 119: Comparison of two phonetograms of young untrained female subjects (Nr.47 and Nr.109)

4. Figures 120 – 121 - 122 (nr. 48, 85, and 115).

Untrained female subject.

Age: 18 years, 1 month

18 years, 11 months.

19 years, 9 months.

Nr.	Y.	M.	1	2	3	4	5	6	7	8	9	10
48	18	01	**c**	**d3**								
			C-M-S	**C-M-S**	M	M	M	M	M	M	**M**	?
85	18	11	**c**	**c3**								
			C-M-S	**C-M-S**	M	M	M	C	C	M	**M**	?
115	19	09	**c**	**b2**								
			C-M-S	**C-M-S**	M	M	M	M	M	M	**M**	?

Table 64: Synthetic Figures of voice classification steps in Cases Nr. 48, 85 and 115.

Longitudinal phonetograms clearly demonstrate the **plasticity** of the human voice. All kinds of influences (voice training, singing lessons, vocal abuse and misuse, pathology …) change the morphology of the phonetogram and its parameters.

One could wonder if changes of some parameters, as reflected in the Voice Field, also induce another **voice category**.

The analysis of the next 3 longitudinal phonetograms of a young girl shows that her voice type (mezzo) remained unchanged, even when a lot of parameters of the phonetogram changed in a period of 20 months. According to her singing range (c – d3/c -c3), she could be a contralto, or a mezzo, or a soprano

The first phonetogram comes from this 18-years old, untrained female subject. After about 10 hours of only logopedic voice training, spread over 10 months, we obtained the second phonetogram. Then followed another schoolyear of only singing lessons before the third phonetogram was taken.

Although this young girl already had a lot of vocal potential from the beginning, as shown in the first phonetogram, logopedic voice training clearly enlarged the surface of the voice field and procured a more powerful voice (up to + 19 dB(A) on e1), much lower minimum intensities, a much larger dynamic range (54 db (A) instead of 28 dB(A)on g1) and higher singing formants (from initially 73 dB(A) to 100 dB(A) on e1, with a maximum of 103 dB(A), instead of 82 db(A)) on e2 (just above the register transition). However, these good results greatly vanished one year later, after having only singing lessons. The *register transition zone, however, remained the same*, be it that the last phonetogram featured a greater dip on d2, paralleled by a dip on d1, typical for a mezzo voice. The voice range is reduced to c – b2.

Voice category, however, has not changed, even when some measurements of specific pitches would indicate a *lower* voice type, which could be considered as typical for an outstanding performance. In pathological cases, some measurements of specific pitches could also indicate a *higher* voice type.

Caution must be taken when interpreting measurements in extreme cases of well-trained voices and in cases of pathological voices.

In any case, *the total picture of the voice must be considered*. Like in all other methodologies, *expertise* can help a lot to make the right diagnosis in some dubious cases. Moreover, we think there is a lot to learn from the comparison of longitudinal phonetograms of the same person over a length of time (Chapter 9).

			A		B		C	
	3	Differentiating range		Indic.		Indic.		Indic.
B								
c		66,77 - 82,46	64	M	81	M	72	M
d		70,83 - 86,42	76	M	88	M	81	M
e		70,34 - 86,91	81	M	91	C	87	M
f		76,63 - 92,50	83	M	94	C	89	M
g		80,91 - 96,18	85	M	98	C	94	M
a		83,97 - 98,24	89	M	101	C	94	M
	4	Differentiating range		Indic.		Indic.		Indic.
B								
c		50,13 - 66,78	52	M	50	M	53	M
d		48,15 - 64,84	53	M	48	M	47	C
e		49,62 - 63,73	54	M	49	M	50	M
f		50,05 - 62,30	51	M	51	M	54	M
g		51,80 - 61,50	53	M	51	M	53	M
a		52,18 - 63,65	53	M	52	M	54	M
	5	Differentiating range		Indic.		Indic.		Indic.
B								
c		4,39 - 24,84	12	M	31	C	19	M
d		11,16 - 31,53	23	M	40	M	34	C
e		15,92 - 34,59	27	M	42	C	37	C
f		21,27 - 37,26	32	M	43	C	35	M
g		24,92 - 39,77	32	M	47	C	41	C
a		25,14 - 41,65	36	M	49	C	40	M
	6	Differentiating range		Indic.		Indic.		Indic.
B								
c		47,993 - 63,547	60	M	64	M	54	M
d		51,069 - 69,031	55	M	72	C	65	M
e		54,603 - 74,597	67	M	82	C	76	C
f		58,106 - 77,954	67	M	83	C	78	M
g		62,671 - 82,149	74	M	89	C	87	C
a		66,629 - 85,831	76	M	92	C	84	M
	7	Differentiating range		Indic.		Indic.		Indic.
B								
c		10,30 - 22,50	4	C	17	M	18	M
d		11,09 - 23,89	21	M	16	M	16	M
e		11,2 - 22,88	14	M	9	C	11	M
f		10,79 - 22,85	16	M	11	M	11	M
g		10,41 - 21,33	11	M	9	C	7	C
a		9,64 - 19,72	13	M	9	M	10	M

Table 65: Comparison of longitudinal step-by-step analysis of Nr. 48, 85, and 115.

LEGEND:

A: first phonetogram of an untrained 18-years old girl.

B: second phonetogram after about 10 hours of only logopedic voice training.

C: third phonetogram after 1 school year of only singing lessons.

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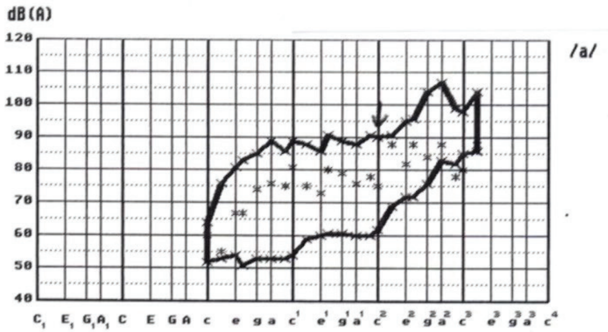

Frekwenties : 23
dB waarden : 46

Toon	Frekw.	Max	Min	dBz
c	131	64	52	60
d	147	76	53	55
e	165	81	54	67
f	175	83	51	67
g	196	85	53	74
a	220	89	53	76
b	247	86	53	75
c 1	262	89	54	81
d 1	294	88	59	75
e 1	330	86	60	73
f 1	349	91	61	80
g 1	392	89	61	79
a 1	440	88	60	76
b 1	494	91	60	78
c 2	523	90	62	75
d 2	587	91	69	88
e 2	659	95	72	82
f 2	698	96	72	88
g 2	784	104	76	84
a 2	880	107	83	88
b 2	988	99	82	78
c 3	1047	98	85	80
d 3	1175	104	86	88

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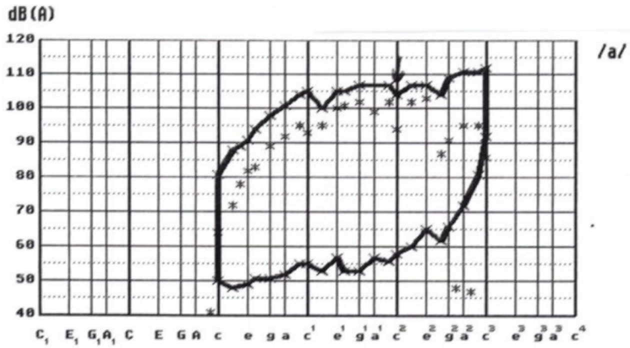

Frekwenties : 23
dB waarden : 44

Toon	Frekw.	Max	Min	dBz
c	131	81	50	64
d	147	88	48	72
d#	156	89	0	78
e	165	91	49	82
f	175	94	51	83
g	196	98	51	89
a	220	101	52	92
b	247	104	55	95
c 1	262	105	55	93
d 1	294	100	53	95
e 1	330	105	57	100
f 1	349	105	53	101
g 1	392	107	53	102
a 1	440	0	57	99
b 1	494	107	56	102
c 2	523	104	58	94
d 2	587	107	60	102
e 2	659	107	65	103
f#2	740	104	62	87
g 2	784	109	66	91
a 2	880	111	72	95
b 2	988	111	81	95
c 3	1047	112	92	86

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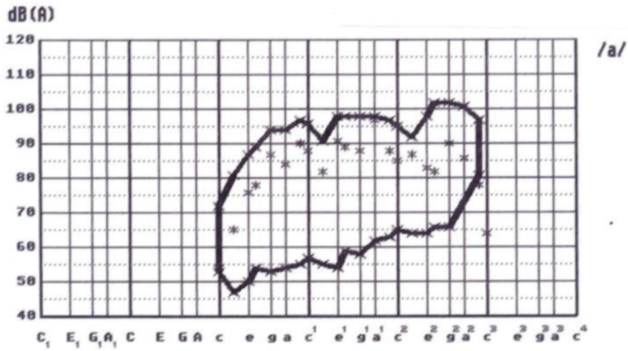



```
Frekwenties :  21
dB waarden  :  41
```

Toon	Frekw.	Max	Min	dBz
c	131	72	53	54
d	147	81	47	65
e	165	87	50	76
f	175	89	54	78
g	196	94	53	87
a	220	94	54	84
b	247	97	55	90
c 1	262	96	57	88
d 1	294	91	55	82
e 1	330	98	54	91
f 1	349	98	59	89
g 1	392	98	58	88
a 1	440	98	62	97
b 1	494	97	63	88
c 2	523	95	65	85
d 2	587	92	64	87
e 2	659	98	64	83
f 2	698	102	66	82
g 2	784	102	66	90
a 2	880	101	0	86
b 2	988	97	81	78

5). Figures 123 - 124 (nr.91 and nr.80).

- Classically trained male opera-singer.

  Age: 31 years, 11 months.

- Male amateur-singer who had singing lessons.

  Age: 29 years; 4 months.

Nr.	Y.	M.	1	2	3	4	5	6	7	8	9	10
91	31	11	E	f2								
			B-b-T	**B**	b	b	b	b	b	b	**b**	Baritone
Nr.	**Y.**	**M.**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
80	29	4	E	c3								
			B-b-T	**B**	b	b	b	b	B	b	**b**	Tenor with great depth

Table 66: Synthetic Figures of voice classification steps in Cases Nr. 91 and 80.

Mimetism plays a major role in speech and voice production. At auditions, the many candidates not only do their utmost to obtain the desired role, but they also are *strongly inclined to produce that kind of voice that is expected for that role.* Here again, the “judges” are left to their own ears and their expertise. Hence, the many discussions during the often-endless lasting auditions.

Having participated as a member of the jury in countless auditions of all kinds, we always proposed phonetography as a concrete method to obtain more objective indications about seemingly similar voices. Take for instance, the next cases of two types of well-trained singers, competing for a major role in a modern musical.

The first phonetogram is that of an internationally famous, classically trained baritone. The second phonetogram is that of a psychologist, who took some singing lessons, and was trained as a “tenor with great depth”.

Both singers possess an extended vocal range, although Wirth[391] maintains that baritones have the smallest vocal range. E is the lowest tone in both singers and belongs, according to Table 6, to a bass, or a baritone, or a tenor voice. The highest pitch of the classically trained baritone is f2, while the highest pitch of the amateur singer is an exceptional c3, both extreme pitches acknowledged as typical of a bass voice.

The register dip for both singers is situated at c1/d1 and is typical of a baritone voice. Note the smooth register transition of the amateur-singer, and the parallel (octave) dips at d and d2.

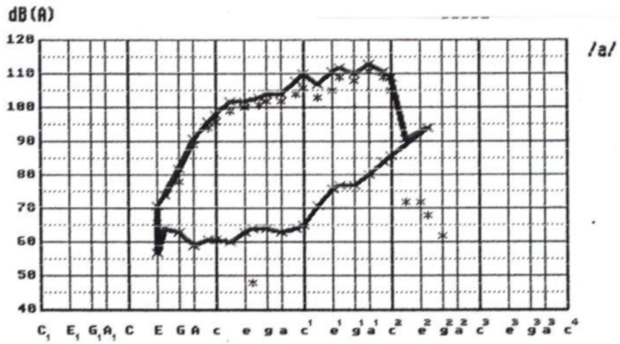
Maximum intensity, minimum intensity, and singer's formant are in the same range for both singers. The musical score, however, required a lot of extremely high and strong falsetto tones. As can be seen from the phonetograms, the top note of the classically trained baritone is a1, produced at a maximum intensity of 111 dB(A). From then on, the maximum intensity and the value of the singer's formant drop considerably. The amateur singer, however, maintains a powerful and beautiful sound throughout his complete highest vocal range, with a c3 top note (one octave above the famous high c2 of a well-paid classical tenor!) at a maximum intensity of 114 dB(A). This is really an exceptional voice!

Based on these comparative VRP's, and, of course, other scenic aspects, the amateur singer got the job and made many successful performances, without any vocal trouble.

In these two cases of exceptional well-trained voices, some measurements of some pitches indeed would indicate another voice type. We explained already why this can happen.

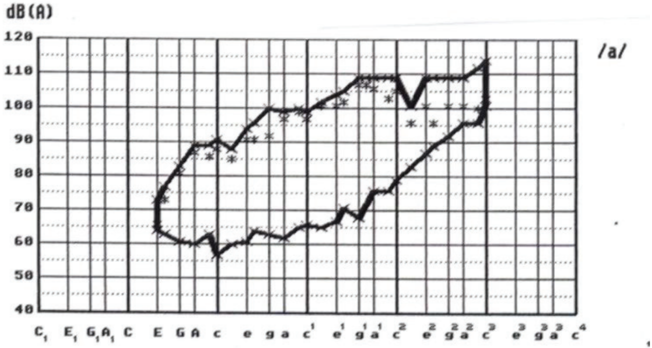
			91			80
	3	Differentiating range	Indic.	3	Differentiating range	Indic.
B1						
C						
D						
E	71	69,30 - 84,70	b	73	68,13 - 82,07	b
F	74	70,40 - 85,60	b	77	72,17 - 86,63	b
G	82	76,12 - 90,28	b	83	74,22 - 90,38	b
A	91	82,32 - 95,88	b	89	79,66 - 93,54	b
	4	Differentiating range	Indic.	4	Differentiating range	Indic.
B1						
C						
D						
E	57	50,33 - 61,47	b	64	50,82 - 61,58	T
F	64	52 - 62,60	T	63	51,56 - 61,64	T
G	63	51,26 - 62,14	T	61	51,58 - 61,42	b
A	59	52,99 - 62,61	b	60	52,14 - 62,66	b
	5	Differentiating range	Indic.	5	Differentiating range	Indic.
B1						
C						
D						
E	14	11,45 - 22,15	b	9	9,84 - 26,76	b
F	10	10,27 - 21,73	b	14	12,49 - 30,11	b
G	19	18,32 - 29,28	b	22	16,19 - 35,61	b
A	32	24,42 - 32,58	b	29	18,63 - 38,77	b
	6	Differentiating range	Indic.	6	Differentiating range	Indic.
B1						
C						
D						
E	66	48,79 - 65,21	B	66	54,41 - 69,59	b
F	64	49,90 - 67,70	b	73	56 - 74,60	b
G	78	55,95 - 76,85	B	81	61,76 - 82,84	b
A	89	64,40 - 83,60	B	87	68,09 - 85,71	B
	7	Differentiating range	Indic.	7	Differentiating range	Indic.
B1						
C						
D						
E	5	9,63 - 20,97	B	7	7,47 - 19,53	b
F	10	8,99 - 19,01	b	4	6,87 - 19,93	B
G	4	7,98 - 19,42	B	2	5,82 - 17,38	B
A	2	6,48 - 18,12	B	2	6,05 - 16,35	B

Table 67: Step-by-step analysis of Cases Nr. 91 and 80.



Frekwenties : 23
dB waarden : 42

Toon	Frekw.	Max	Min	dBz
E	82	71	57	66
F	87	74	64	64
G	98	82	63	78
A	110	91	59	89
B	123	96	61	94
c	131	98	61	96
d	147	102	60	99
e	165	102	63	100
f	175	0	64	48
f#	185	103	0	101
g	196	104	64	102
a	220	104	63	102
b	247	108	64	104
c 1	262	110	65	106
d 1	294	107	71	103
e 1	330	111	76	105
f 1	349	112	77	109
g 1	392	110	77	108
a 1	440	113	80	111
b 1	494	111	84	109
c 2	523	109	86	105
d 2	587	91	0	72
f 2	698	94	0	68



Frekwenties : 28
dB waarden : 55

Toon	Frekw.	Max	Min	dBz
E	82	73	64	66
F	87	77	63	73
G	98	83	61	81
A	110	89	60	87
B	123	89	63	86
c	131	91	57	88
d	147	88	60	85
e	165	94	61	91
f	175	96	64	91
g	196	100	63	92
a	220	99	62	97
b	247	100	65	99
c 1	262	99	66	97
d 1	294	102	65	101
e 1	330	104	67	101
f 1	349	105	71	102
g 1	392	109	68	107
g#1	415	109	0	107
a 1	440	109	76	106
b 1	494	109	76	103
c 2	523	109	79	105
d 2	587	101	83	96
e 2	659	109	87	101
f 2	698	109	89	96
g 2	784	109	92	101
a 2	880	109	96	101
b 2	988	112	96	100
c 3	1047	114	101	103

6). Figure 125 (nr. 63).

Untrained male subject.

Age: 25 years, 2 months.

Severe functional voice disorder with an exceptional vocal range.

Nr.	Y.	M.	1	2	3	4	5	6	7	8	9	10
63	25	2	**E1**	**g2**								Functional voice disorder
			B	**B**	b	b	b	T	T	B	**B**	?

Table 68: Synthetic Figure of voice classification steps in Case Nr. 63.

Finally, we want to demonstrate 3 *cases as curiosa cases in our selection of "exceptional voices", be it very good ones or very bad ones.*

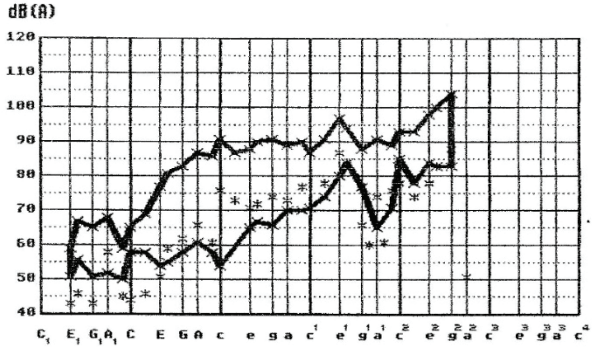
The first rare case is the phonetogram of an "**untrained male subject**" of African origin, who presented with a severe functional voice disorder.

Serious vocal pathology is normally accompanied by a shrinking of the vocal range. This young man, however, provided our collection of phonetograms with the largest vocal range we have ever seen. With four octaves and two tones (E1 – g2), he really presented a classification problem.

According to Habermann[389], basses possess the largest vocal range. Besides, because the lowest tone E1 (41 Hz) of this untrained young man is even not mentioned in the literature and the distinction between bass and baritone starts at B1, according to Table 6, this young man undoubtedly must be a bass. Other indications for a bass voice are the register transition gap between g and d1, paralleled each octave (B1, B, and g1/b1). In this exceptional case, however, all other measurements, according to our methodology, suggest a *higher* voice type (even tenor!).

	3	Differentiating range	Indication
B1	59	65,05 - 80,15	T
C	65	62,23 - 79,37	b
D	69	62,97 - 80,23	b
E	77	68,13 - 82,07	b
F	81	72,17 - 86,63	b
G	83	74,22 - 90,38	b
A	87	79,66 - 93,54	b
	4	Differentiating range	Indication
B1	50	50,97 - 63,03	b
C	58	49,43 - 66,17	b
D	58	53,17 - 62,83	b
E	54	50,82 - 61,58	b
F	55	51,56 - 61,64	b
G	58	51,58 - 61,42	b
A	61	52,14 - 62,66	b
	5	Differentiating range	Indication
B1	9	8,19 - 20,21	b
C	7	6,73 - 22,07	b
D	11	5,86 - 23,74	b
E	23	9,84 - 26,76	b
F	26	12,49 - 30,11	b
G	25	16,19 - 35,61	b
A	26	18,63 - 38,77	b
	6	Differentiating range	Indication
B1	45	45,9 - 64,50	b
C	44	49,09 - 64,71	T
D	46	51,60 - 67,40	T
E	51	54,41 - 69,59	T
F	59	56 - 74,60	b
G	62	61,76 - 82,84	b
A	66	68,09 - 85,71	T
	7	Differentiating range	Indication
B1	14	11,94 - 22,86	b
C	21	10,63 - 19,57	T
D	23	6,85 - 18,55	T
E	26	7,47 - 19,53	T
F	22	6,87 - 19,93	T
G	21	5,82 - 17,38	T
A	21	6,05 - 16,35	T

Table 69: Step-by-step analysis of Case Nr. 63.

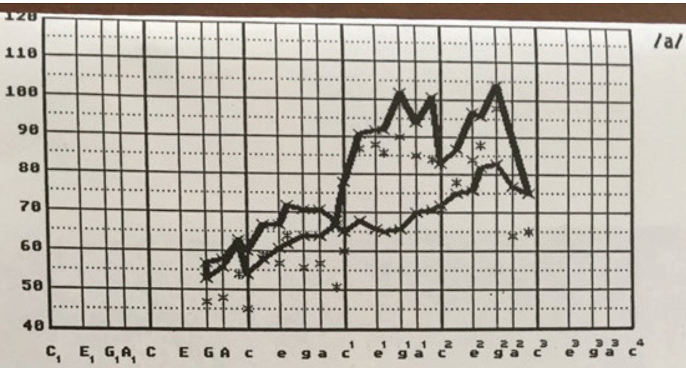


Frekwenties : 31
dB waarden : 61

Toon	Frekw.	Max	Min	dBz
E 1	41	59	51	43
F 1	44	67	56	46
G 1	49	65	51	43
A 1	55	68	52	58
B 1	62	59	50	45
C	65	65	58	44
D	73	69	58	46
E	82	77	54	51
F	87	81	55	59
G	98	83	58	62
A	110	87	61	66
B	123	86	58	61
c	131	91	54	76
d	147	87	0	73
e	165	88	65	71
f	175	90	67	72
g	196	91	66	74
a	220	89	70	73
b	247	90	70	77
c 1	262	87	71	71
d 1	294	91	74	78
e 1	330	97	80	87
f 1	349	94	84	84
g 1	392	88	77	66
a 1	440	91	65	74
b 1	494	89	71	76
c 2	523	93	85	78
d 2	587	93	78	74
e 2	659	98	84	78
f 2	698	100	83	83
g 2	784	104	83	88

The following curious case ((Fig. 126) is the phonetogram of a **famous professional mezzo who performed during 28 years on many international opera stages**. At the time of the F-SPL measurement she had just retired at the age of 60 years and was starting to give singing lessons.

No comment…



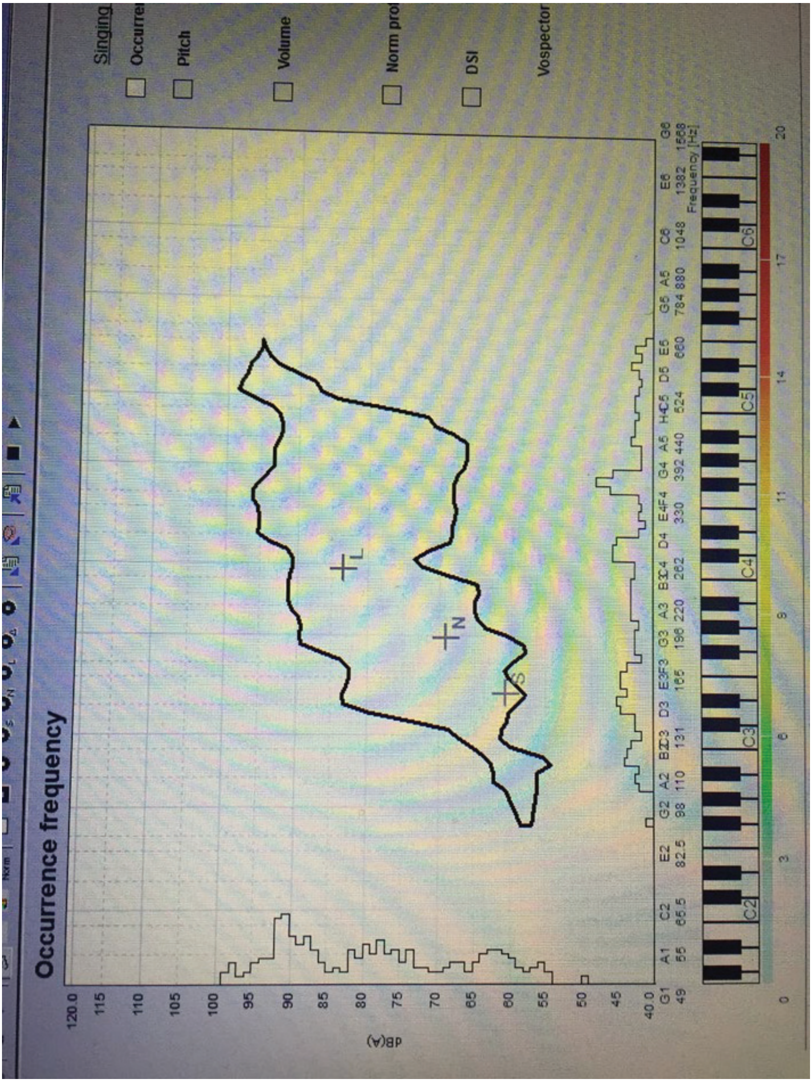
Frekwenties : 24
dB waarden : 46

Toon	Frekw.	Max	Min	dBz
G	98	57	53	47
A	110	58	56	48
B	123	63	62	54
c	131	60	54	45
d	147	67	58	59
e	165	67	61	57
f	175	72	62	64
g	196	71	64	56
a	220	71	64	57
b	247	68	67	51
c 1	262	78	65	60
d 1	294	91	68	87
e 1	330	92	66	88
f 1	349	92	65	86
g 1	392	102	66	90
a 1	440	94	70	85
b 1	494	101	71	84
c 2	523	83	72	71
d 2	587	87	75	78
e 2	659	97	76	84
f 2	698	96	82	88
g 2	784	104	83	98
a 2	880	0	77	64
b 2	988	0	75	65

The third phonetogram (Fig. 127) was recently taken of another **famous mezzo, age 88**, who has been a very popular singer for years, winning international song contests, combined with many performances on radio and television.

We know each other for more than 40 years. During one of her recent stays at our place, she told me she has been asked to return to the stage for a big new show, including TV appearances and making new CD's. Unbelievably, during the past three years, she has been regularly performing on the stage again, and with great success!

No comment either…


Occurrence frequency
Singing
Pitch
Volume
DSI
Vospector
dB(A)
Frequency [Hz]

CHAPTER 9

CASE STUDIES REVEALING LONGITUDINAL ASPECTS OF PHONETOGRAPHY

9.1. Introduction

According to Sataloff et.[1517], voice research has been plagued by numerous apparently random, unpredictable aspects of phonation, which have defied study and measurements. Chaos theory and fractal analysis tried to characterize nonlinear behaviour of biological systems, in casu voice production.[1517-1519] As Titze[1519] puts it: “Chaotic behaviour is part of a normal self-oscillating vocal fold system, and “normal” vibration patterns can be seen when the vocal folds are visually impaired “. On the other hand, Chernobelsky[1521] observed that “after long periods of singing, opera singers often complained of a feeling of discomfort in the region of the larynx. On examination of the larynx, usually no abnormality was revealed”.

Longitudinal studies on voice changes are very rare and difficult to compare because of the different methodology, often only considering fundamental frequency.[1522]

Chan[1523] emphasized the lack of systematic research to show possible influences on professional voice users over long periods of time.

Linville[1524] detected surprisingly few studies that documented the effects of loud voice use on the larynx and vocal performance, while Gelfer et al.[1525] observed that susceptibility to vocal fatigue appeared to be highly idiosyncratic.

Sabol et al.[1526] found that improved measures of vocal function not necessarily affect frequency range of the singer who had already developed a maximum frequency range, while our own phonetographic results demonstrated that the influence on vocal range (and other parameters of the voice) specifically depends on the *kind and the quality of vocal training*. (cfr. our case studies).

As Awan[1527] stated: "It is important that future research should attempt to identify those training techniques that may particularly affect the development of F° and intensity ranges. Only after this identification has been made can the efficient application of vocal training techniques to speech and voice therapy situations be made". We sincerely hope that the results of our lifelong research may contribute to this goal.

A study by Mann et al.[1528] on the effects of excessive vocalization on acoustic and videostroboscopic measures of vocal fold condition also revealed a considerable intersubject variability.

Baten and Van Eeghem[1529] studied 3 phonetograms of 7 trained, mutational choir boys over a period of one and a half year. Vocal range and dynamic range were reasonably stable. Although the shape of the phonetogram was different for each boy, there was, however, few intraindividual variability. Voice classification of these "(pre)-mutants was not considered.

Frank and Donner[1530] reported slight differences in the voice ranges at different times of the day and a better voice quality in the evening, as objectivated by sonographic analysis.

In her experimental and clinical study on phonetography, Gramming[1531] remarked that "the SPL for any vocalization is not kept perfectly constant and the voice may vary from day to day". In other words, there is a short- and a long-term variation of SPL. However, phonetographic studies on long-term variations, are extremely rare to find. Gramming[1531] analysed only one female and one male subject for long-term variations during a period of only 3 weeks. The authors suggest that the phonetogram is a rather reliable description of certain aspects of voice function, because the variability they found was comparatively modest.[1531] This is also the conclusion of a study by van Mersbergen et al.[1532] who found little evidence of a clear time-of-day effect on VRP performance in young, vocally untrained, vocally healthy adult females.

Frank[1533] criticizes the fact that voice exercises and their effects on vocal improvement are largely neglected in phoniatric research. We certainly do agree with this statement!

Based on clinical practice, many authors demonstrated the influence of training on the phonetographic curves[1534-1541], but their results are predominantly divergent. That's why Awan[1535] proposes to investigate by phonetography the vocal capabilities of untrained, beginning, intermediate, and advanced vocalists. This was also the aim of our study.

According to Seidner[1542], analyses of the measurement of the singer's formant present not only *data for a voice selection criterion,* but also provide an *evaluation of the educational and therapeutic results and an assessment of voice disorders.*[1542,1543] In our selected case studies, we will give ample proof of this statement.

Based on our earlier study of 54 subjects, all choir singers, we made an exceptional longitudinal study of the "survivors", *27 years later*, in our gerontologic thesis 'Functional voice diagnosis of the evolution of the singing voice in adults'.[1316]

We concluded that the total range and the vocal intensity of our subjects were unchanged, lesser, or even greater, while the voice quality, in most cases, was deteriorated. Maximum intensity decrease was more pronounced in the head register.

In this study, *212 longitudinal phonetographic measurements of 69 subjects (25 males and 44 females)* were taken. These repeated measurements over time vary from 2 to 18 measurements per subject, with an average of 3 measurements per subject. The results are proof of the *intrasubject variability*, induced by voice training and/or voice therapy. From 8 male subjects and 23 female subjects, 27 resp. 59 complete (i.e., including the singer's formant) measurements were taken over a long period. In all these cases the diagnosis of *voice category*, based on our step-by step procedure, remained the same over the years.

We will also provide some revealing cases, demonstrating a *common trend in the variability of voice range profiles,* although the discussion of this item is beyond the scope of this study.

A study on the effects of preventive vocal hygiene education on the vocal hygiene habits and perceptual vocal characteristics of training singers revealed only minimal changes.[1523] Another study,[1524] however, suggests the effectiveness of vocal hygiene education "for people who constantly use their voices over long periods of time (e.g., actors, singers, and teachers)".

Based on other publications, Chan's[1523] "Program of Vocal Hygiene Education" contains an explanation of 16 vocal abuses and their consequences; 13 of them have to do with excessive voice use. Obviously, most subjects of our study fall in this risk category.

In a questionnaire about issues related to vocal fold nodules, Hogikyan et al.[1546] propose a list of 13 etiologic factors; 9 of them are related to vocal overuse, abuse, and misuse of the speaking and/or singing voice.

Vilkman et al.[1547] recommend that "students of vocally demanding professions should be taught to avoid increased pitch and loudness levels" and conclude that these conclusions suggested by the results of their study are "apparently well in line with experiences based on clinical work, voice therapy, and principles of vocal training".

In their extensive report on the populations in the U.S. workforce who rely on voice as a primary tool of trade, Titze et al.[1548] assume that the well-known "factors contributing to abnormal voice", already summarized by many authors long ago, are also present among the voice professionals. One of these factors is "singing or speaking outside acceptable physiological range". Unfortunately, once again, the connection with *voice classification* is neglected. We think voice classification by phonetography can provide a practical solution to this long-standing problem in voice diagnosis and voice therapy.

The specific cases we have chosen demonstrate the *continuum between voice training and voice therapy*. It is obvious that during a follow-up of several years, a lot of influencing factors, which are not always recognisable, are responsible for the changed VRPs. In a lot of cases voice training evolved into voice therapy for a functional voice disorder. As voice training and/or therapy is multimodal, it is difficult to determine which factors are primarily responsible for an observed and /or measured effect.

Acknowledging some controversy in the literature about where exactly the division between organic and nonorganic voice pathology lies, Friedrich[1549] and Carding et al.[1550] consider organic and nonorganic voice disorders to be on a *continuum*. As they consider that the treatment of nonorganic dysphonia does not involve any surgical or medical intervention, the general aim of voice therapy for nonorganic voice problems is to minimize or correct the inappropriate use of the voice to restore normal phonatory function.[1550]

We assume that the subjects in our study fit these criteria and agree that, in most cases, a voice education and/or therapy program should use a combination of *indirect* and *direct* treatment techniques, as expressed by this and other authors.[1551-1554]

D'Antoni et al.[1555] even remarked that "some commonly accepted voice therapy techniques appear strikingly similar to practices classified as "alternative". Besides, according to a questionnaire developed by Surow and Lovetri[1556], 71% of the questioned singers admitted an *overall use of "alternative medicine"* (i.e., usually implying treatments not generally embraced by the "mainstream" medical community), with a median use of 60 months! Singers also frequently turn to "alternative medicine" care for a voice related problem rather than to traditional medicine.[1556]

Siegert[1557] comments the results of physiotherapeutic methods and Gundermann[1558] stresses the importance of muscle tone for a correct and hygienic use of the voice.

Hülse[1559] describes the benefit of chiropractic manipulation of the cervical spine "which can unlock the stiffness of the spine and normalize the voice within a few minutes", while Roy and Leeper[1560] report on the positive effects of the "Manual Laryngeal Musculoskeletal Tension Reduction Technique" as a treatment for functional voice disorders, even within one treatment session.

To Schmidt et al.[1561] the primary goals of therapy were "reduction of tension in the laryngeal musculature, increased airflow, the initiation of relaxed phonation, and sustained easy voicing".

Fex et al.[1562] tested the well-known "Accent Method", focusing on developing a relaxed body position, abdominal breathing, and a natural optimal pitch.

Boone and McFarlane[1563] observed that a lower-positioned larynx and an open pharynx ("Yawn-Sigh") can also produce a more relaxed *speaking* voice in cases of vocal hyperfunction.

Introducing the IVP ("Index of Voice Plasticity") as a predictor of possible successful voice therapy, Dejonckere and Lebacq[1564] discussed the degree of improvement in voice quality that can be obtained (quasi-)immediately by changing some basic vocal techniques such as (laryngeal) posture, resonance, breathing techniques and son on.

In psychogenic voice disorders surprise-evoking tactics can be applied successfully.[1565] In voice function therapy, however, emotional motivation of the patients seems to have only a small influence on the results but mainly affects the duration of the therapy.[1566,1567]

Sapir[1568] stresses the importance of decoupling the articulatory and phonatory systems for healthy singing, while Laukkanen et al.[1569] experimented with phonation into a tube as a voice training method.

One can also bear in mind the results obtained by a vocal warm-up, raising the muscle temperature, and decreasing the viscosity of the muscle tissue[1570,1571] or by the significant voice improvement obtained after participating in a program of vocal hygiene education.[1572]

Last, but not least, in all cases, our attention was always directed to both the speaking and the singing voice, convinced that "it may be advantageous to bridge the gap between techniques used in singing and spoken phonation during training".[1572-1574] After all, in all ratings of vocal technique (from very deficient to good), in "singers with less than 2 years of formal vocal training", abuse or misuse of the speaking voice was always present.[1575]

We are also aware of some difficulty to interpret our results because of the exclusive use of a single measurement technique to measure vocal change.[1576]

In conformity with the remarks of Carding et al.[1577], the examination of the cause and effect of individual therapy techniques, within the therapy process, was likewise not addressed in this study.

"Voice therapy is a combination of science and art"[1577]. In my own practice I always advocated an *eclectic voice therapy.* [1560-1562] However, as Boone[1563] quite rightly remarked, in contrast to the continuous emergence of new instrumentation, "there have not been many new, innovative therapy techniques for improving the speaking voice".[1563]

To prove the *utility of longitudinal F°-SPL measurements*, the limited choice of subjects is based on *three exceptional criteria*:

- to demonstrate the results of logopedic voice training, even over a short period of time.
- to demonstrate the different reciprocal influences of singing and/or acting lessons or dancing lessons, sometimes in opposition to basic logopedic voice therapy.

- to demonstrate the stability of a well-trained voice over a period of more than 12 years.

In a study on acoustical and perceptual performers effects of 10 choral tenors, Kitch et al.[1583] measured jitter, shimmer, harmonic-to-noise ratio, pitch range, and amplitude range. Pitch and amplitude ranges were selected because of their sensitiveness to *vocal fatigue*. However, pitch and amplitude ranges were not included in their within-subject analysis because there were insufficient testing items to allow it. Changes in the voices after performance were detected for most of the subjects, but no clear relationship was found between the perceptual and acoustic results.[1583]

Kötter and Klingholz[1584] too, studied the fluctuation of phonation parameters in amateur choir singers. However, they found no significant alterations of the phonetogram parameters after two hours of intensive voice training.

Measuring objective data in 10 normal speakers, before and after prolonged voice use, Stemple et al.[1585] found significant changes in the fundamental frequency of connected speech. As subjects found it difficult to maintain the lower pitches, the straining of the thyroarytenoid muscles as expression of the vocal fatigue was hypothesized.[1585]

Linville[1586] studied changes in glottal configuration in 12 young women under a variety of pitch and loudness conditions after an interval of loud reading. She found that individual speakers varied considerably in their response to 15 min of loud reading. Laryngeal adjustments are more affected by changes in pitch than by changes in loudness.[1586]

Prolonged belting is associated with *laryngeal hyperfunction* and the development of vocal pathologies.[1587-1591] Lots of our subjects, however, were excited by this popular vocal technique, often associated with “pop”, “rock”, gospel”, “jazz”, and “American musical theatre”.

As Pahn[1166] wrote, many years ago: virtually every singing student starts his singing education with functional voice disorder, developed in his childhood.

In the present study, every subject we selected for our discussion on longitudinal F°-SPL measurement was *subjected to contradictory influences in their training of acting, singing and dancing.* These contradictory influences are manifold. Borden and Gribnau[1592], for instance, testified that co-operation between speech therapists and docents of dance in the Dutch academies of ballet is practically nihil.

We will explore those contradictory influences by the interpretation of the changing voice profiles of our selected subjects. Besides, as Spiegel et al.[1593] stated, "young adulthood is perhaps the most difficult age for the assessment and treatment of vocal difficulties. The young adult has matured enough to begin active vocal training and perhaps a vocal career yet remains inexperienced and prone to vocal overuse and abuse". This was exactly the category of subjects we had to deal with, and our chosen examples illustrate the many difficulties encountered.

Upper respiratory infections (URIs) and allergies are common in younger age groups.[1572] For instance, the voice training we gave to young dancers was permanently jeopardized by colds, laryngitis, and allergies, but no specific medical treatment took place. Many young students who still had to develop their own vocal instrument were already given dance lessons to young children and thus prone to vocal overuse and abuse.

Excessively performing or rehearsing is a common practice.

Many psychological problems, lacking support systems, eating disorders, symptoms of anxiety and depression and performance stress[1594,1595] are legion. Andrews[1596] gives an accurate description of the many difficulties and specific challenges encountered in dealing with adolescents engaged in (pre)professional vocal activity, thus demanding both skill development and counselling. Both talent and training are needed.

And last, but not least, there is the "*vocal image*" of the subjects, i.e. "that sound of voice which a singer or speaker either seeks or rejects, depending upon his like or dislikes, encompassing pitch level and range, tone (focus) and breath support technique".[1596-1599] According to Haskell[1600], *vocal self-perception*, i.e. "the physical and psychological experience of one's own voice", may be the centre of voice production: "what is experienced by the speaker or singer may be just as valuable as what can be observed from the outside".[1600]

9.2. Results and discussion

Standardized ratings of aspects of laryngeal function by Sulter et al.[1601] showed only minor differences between untrained and trained subjects. Regarding the comments expressed in Chapter 1 ("Subject Classification in Voice Research"), our results are in concordance with the conclusion that differences in vocal capacities, as established by phonetography, seem to be based on a better control over the voice,

Vocal capacities can indeed switch in both directions (better or worse), regardless of their "status" of "trained" or "untrained" subjects. This explains the inter- and intrasubject variability and questions the a priori assigning of labels. Untrained subjects can show "better" phonetograms than a lot of "trained" subjects. *What really matters is the comparison of the evolution of vocal capabilities of the same subject.*

As a distinct effect of vocal violence (grunting, groaning, sobbing, and shouting) in actors, Roy et al.[1602] observed significant increases in both fundamental frequency range and maximal F°. They concluded that, as an "unexpected and contradictory effect to what has been anticipated, engaging in short term vocal violence may facilitate an expansion of the uppermost region of the fundamental frequency range".[1602] The same authors stated that "little is known about the frequency, duration, and intensity of vocal abuse necessary to produce a perceptible change (i.e., auditory perceptual, acoustic, or morphological) in voice".[1603]

The cases in this study give proof of two of the three above mentioned aspects of perceptible voice change. The auditory perceptual change in voice, remarked by the author and his subjects, were elucidated by the longitudinal phonetographic measurements. A morphological examination, however, was not possible.

According to Roy et al.[1603], training may serve as a buffer against undesirable laryngeal changes. Their objective data suggest that actors (and singers), frequently operating at the extremes of their pitch range at high intensity levels, can be trained to use an optimal vocal output on the stage. Moreover, "actors need not destroy their voices for an emotional moment".[1604]

Meijer and Sulter[1605] compared the changes in vocal capacities of 26 female therapist students, receiving 260 hours of voice training during a period of 2 ½ years. They only measured 4 pitches in the region of the speaking voice and found an average increase in dynamic range of 12,3 dB on a, 9,7 dB on c1, 11.6 dB on a1 and 5.5 dB on a2. The voice range of the students, however, didn't change, which is contrast with the results of the examples of the present study, obtained in only a few hours of voice training over a much shorter period.

Wedin et al.[1606] noted a marked result in educated, professional singing voices after a 5 days intensive training program; in all cases the improvement of the speaking voice was showed to be even greater by LTAS (Long Tome Average Spectrum) analysis.[1606]

The differing phonetographic curves of the same subject can also be interpreted as the result of *divergences in approach by speech pathologists and singing teachers.* The Journal of Voice (1988; Vol. 2: 20-25 and 26-29*),* for instance, provides a fair example: Boone[1607], a speech pathologist, advocates that "many patients with dysphonia do not need to modify their respiratory patterns", while in the following article, White[1608], a singing teacher, states that "training the use of breath is the single most important component in the development of the singing voice", or, as Emmons[1609] puts it:" the singer must truly be a "professional breather".

Let us just refer to the remarks of Griffin et al.[1610] Although they found no significant differences in breathing patterns between the supported and unsupported voice, their subjects felt that the supported voice is produced by different breathing strategies. The authors wonder:" If singers are not using the mechanisms, they think they are to produce a supported voice, why do voice teachers spend so much time teaching specific breathing techniques?"[1610]

Our results prove that *voice training* (i.e., not singing lessons) can have a very positive effect on both the *speaking and singing voice*. Sataloff[1611-1616] already remarked that the taught techniques by a specialized speech pathologist may carried over easily into singing. Singing training, however, mostly affects the singing voice and rarely the speaking voice.[1611-1616]

The specific changes in the selected phonetograms show the different effects on the voice of the same subject by misuse, overuse, singing lessons and voice training (or therapy) in a lapse of time. Exact *voice classification* and the deducible criteria for healthy voice use are decisive.

Still according to Sataloff[1611-1616], vocal nodules in singers may be due to abuse of the speaking voice rather than the singing voice. He states that "in many instances, training of the speaking voice will benefit the singer greatly" but he provides no numerical data.

Our numerical data, however proved by phonetography, show that *voice training on specific pitches of the speaking range also has beneficial influences on pitches of the higher singing range*: higher maximum intensity, lower minimum intensity, greater dynamic range, higher singer's formant, and singer's formants closer to the maximum intensity. Of course, extensive training of the head register is also necessary, as Pfau[1617] stated. We also paid much attention to the zones of register change, as we will demonstrate by our example in which the professional singer tried diverse techniques to bridge the gap between registers. (See this Chapter 9.1.8.)

In testing the efficacy of vocal function exercises as a method of improving voice production in a group of female graduate students, Stemple et al.[1618] found an extending of the low end of their frequency range by an average of 15 Hz and the high end by an average of 123 Hz. These results were obtained after a program of experimental exercises two times each day, with two repetitions each time, 7 days per week. Each exercise session required 15-20 min. Acoustic, aerodynamic, and videostroboscopic analyses of each subject's voice were done on two occasions, 28 days apart. Our case studies, however, show quite different results.

According to Sulter et al.[1619], the averaged phonetograms of untrained and trained men show a high degree of similarity. Trained men, however, have greater voice capacities in the lower frequency range, whereas the phonations in falsetto are limited, particularly with respect to the frequency range. Our results, however, demonstrate a lot of phonetograms with exceptional falsetto ranges both in trained and untrained subjects.

If one pays attention to the voice category, one can easily discover that these (almost unlimited) falsetto ranges are typical for low voices (mostly basses). Those trained voices, according to the same authors[1619], show a smooth contour of loud intensities at the 70-80% frequency level greatly depends on what kind of singing training the subject received. *Training in the classical Western opera style aims at smoothing out register transitions*, as earlier mentioned, but this is not the case for a lot of other popular singing styles, some of them which even purposely exaggerate this voice break. Closer observation of this specific region in the VRP will reveal the register transition(s). Moreover, the use of the rescaling method smoothes out the *averaged register transitions of mixed-up subjects of every voice category*!

Longitudinal studies on changing values of the singer's formant are hard to find. Vintturi et al.[1620] only mention that vocal warm-up increased the spectral energy in the singer's formant region significantly in the female subjects at all (5) pitches and a similar trend could be seen in the male subjects at all (5) pitches. Our results show clear differences of the value of the singer's formant at *specific* pitches relating to vocal improvement, due to specific voice training.

According to our methodology, we always start working on the modal register, at pitches in the neighbourhood of the (supposed) optimal pitch, *thus training the speaking and the singing voice altogether.* The results of this method are shown in the longitudinal VRP's, where often spectacular improvements are visible in the highest pitches, which have not yet been trained at all! In fact, Wolf et al.[1621] already remarked that "where the range is wide and the intensity high over the range, the lower register is well developed".

We were not able to compare the in our case studies illustrated changes in phonetographic results with other objective methods. Next to the *better results of the singing formant data,* the *subjective appreciation of the changed vocal quality by the author and other experienced listeners* is all we can offer.

However, what counts most of all is the subjective impression of the subject himself. As Pfau[1622] showed in a longitudinal study on the factors determining the efficacy of voice function therapy, "only the patients answers" to the question, if the therapy had caused any changes in their subjective speech complaints, were statistically significant". The remarks by Haskell[1623] about "vocal self-perception" point into the same direction.

Let us start now with the interpretation of a selection of longitudinal phonetograms, arranged according to different time spans.

9.3. Case studies

9.3.1. Case studies over a long period of time

Case 1. Longitudinal phonetograms over a period of more than 10 years.

Our first subject is an **internationally well-known musical singer/actress**, we were able to follow in her professional career for more than 40 years.

More than 20 months had passed after our first brief logopedic voice examination, before her first phonetogram was taken. The professional singer/actress complained about the loss of her high tones and her voice was breathy. An E.N.T. specialist found a disclosure of the vocal folds. At that time, she already had successfully performed on many international stages as an actress – commercial singer – musical singer. She graduated at a well-known musical conservatory, taking acting, singing, and dancing lessons. She declared herself a soprano and had been educated as such by different singing teachers, but she always had felt that her voice classification didn't feel right. According to the results of the F°-SPL measurement, her voice classification was undoubtedly mezzo, which she unwillingly accepted. We tried to explain the many advantages of this voice type in the world of musical performance: a warm and rich speaking and acting voice, a well-balanced chest register, the possibility (after voice training) to obtain beautiful high tones instead of the forced, shrill tones she usually produced trying to become a soprano, and the possibility to perform in more diversified roles on the musical stage.

1.1 Six curves of maximum intensity over a period of 52 months

Because of the hectic professional life of this singer, we only had a chance to work on her voice for very short periods in a lapse of time: 4 sessions in a period of 21 months after the first phonetogram was taken; 16 sessions during the following 12 months; 7 sessions in the next 2 months; 8 sessions during the following 9 months and 1 session in the next 8 months. This makes a total of 36 sessions over a period of 52 months, which hardly can be seen as a regular, consistent method of vocal training! Useless to say that our intervention was solicited in the first place, every time that an important role was coming up or when some voice problems arose. Regular colds, sinusitis, hay fever, headaches, and problems with her back (especially the zone of the neck), many faulty vocal techniques such as a firm tendency to sing with an "open voice", combined with a horizontal hyper articulation pattern, a too high habitual pitch level, a marked hypertension of the m. omohyoideus when singing high notes, and on top of this all, a lot of psychological stress.

This complex case necessitated an *eclectic approach*, including different vocal techniques for the speaking (acting) and singing voice, adapted to the many different stage situation, and combined with some methods of stress-management. However, the methodological analysis of this approach is beyond the scope of this study. Nevertheless, we can provide the available values of maximum intensity because they are worthwhile to analyse.

Despite the many ups and downs in the evolution of this voice, the six curves of maximum intensity display the same shape. The *register change* in the six curves is always situated between a1 and e2 and is typical for a mezzo. Her *vocal range* expanded from e – b 2 to e – d3. The last maximum curve is irregular, with a deep dip in the register transition zone (between b1 and e2). She explained this by vocal fatigue, due to too many performances, excessive stress, and no more regular exercise during the last months. She finally promised to practice the learned exercises on her own, and this on a regular base…

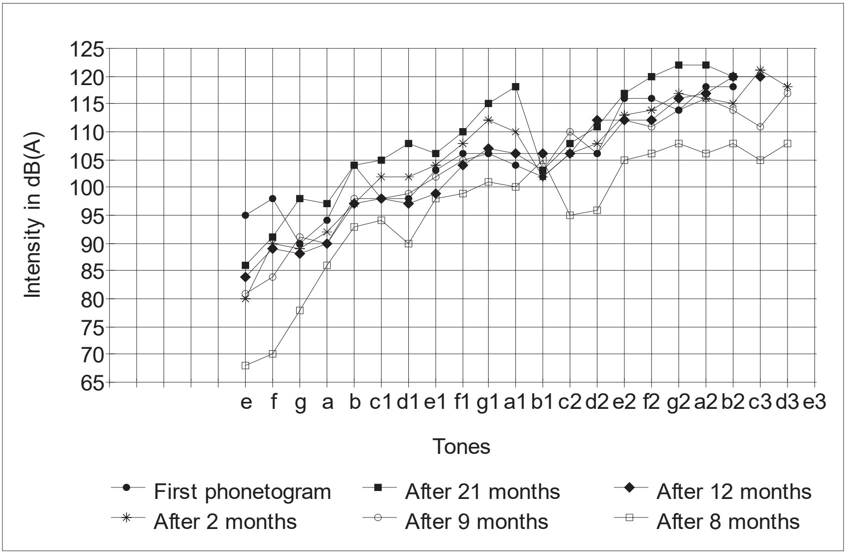


Figure 128: 6 longitudinal curves of maximum intensity in a period of 52 months.

1.2. Longitudinal phonetograms over another period of 65 months

The next 2 superposed longitudinal phonetograms are interesting because they show how this voice evolved 65 months later.

Our intervention was again restricted to *occasional control visits*, some more experiments in phonation with a "covered voice" in the high tones, and further developing of the (since long lost) low tones. As can be seen, the singer made some improvement after all. First, even though she got higher pitches than ever (e3 instead of the initial b2), she also got beautiful lower pitches (c instead of e) – like a real mezzo!

The register transition, however, is still a problem, because she clearly does not like the covering method of the voice, "sounding too much like opera". Her high tones (above d2) became somewhat less loud but were not shrill anymore and now sounded rich and full. At last, she understood that she could sing the high pitches of a soprano voice, without being a "forced" soprano with vocal problems. The much better voice control can be seen in the minimum intensity curves. After training, the subject was able to phonate much more softly (up to 22 dB on g2, which previously happened to be her last attainable lowest minimum pitch! This means *a much better controlled use of her voice*. The elongated and larger ellipse form of the phonetogram clearly demonstrates her augmented vocal capacities (larger *dynamic range*).

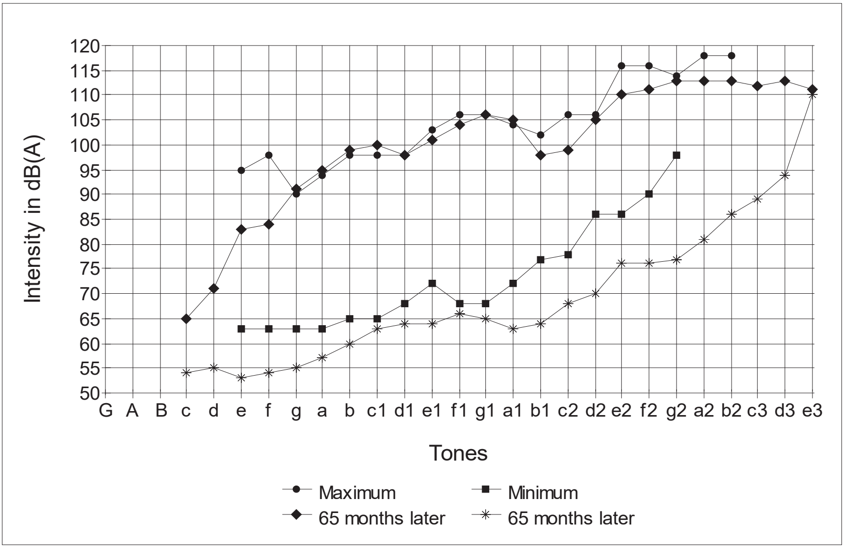


Figure 129: 2 longitudinal phonetograms over a period of 65 months.

1.3. Longitudinal phonetograms over another period of 44 months

In the following 44 months, the general shape of the maximum curve became still more regular, as can be seen from the following 3 superposed phonetograms. For many years, e was her lowest tone; now she got G, without losing, however, her highest pitches (up to e3).

The register change has become smoother now but is still not perfect.

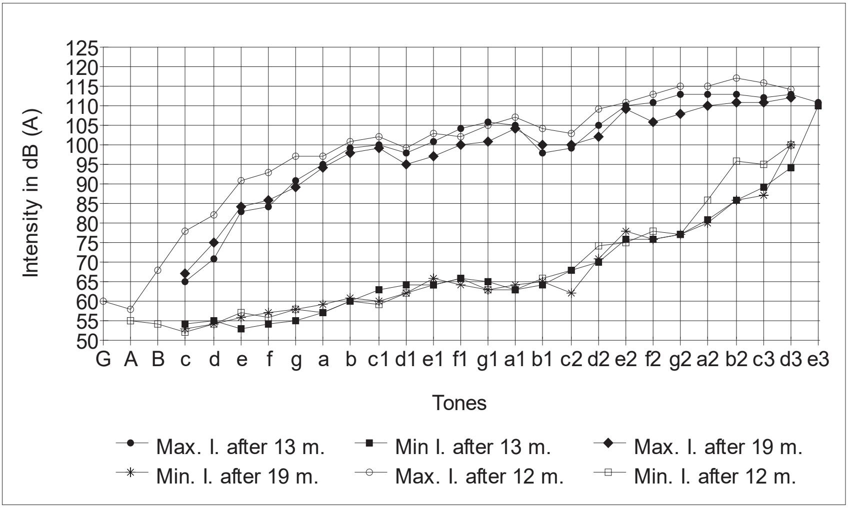


Figure 130: 3 superposed longitudinal phonetograms over a period of 44 months.

1.4. Longitudinal phonetograms over the next period of 29 months

During the next 29 months, the general shape of the phonetograms remained the same, as can be seen from the 3 superposed longitudinal phonetograms. Remark again, the parallelism of the dips around d1 and d2, typical for a mezzo. The register change is still very visible on the phonetograms. The dynamic range of the pitches c1-d1-e1-f1-g1-a1 and b1 became larger.

Generally, the data collected in the longitudinal phonetograms (1.3 and 1.4) over a period of 73 months thus remained stable.

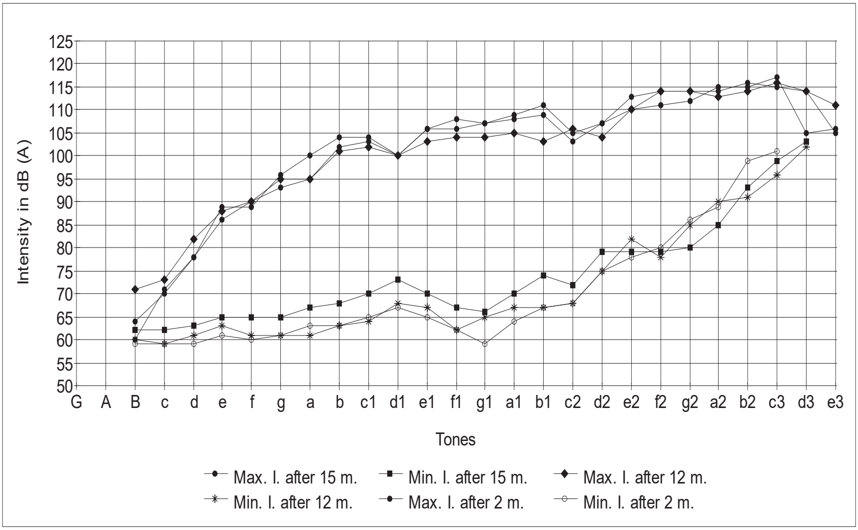


Figure 131: 3 superposed longitudinal phonetograms over a period of 29 months.

1.5. Six curves of the singer's formant over a period of 73 months

To have an idea of how the quality of this voice evolved during the next period of 5 years, *without specific further voice training*, it is interesting to analyse the different curves of the singer's formant. As can be seen, the general shape of the singer's formant remained stable. Specific differences at certain pitches can be explained by the quality aspects of the voice at that given moment. This changing quality is evident when comparing the differences between the best and the worst results: only 5 dB (A) on f (speaking voice zone), but 18 dB (A) on d2 (the register transition point!). Curve 3 (after 12 months globally proved to be the worst curve); curve 4 (15 months later) was the best. The more distinct differences are (of course) visible in the register transition zone (a1 – e2), corresponding to the already remarked differences in maximum and minimum intensity curves. These differences, however, are not dependent on the maximum intensity. In curve 1, for instance, the maximum intensity on d2 was 105 dB (A) and the singer's formant was 104 dB, while in curve 3 the maximum intensity was 109 dB (A) and the singer's formant only 86 dB (A). We will give more details on this relationship in the next section.

These differences in quality are due, of course, to the way the singer realized the register transition. Because this singer tried to change her technique of register transition in function of the style of the song (e.g., opera, musical, pop song), she experimented a lot with open and covered tones, thus resulting in little shifts of the register transition. By acting this way, she consequently did not acquire a stable type of register change, as can be obtained by consistent classical singing training. Some examples of these experiments are given in a following section. Remark also the specific dip of the singer's formant at d1 in all curves, one octave below the register transition and parallel to the changes in maximum and minimum intensity already cited.

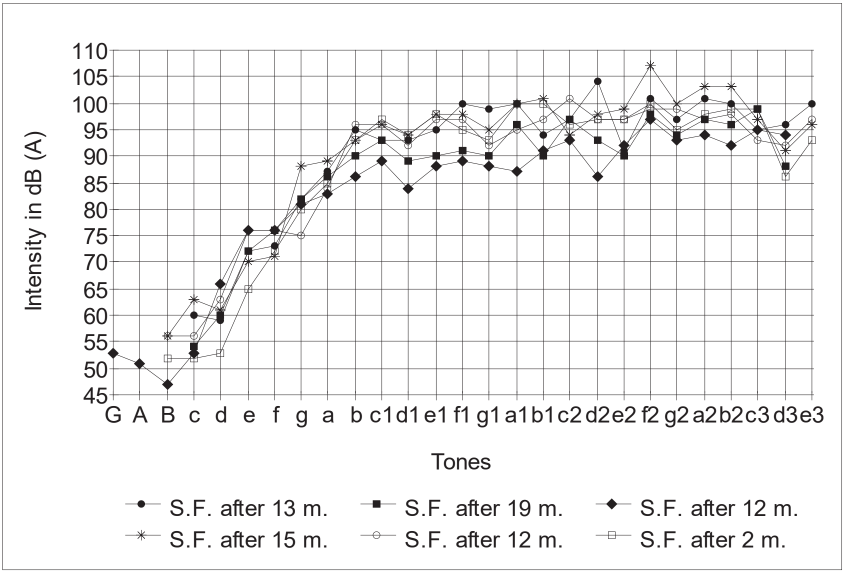


Figure 132: 6 superposed longitudinal measurements of the singer's formant over a period of 73 months.

1.6. The same 6 longitudinal curves of the singer's formant in relationship to the longitudinal curves of the maximum intensity over a period of 73 months

To have another idea of the quality evolution of this voice over a period of more than 6 years, it is interesting to compare the relative distances between the curves of the singer's formant and those of the maximum intensity measurements. According to Seidner[1364], female voices can better be differentiated by the measurement of the *singing formant*, while male voices are better differentiated by the *difference between the maximum intensity measurement and the intensity of the singing formant.*[1479,1480] Nevertheless, we experimented with both methods. As can be seen from the next Figure 133, the difference between the values of the maximum intensity and the values of the singer's formant varies considerably: between 1 and 22 dB (A) over the total vocal range. In conformity with the interpretation of the six curves of the singer's formant, the worst results are also obtained in the third curve (after 12 months), but the best results are obtained in curve 1. Again, the most distinct difference is on d2 (register transition), varying between 1 dB (A), a perfect register transition, and 23 dB (A), a very bad register transition.

These results clearly show how variable the register transitions of this voice really were. Pitches above f2 also score bad, which means that these high pitches eventually do not belong to the suitable range of this mezzo voice.

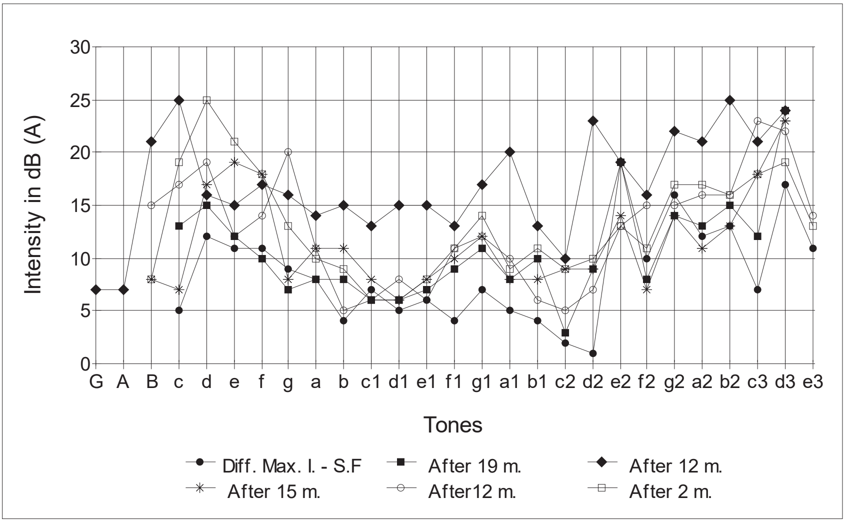


Figure 133: Differences of the values of the maximum intensity and the values of the singer's formant over a period of 73 months.

1.7. Different ways of registration as featured in the longitudinal phonetograms

To analyse the *different ways of registration*, demonstrated by this singer, we schematised the measurements of the maximum intensity and of the singer's formant in the register transition zone a1 – e2:

	a1	**b1**	**c2**	**d2**	**e2**	
First phonetogram	105	**98**	**99**	105	110	Max. I. in dB (A)
	100	*94*	*97*	*104*	*91*	*S.F. in dB (A)*
After 19 months	104	**100**	**100**	102	109	Max. I. in dB (A)
	96	*90*	*97*	*93*	*90*	*S.F. in dB (A)*
After 12 months	107	**104**	**103**	109	111	Max. I. in dB (A)
	87	*91*	*93*	*86*	*92*	*S.F. in dB (A)*
After 15 months	108	109	**103**	**107**	113	Max. I. in dB (A)
	100	*101*	*94*	*98*	*99*	*S.F. in dB (A)*
After 12 months	105	**103**	106	**104**	110	Max. I. in dB (A)
	95	*97*	*101*	*97*	*97*	*S.F. in dB (A)*
After 2 months	109	111	**105**	**107**	110	Max. I. in dB (A)
	100	*100*	*96*	*97*	*97*	*S.F. in dB (A)*

Table 70: Scheme of the measurements of the maximum intensity and of the singer's formant in the register transition zone (a1 – e2) of this mezzo voice. The numbers in bold are the lowest values of the maximum intensity ("register dips") in this register transition zone.

As can be seen there are different types of dips: in the first, second and third phonetogram, the dip is situated at two pitches: b1 and c2. In the fourth and sixth phonetogram, the dip is situated at two other pitches: c2 and d2. In the fifth phonetogram, the dips are situated at still two other pitches: b1 and d2. *Register dips are thus movable within the range of the transition zone and this is clearly visible in the phonetogram*! The singer's formant, however, does not follow the same pattern, as we demonstrated in our results.

According to the used technique, the singer's formant is approximately close to the maximum intensity measurement. Look, for instance, at the first phonetogram, where the maximum intensity on the dip b1 with 98 dB (A) is coupled to 94 dB (A) of the singer's formant. However, the highest measured maximum intensity on b1 of the six phonetograms, as found in the third phonetogram: 104 dB (A) is coupled to only 91 dB (A). Hertegard et al[1624], however, reported that the sound pressure level does not differ consistently between open and covered singing. Sundberg et al.[1625] found that SPL was quite similar in operatic and mixed styles, while it was at least 10 dB louder in belting. In the next section, more details of the influence of the singing technique on the register transitions will be given by some experiments performed by the same subject.

1.8. Some experiments with register transitions, visualized in the phonetograms

We mentioned already the preference of this singer for open singing, even belting. Confronted, however, with continuing vocal difficulties in the register transition zone, she finally agreed to experiment with different singing styles, expecting that the results could be visualized in the phonetograms. Below we schematised the results of 6 measurements of the singer's formant in the zone of the register transition, realized in 3 experiments by the same singer, with two consecutive tries per experiment, The 3 experiments took place within a period of 46 months.

The results below show that the value of the singer's formant, measured during two successive phonations, can vary within large limits (1 to 13 dB(A), depending on the singing style. In our opinion, this kind of phonetographic analysis of the vocal quality, especially in the region of the register transition should receive careful attention of everyone involved with voice education and/or voice therapy.

1st exp.	**a1**	**b1**	**c2**	**d2**	**e2**
S.F. 1	100	94	97	104	91
S.F. 2	95	98	98	98	102
After 19 m.					
S.F. 3	96	90	97	93	90
S.F. 4	98	93	94	97	90
After 27 m.					
S.F. 5	100	101	94	98	99
S.F. 6	87	90	90	96	89
Minimum	87	90	90	93	89
Maximum	100	101	98	104	102
Average	96	93,71	94,75	97,88	94

Table 71: 6 measurements of the singer's formant in the zone of register transition, realized in 3 experiments by the same singer, with two consecutive tries per experiment.

1.9. Maximum, minimum, and average of maximum intensity, and of minimum intensity of each tone in the longitudinal phonetograms of our subject, over a period of 125 months (10 years, 5 months)

The analysis of the results of the intensity variations in longitudinal phonetograms offers a unique opportunity to understand the evolution of a given voice over a period. Unfortunately, longitudinal phonetograms are extremely rare in the scientific and clinical literature. Although this special aspect of phonetography is beyond the scope of this study, we will analyse, anyway, the longitudinal phonetographic results of this singer/actress.

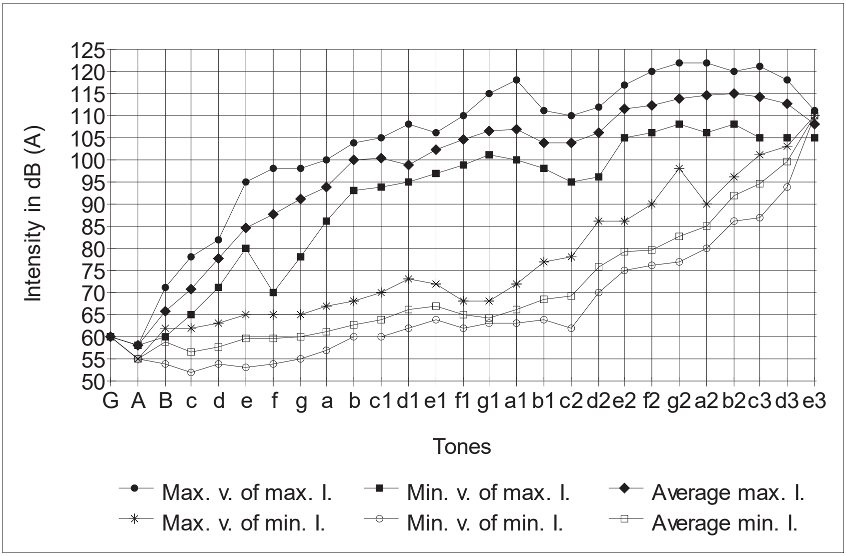


Figure 134: Maximum, minimum, and average values of maximum intensity and of minimum intensity over a period of 125 months.

This fabricated phonetogram, based on 12 selected phonetograms, shows the extremes and the averages of the maximum and minimum intensities of this mezzo voice during a long active singing and acting period of more than 10 years.

As already mentioned, her lowest pitch became G instead of e, without having lost her highest pitch (e3). This can be called an exceptional vocal range of almost 4 octaves.

The differences between the maximum, minimum and average values of the maximum and minimum intensities, are interesting, because they show, for each tone, between which range of values this voice evolved during that long period.

The minimum difference of the maximum intensities is 6 dB (A) on the extreme pitch e3, the maximum difference is 28 dB (A) on f. The minimum difference of the minimum intensities is 5 dB (A) on g1, the maximum difference is 16 dB (A) on d2 (register dip). The large differences on each specific pitch can be explained by a lot of influences during that very long period, without the possibility, however, to point to exact causes …

What remained stable over the years, however, is the register transition zone, which is always situated in the zone a1 – e2. This is typical for a mezzo, as can be seen on the different longitudinal phonetograms of this subject. The register zone is characterized by a dip in the maximum intensity curve, but also in the curve of the singer's formant. The minimum intensity curve, however, is elevated at that point or in this zone. Noteworthy is also the parallelism of these features, one octave below, around d1. This indication often provides a good hint in cases where voice classification proves to be difficult by data obscured by different causes (misleading by faulty training, forced phonation, pathology …). Following the step-by-step procedure, however, as proposed in this study, leads to an exact voice classification.

The *maximum, minimum and average values of the singer's formant* also offer interesting features: with exception of d2 again, the differences between the maximum and the minimum values of the singer's formant of each tone remained in the same range, which means that the quality of the voice also remained quite stable during many years of professional voice use. As mentioned before, the general curve of the singer's formant follows the general curve of the maximum intensity, but the distance to the maximum curve is not the same for every pitch. *The continuous problems of this singer with the register transition zone (a1 – e2) can easily be detected from the different phonetograms*. The pitch f2 always has the highest value of the singer's formant, which can be interpreted as the highest pitch, best suited to this mezzo voice. *The pitches above f2, however, are more suitable to a soprano voice, although this mezzo was quite capable to produce those high pitches without causing any vocal harm over the years*.

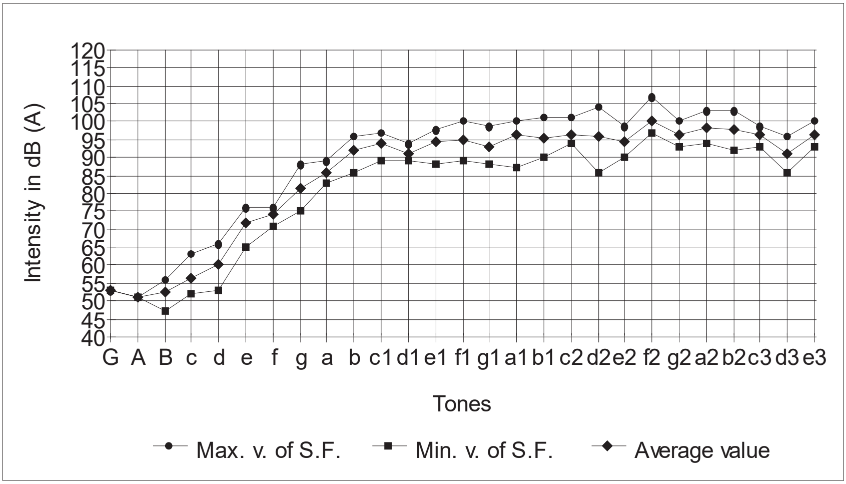


Figure 135: Maximum, minimum, and average values of the singer's formant over a period of 73 months.

1.10. Differentiation between mezzos and sopranos, as displayed in the phonetograms

The longitudinal phonetograms of this singer/actress clearly show the evolution of a versatile voice over a very long active period of artistic performances. *After many years of training and performing as a soprano (with many vocal difficulties), she finally accepted the reality of the many possibilities of her mezzo voice.* This process took considerable time and can be followed by closely observing her longitudinal phonetograms. However, as we explained above, the acquired potential to produce high pitches without vocal complaints does not mean that the singer's voice classification has changed! We will demonstrate this by provide a phonetogram of a classically trained *real soprano* of the same age with a comparable (exceptional) voice range (c – e3):

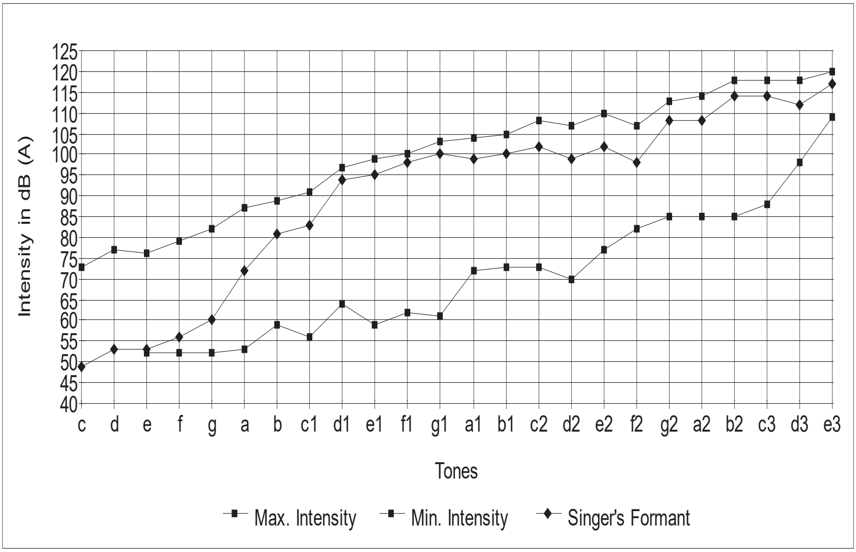


Figure 136: Phonetogram of a classically trained soprano.

As can be seen the maximum intensity curve of this soprano rises in an almost rectilinear way. The less regular minimum curve parallels the maximum curve so that the ellipse form of the phonetogram is elongated. The hardly audible register transition on f2, typical for a soprano voice, is characterized by a slight dip in the maximum intensity and in the singer's formant but also by a slight elevation of the minimum intensity. Although this classical soprano singer possesses exceptional low tones – some sopranos even cannot (or want not to) phonate below c1 - the much-lowered singer's formant in her lowest tones shows, of course, the lesser quality of these low tones. This quality is clearly in contrast to the warm and rich speaking and acting voice of our mezzo. On the other hand, in this classical soprano voice, tones from d2 on (above the register transition of the mezzo) are characterized by a much better quality, as expressed by close distance between the maximum intensity curve and the curve of the singer's formant.

Also note the discriminating differences between the maximum intensities of the lowest and medium pitches of this soprano voice and the better performance of this mezzo voice in this region:

	MEZZO	**SOPRANO**
c	78	73
d	82	77
e	91	76
f	93	79
g	97	82
a	**100**	87
b	104	89
c1	104	92
d1	100	97
e1	106	98
f1	108	**100**

Table 72: Differences in dB(A) for the lowest and medium pitches of a mezzo and a soprano voice.

As already demonstrated and explained, mezzo's produce more vocal intensity in the lowest and middle tones than sopranos. The difference in maximum intensity amounts to 15 dB(A) in these two voices. In fact, while this mezzo already reaches 100 dB (A) at a (220 Hz), our soprano only reaches 100 dB (A) at f1 (349 Hz)!

Case 2. Longitudinal phonetograms over a period of 5 years.

2.1. Two longitudinal curves of maximum intensity over a period of 6 weeks.

In our first case we demonstrated the evolution of the speaking and singing voice of a performer, after a long professional training period and after successfully performing for many years on international stages. The analysis of the longitudinal phonetograms, completed by some extra longitudinal measurements of the singer's formant during some experiments on the register transition zone, allowed a close observation of the many ups and downs of this mezzo voice along her strenuous professional life.

Our second case, however, concerns a young **14 year's old girl** who had followed intensive ballet lessons for many years and who eagerly wanted to become a musical star. After many auditions, she was chosen from hundreds of children for the leading role in a famous American musical.

During our first meeting, she was complaining of hoarseness and a frequently loss of voice during the first weeks of rehearsals. The stress of the rehearsals, to which she was not at all accustomed, accompanied by continuous colds, did not allow for much improvement during a short series of 7 sessions over a period of 6 weeks, prior to the première of the musical, as can be seen from the 2 measurements of maximum intensity.

As can be deducted from the next Figure 137, only the lowest and the highest pitches gained some decibels; this was also the case on the register dip d2. Being a young mezzo, we supposed she had forced her voice range to get higher pitches, with as a predictable result, the loss of her low pitches.

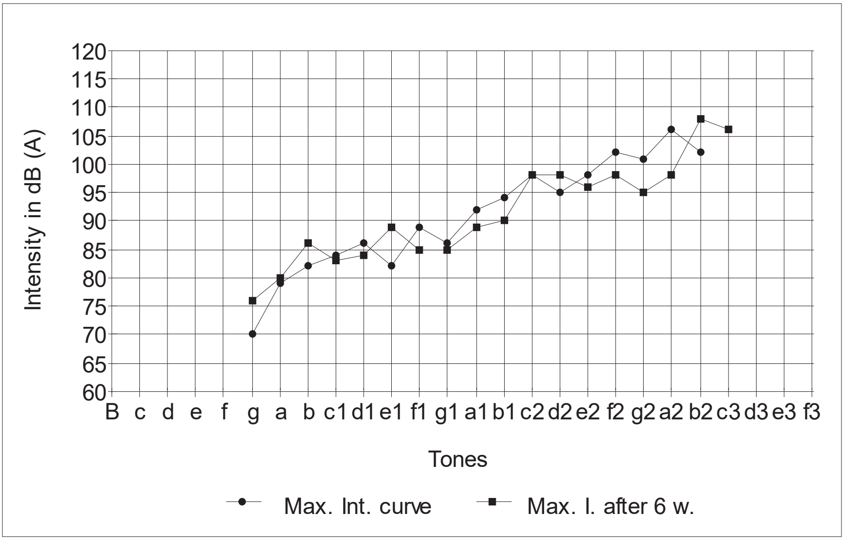


Figure 137: Maximum intensity curves over a period of 6 weeks.

2.2. Longitudinal phonetogram after a period of 3 years of professional musical singing training.

Shortly after the end of a series of successful musical performances, the parents of the now 15 years old girl sent her abroad to a famous Musical Theatre school. We did not see this girl for more than 3 years.

Being back in her country for a short vacation after she had finished her studies, she eagerly wanted a phonetogram session to see the results of the many voice lessons she had taken. Complaining again about a lot of vocal problems, she really worried about her future as a musical singer.

As can be seen from the next phonetogram, the expected good results of her singing lessons were really deceiving. The total voice range is stretched at both sides from g - c3 to c - f3. She had been educated as a soprano. The overall curve of maximum intensity has considerably gained in decibels, probably partly due to the maturation of the voice (the girl was more than 18 years when her second phonetogram was token), except fort the zone of the register transition (a1- f2) which was considerably deepened. The dynamic range is small from the register transition zone to the highest pitches, especially at the forced highest pitches. From b1 on to f3, the singer's formant is even lower than the minimum intensity, which means a very bad quality, as could easily be heard too.

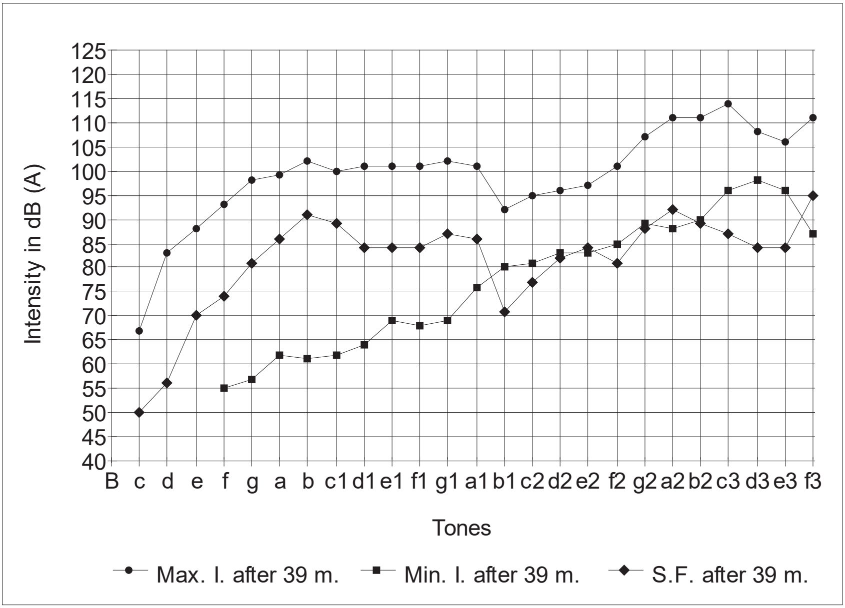


Figure 138: Phonetogram after 3 years of professional musical training.

2.3. Two longitudinal phonetograms after one month of voice therapy

The parents and their daughter were very upset and begged us “to do something” during the one-month holiday of the young girl.

We will explore the results of our short intervention by comparing the next two phonetograms. The most striking feature is the shape of the second phonetogram, after voice therapy, due to an overall lowering of the minimum intensity curve, up to 20 dB(A) difference with the former measurement. In the first two measurements of the maximum intensity (2.1), the register zone was situated between c2 and f2, with the register dip on d2/e2. After 3 years of professional musical training (2.2), the register transition zone has considerably widened to one octave: g1-g2, with an extremely low singer’s formant on b1. After 4 weeks of voice therapy (2.3), however, the register transition zone is again situated between b1 and f2, with the normalized register dip on d2.

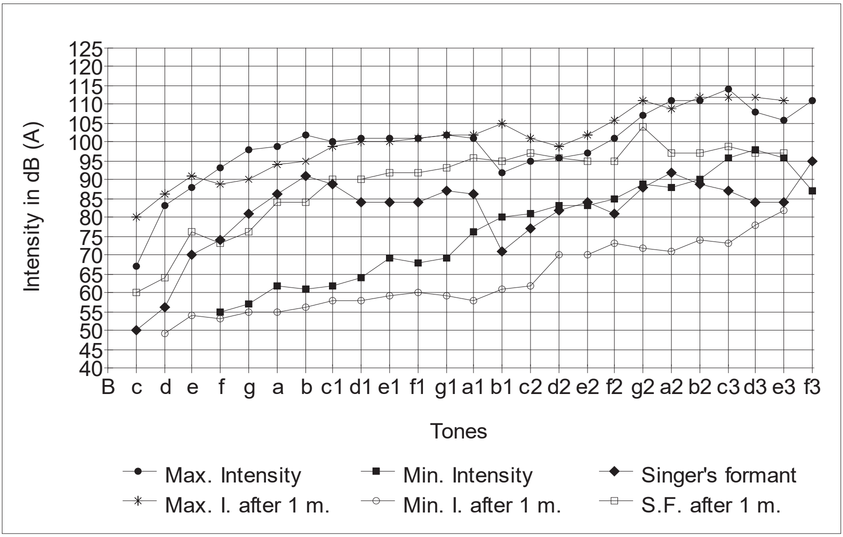


Figure 139: 2 longitudinal phonetograms over a period of 1 month.

2.4. Two longitudinal singer's formants after one month of voice therapy

To have a better insight into the specific quality differences between the 2 longitudinal phonetograms, let us compare the 2 longitudinal singer's formants after a few sessions of voice therapy over a period of 4 weeks. The overall curve of the singer's formant is now much more regular, with a peak on g2. The value of the singer's formant is greater on every pitch from c1 to e3 and amounts to 24 dB (A) on b1. The previous very deep register dip on b1 thus has been considerably smoothed out.

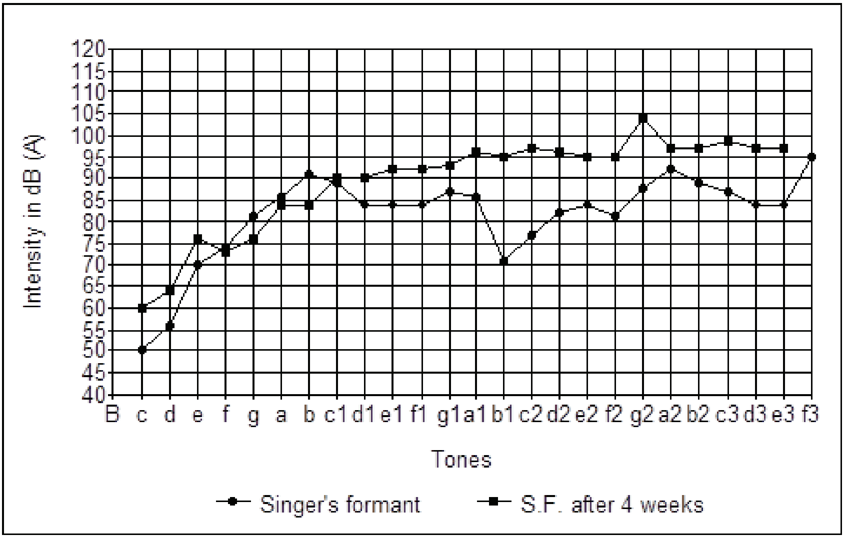


Figure 140: 2 longitudinal singer's formants over a period of 4 weeks of voice therapy.

2.5. Comparison of the differences of the values of the maximum intensity and the values of the singer's formant after 4 weeks of voice therapy.

Comparing the differences between the values of the maximum intensity and the values of the singer's formant in longitudinal phonetograms offers another possibility *to detect quality changes of the voice*. Here again, the best results are obtained in the range c1 to g2. The best results are on c2 and c3 (+ 14 dB (A)). Needless to say, that her voice also sounded much better.

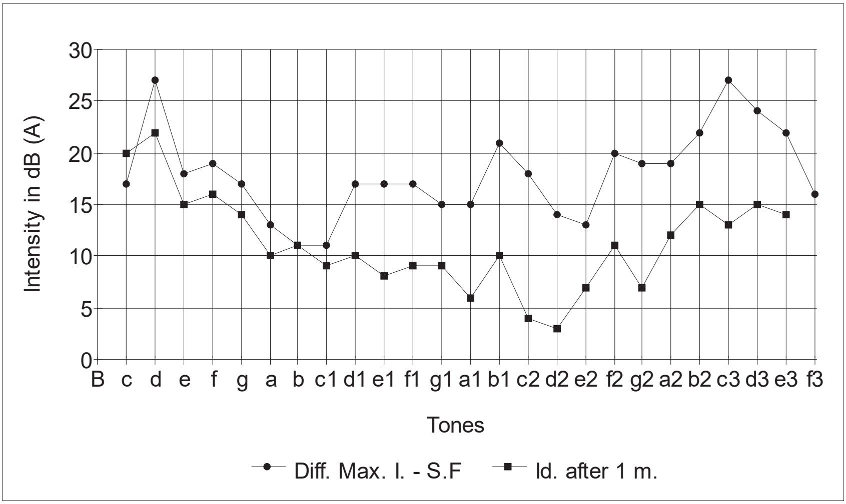


Figure 141: Differences between the values of the maximum intensity and the values of the singer's formant over a period of 4 weeks of voice therapy.

2.6. Three longitudinal phonetograms within a period of 1 year

In the summer vacation of the following year, the now 19-year-old girl came back again for another voice control. She had done a lot of auditions and eventually got a little role in a new musical. She had also taken some private singing lessons and intended to stay abroad with her boyfriend.

We will compare her new phonetogram with that of the two former phonetograms. One can see that the general shape of the phonetogram has remained the same, but the values of maximum and minimum intensities are quite different. She forced her voice again to get her lowest pitch B and her highest pitch f3. The maximum intensities of the three curves are of the same magnitude, except for the pitches f1-g2 (including the register transition zone) which are lower now than after voice therapy. The deep register dip in the last F°-SPL measurement is again on b1 instead of on d2.

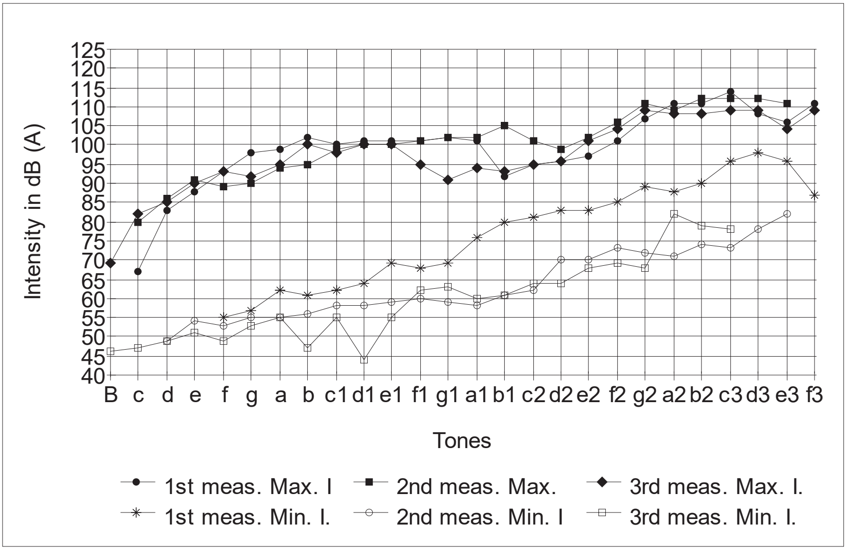


Figure 142: 3 longitudinal phonetograms within a period of 1 year.

2.7. Three longitudinal measurements of maximum intensity within a period of 1 year.

The in section 2.6. shortly analysed phonetograms give a fairly good idea about what has happened during one year of moderate professional vocal activity.

A good insight in the changed vocal capacity is given by an analysis of the evolution of the maximum intensity over the period of one year. The much higher maximum intensities over the whole vocal range, after only 4 weeks of logopedic voice therapy are now again spectacularly lowered from 18 to 22 dB (A) in the range g1 – c2 (register transition zone!) The well smoothed out register transition zone has become again a large zone of less intensity with a deep dent on b1.

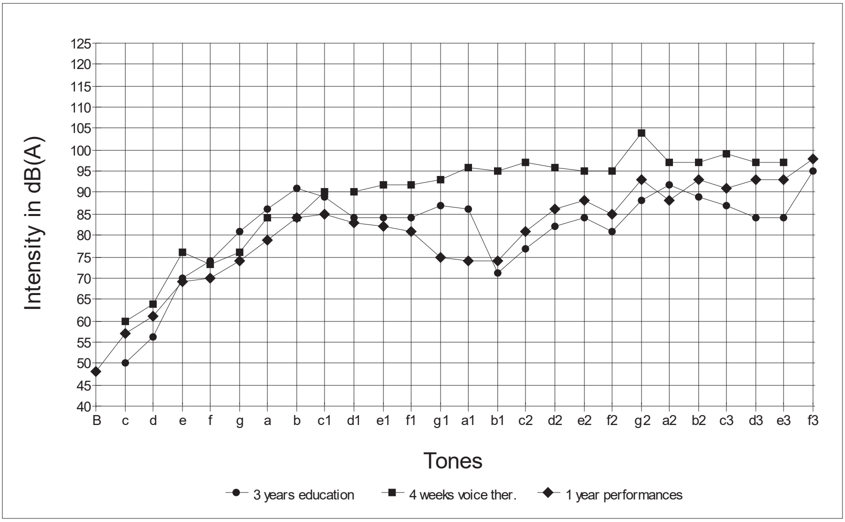


Figure 143: 3 longitudinal measurements of the maximum intensity within a period of one year.

2.8. Longitudinal differences between 3 values of the maximum intensity and the values of the singer's formant within a period of 1 year

Comparing the differences between the values of the maximum intensity and the values of the singer's formant in longitudinal phonetograms still offers another possibility to detect quality changes of the voice, as we have seen above. These differences are again much greater over the total vocal range. Strangely enough, the last curve resembles the first one. The difference between the second and the third curve can amount to 13 dB (A) on a1.

Of course, we discussed these 3 consecutive phonetograms within a period of one year with this musical performer…

Unfortunately, we have not seen her again since.

Almost 10 years later, we have been told that this once so talented 14-years old girl is still living abroad, but only occasionally performing as a dancer in minor musical productions…

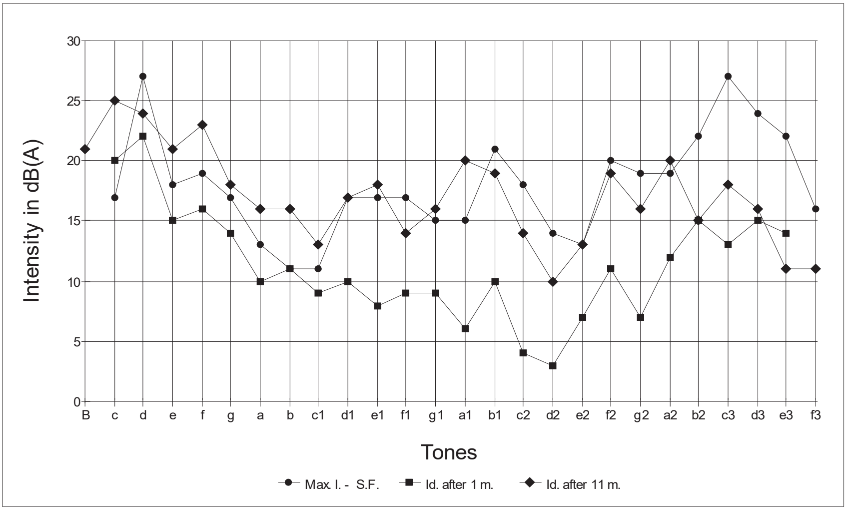


Figure 144: Differences between the values of the maximum intensity and the values of the singer's formant over a period of 1 year.

9.3.2. Case studies over a short period of time

In the literature, most presented longitudinal phonetograms are only quickly superficially analysed, by describing de visu the changed shape or surface of the phonetogram, or using terms as "little", "irregular" or "pathological".

The notion of averaged phonetograms or even standard phonetograms do not satisfy either. The de visu interpretations, however, can be useful as a *quick screening method*, providing a quick idea about a given voice.

Most important, however, remains the fact that both "bad" and "good" phonetograms illustrate the typical features of the voice category of a given subject, based on the parameters, indicated in the chapter on "voice classification by phonetography, a step- by- step procedure".

As we stated many times, *the assessment of the voice category provides the best basis for any implementation of voice care*.

To this end, we will according to our *own methodology*, demonstrate *two specific case studies*, by comparing the VRP curves, *tone by tone*, of maximum intensity, minimum intensity, singer's formant, dynamic range, difference between the maximum intensity and the singer's formant, including their maximum, minimum and average values.

In analysing these two specific cases, much attention went to changes in voice range, zones of register transition and register dips.

Experiments with different vocal techniques and singing styles were analysed and commented. and different voice categories were compared, to get a better insight in the specific differences between the voice categories.

The two cases 1 and 2 clearly demonstrated the evolution of the voice of an adult professional actress/(musical) singer and a very young aspiring musical artist. A lot of longitudinal F°-SPL measurements *over a period of many years* illustrated their individual voice evolution.

But what can happen to the voice, in a short time, during the education process of young musical artists?

In conservatories and dance academies the students usually are often confronted with a lot of disciplines which are seldom coordinated. This can lead to a lot of conflicts between the docents and is very confusing to the students (cfr. the report of Botden and Gribnau[1592]).

Some years ago, *a well-known European conservatory and dance academy wanted to start with a brand-new education program for aspiring musical artists*. Next to the many dancing lessons, the singing and acting lessons were given by experienced teachers, and *we were asked to supervise and coordinate the voice department*.

On our explicit demand, we were allowed, *as a unique experiment*, *to provide some basic voice training, before any implementation of artistic directives, concerning the use of the voice, would happen*. Inherent to the necessary teamwork, many subjective evaluation meetings took place.

As an objective method, F°-SPL measurement was intended to control the obtained results of our voice training. Needless to say, we hoped that this new experience could be used in the future to monitor the development of young voices and also to contribute to the establishment of a refined training program for actors, singers and dancers.

To demonstrate, once again, the *plasticity of the voice*, as visualized in longitudinal phonetograms, we will propose an overview of this exceptional experiment.

During the summer holidays, many candidates for the new musical education program were examined to assess their individual initial capacities.

Based on F°-SPL measurement, 34 students (8 males, ages between 16 and 23 years; average age: 20 y., 3 m.) and 26 females, ages between 16 and 20 years; average age: 18 y., 2 m.) were accepted for our short program of voice training.

In the context of this study, comparing the different parameters of longitudinal phonegrams of these 34 subjects, is too cumbersome. So, we analysed only the results of a short period of logopedic voice training in a group of young starting musical students, providing some striking examples.

9.3.2.1. Changed phonetogram after 20 sessions of voice training

We already mentioned a few times the fact that many mezzos display a large vocal range, which still can be enlarged by judicious training, instead of trying to become a fake soprano.

The next two phonetograms demonstrate the results of voice training in an 18-years old mezzo, who never had any singing lessons. As Hollien[1597] stated, even “golden voices” need careful training.

Referring to our remarks on Subject Classification in Chapter 1, the first phonetogram of this new female musical student could be interpreted as showing the *vocal capacities of a (remarkable) “untrained voice*”.

After logopedic voice training, the surface of the second phonetogram has become even greater by an increase of the maximum intensity curve and a lowering of the minimum intensity curve. The overall gain in dynamic range amounts to 26 dB (A) on g1! Over 2 octaves (c - c2) the minimum intensity is lower than 60 dB (A), which means an exceptional good voice control. The beautiful voice quality is also proved by the much higher values of the singer’s formant and the little distance between the values of the maximum intensity and the values of the singer’s formant. Unfortunately, this beautiful young girl, gifted with a “golden voice”, finally preferred a future dance career… Perhaps, after some time, she could be assigned again as an "untrained voice" …

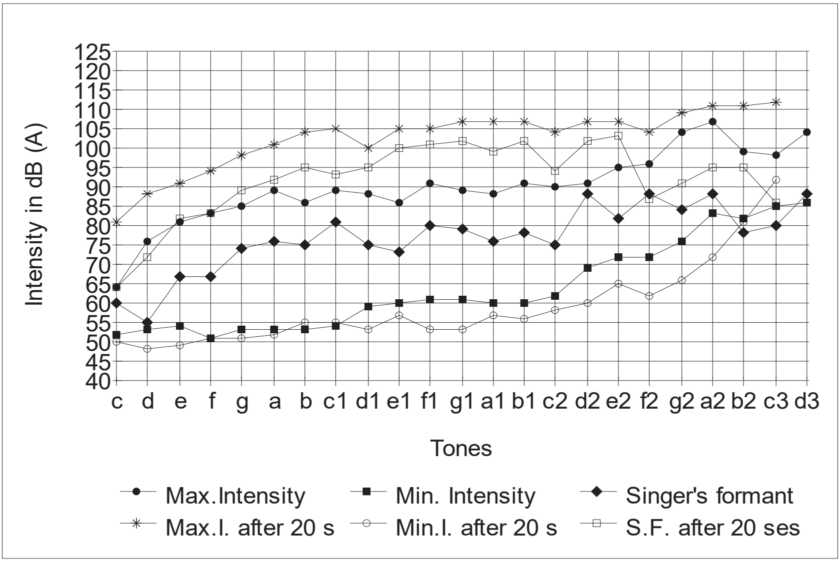


Figure 145: Maximum intensity, minimum intensity, and singers' formant after 20 sessions of voice training.

9.3.2.2. Changed phonetogram after 9 sessions of voice training

In contrast to our first subject, *another 20-year's old girl was dreaming about a musical career, including acting, singing, and dancing.* She already had received a 2-years education at a theatre school for show / musical and jazz dance. According to her singing teachers, she was a soprano, but she declared no to be certain about this, because her singing voice was hoarse, especially at the highest pitches, and her speaking voice was breathy.

The first phonetogram shows a voice range between c and a2, which could be an indication for a mezzo or contralto voice. There is a great dip between d1 and a1, and the minimum intensity on a1 is too high). The maximum intensity has an abrupt fall at e1, while the minimum intensity increases very quickly from d2 on. From f2 on, the minimum intensity approaches the maximum intensity and the singer's formant is very low at these high pitches.

The second phonetogram demonstrates the results of a short session of logopedic voice training. The voice range is even enlarged (c – c3), corresponding to the student's insistent demands! The voice quality is much better now: all singer's formants are much higher, except for d2 and e2 in the now more normalized register transition zone. Interestingly, the maximum intensities are higher now, especially in the former great dip between d1 and a1, but lower in the (new) register transition zone d2 - e2. The highest values of the maximum intensity are even situated on the highest pitches f2 – c3.

Minimum intensities are a lot lower now over the whole vocal range, indicating a much better voice control (dynamic range). The extended maximum and minimum intensities cause a much broader shape of the phonetogram, providing much better vocal capacities. Unfortunately, we were not able to follow her vocal evolution.

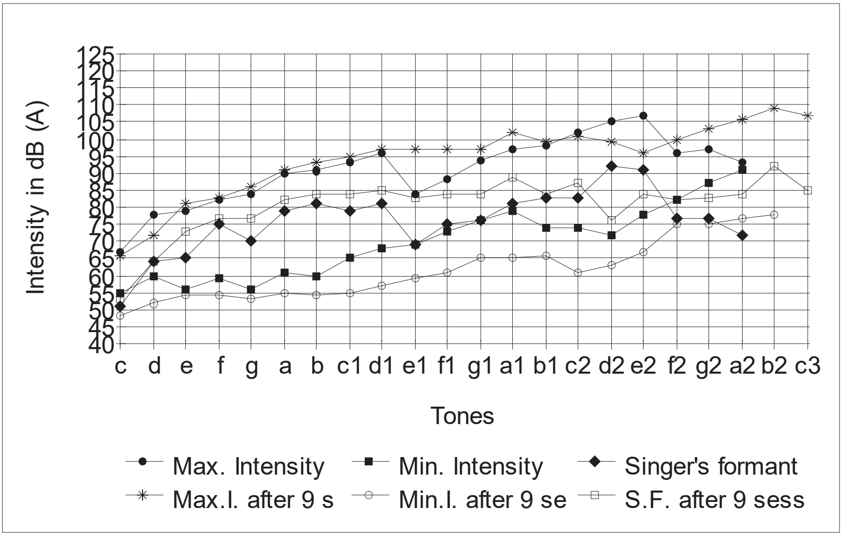


Figure 146: Max. I., min. I. and singer's formant after 9 sessions of voice training.

9.3.2.3. Changed phonetogram features after 5 sessions of voice training

To illustrate the *possible misleading register transitions, due to a forced training,* now we will present the case of a *21- years old female student, who was used to sing the repertoire of alto, mezzo, and soprano, but who was complaining about hoarseness in the lowest and in the highest pitches*. She had great fun with her cat-shaped phonetogram, with prominent cat ears, corresponding to the two mixed register zones, i.e., the mezzo voice (register dip on d2) and to the soprano voice (register dip between e2 and a2)! The very low singer's formants on the pitches from a1 to c3 correspond to the bad quality of her voice.

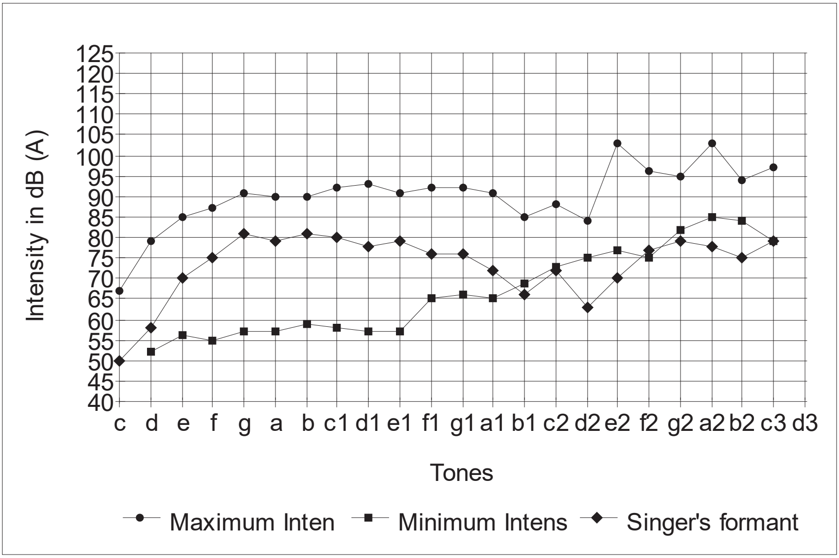


Figure 147: Maximum intensity, minimum intensity, and singers' formant of a 21-years old student, singing the repertoire of alto, mezzo, and soprano.

After 5 sessions of logopedic voice training, the next phonetogram shows an enlarged shape, with an overall greater maximum intensity. The former highest pitch c3 with 96 dB (A) is now extended to d3 with 114 dB (A). The minimum intensities are lower, with a normalized register transition zone. The better quality of the voice is clearly visible in the generally increased singer's formants.

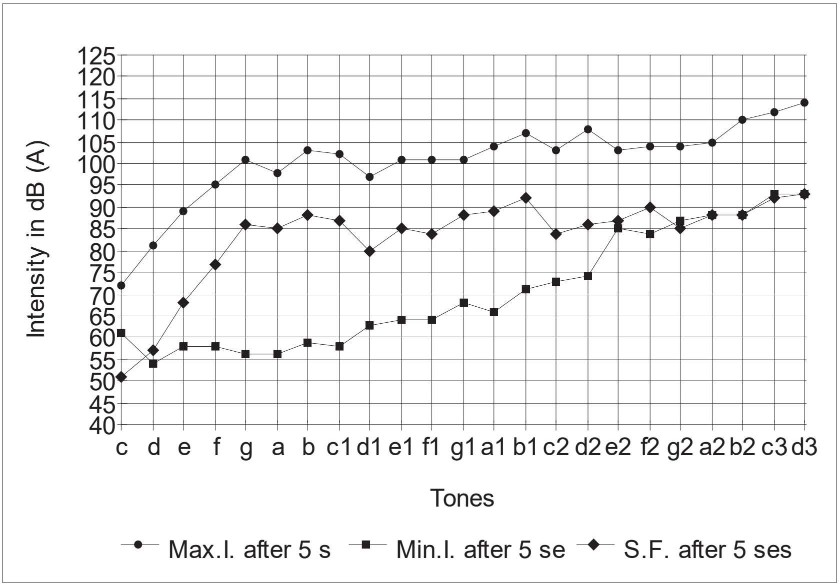


Figure 148: Maximum intensity, minimum intensity, and singers' formant of the same female student after 5 sessions of voice training.

9.3.2.4. Decreased maximum intensity of lowest pitches, after excessive voice use in only one drama lesson

A relevant example of the immediate impact of voice abuse is given by the striking story of our third subject. The initial phonetogram of this *22-years old dancer*, who wanted to become a musical artist, shows the good capacities of his bass voice. He has a vocal range of almost 3 octaves (C – a1) with maximum intensities above 100 dB (A) and minimum intensities below 60 dB (A), with an ample dynamic range. The quality of his untrained voice is good, but his head voice has still to be developed. From a on, his maximum intensity decreases, including the register transition zone, with a register dip on b – c1.

During our third session of vocal training, he was *complaining of hoarseness, after a 3-hours during drama lesson the day before, in which he had to shout and act with a high feminine falsetto voice.*

This type of experimental drama lesson was, of course, not at all in concordance with our initial agreement with the other teachers about a new voice education program!

The *immediate negative result* can be easily seen in a quick testing of the maximum intensity of the *lowest pitches* (*dotted lines*). In fact, his *lowest pitch* (C) was almost inaudible, having decreased by 23 dB (A), and being even weaker than his former minimum intensity at that pitch. D was decreased by 19 dB (A) and E by 6 dB (A).

To have a good idea about the magnitude of this sudden loss up to 23 dB(A) of vocal intensity, after *just one drama lesson*, it is worthwhile keeping in mind the in Chapter 6.2 explained formula: '*the decibel works to a* ***logarithmic scale'*** *(exactly as our ears do:*

INTENSITY RATIO	**DECIBEL EQUIVALENT**
1	0 dB
10	10 dB
100	20 dB
1.000	30 dB
10.000	40 dB
100.000	50 dB
1.000.000	60 dB

Kitch et al.[1583], studying performance effects on the voices of 10 choral tenors, found comfortable pitched notes, high soft notes, and the *bottom notes* in scale singing, the most sensitive vocal tasks, whereas a *reduction in pitch range* was present after performance. It is important to note that these authors reported that, after a short choral performance, most of their subjects demonstrated significant negative changes in their voice across acoustic variables, which were not fully detected by the singers themselves![1583]

Investigating time-of-day effects on voice range profile performance in young, vocally untrained adult females, van Mersbergen et al.[1626] mentioned that both warm-up and fatigue effects could affect VRP performance, in opposite directions. In the theatrical world, however, examples of extreme misuse, abuse, and overuse are widespread, having disastrous effects on the voice, which are easily demonstrable by phonetography.

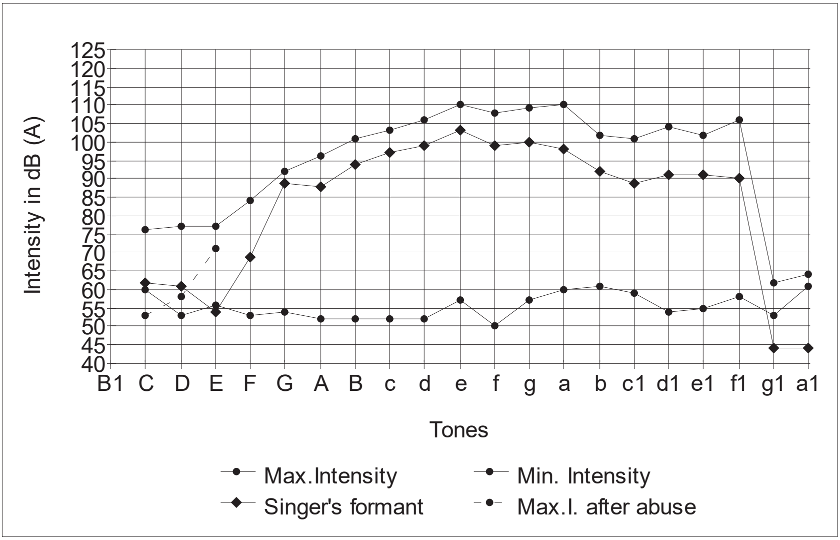


Figure 149: Influence of vocal abuse on the lowest pitches of a bass voice (dotted lines).

In the next Figure 150 we marked again (*in dotted lines*) the decrease in maximum intensity due to vocal abuse. It took us a lot of work to restore the voice to its initial capacities. In comparison to the first phonetogram, the overall maximum intensities increased, as can be seen in the maximum curves, measured after 3 periods of logopedic voice training. The general slope of the maximum curve remained stable.

We didn't see this student again because he left the conservatory and wanted to start with private singing lessons. However, after one year of singing lessons, he came back to me for a control session. As can be seen, the maximum curve has (again) decreased considerably and is even lower than in his first phonetogram, when he still was an "untrained subject"!

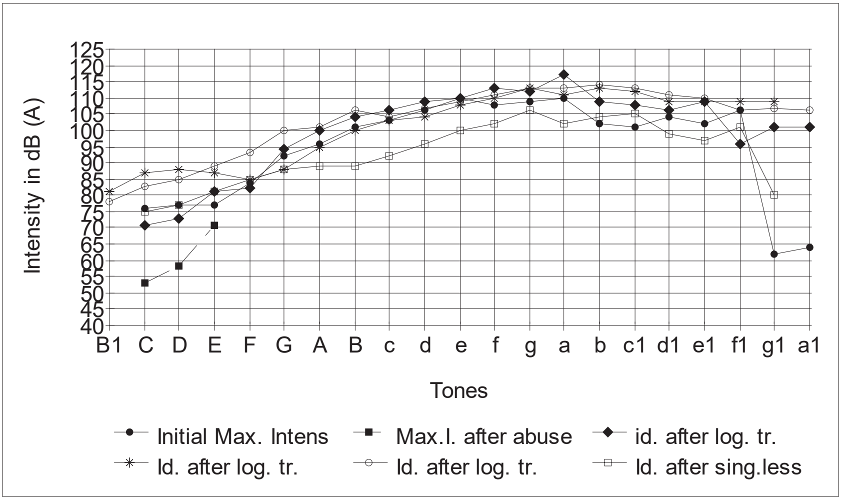


Figure 150: 6 longitudinal measurements of maximum intensity during the training period of a young student of musical theatre.

It is indeed not easy to indicate the different causes which have a direct or indirect influence on the features of a given voice. After all, phonetography only provides us with a short picture in time, just like the measurement of the blood pressure, the heartbeat, and so many other physiological values do. Nevertheless, this instant picture is very valuable, when compared with other instant pictures, thus indicating the evolution of a given voice in time.

The 6 longitudinal measurements of the maximum intensity of this young student of musical theatre show the evolution of his bass voice: the first curve shows his already good vocal capacities, the measurement of the 3 lowest pitches show the immediate loss of vocal power because of vocal abuse, the next 3 curves show the stable results after logopedic voice training, and the last curve, the negatively changed curve after more than 1 year singing lessons.

One could argue that maximum intensity is just one aspect of the voice picture. A lot of beautiful voices are not at all powerful. According to a popular guide, giving advice on how to become a singing star[1627], only one of the 300 pages is dedicated to the voice! Not everybody has a powerful voice, but singing on pitch, with a beautiful and very personalized timbre is sufficient, the authors claim. *"Personality"* is often seen as more important than vocal efficiency.[1627]

As stated in Chapter 6 on the parameters of the voice, the *analysis of voice quality remains a hot debated item.* In this study, we just want to share our own experience with the *measurement of the singer's formant, as an indication of the quality of the voice.*

That's why we want to show another example in the next Figure 151: 3 longitudinal measurements of the value of the singer's formant: the first, original curve of the singer's formant of a male "*untrained voice*", the second after logopedic voice training, and the last curve, after more than 1 year of private singing lessons. We abstain from any comment.

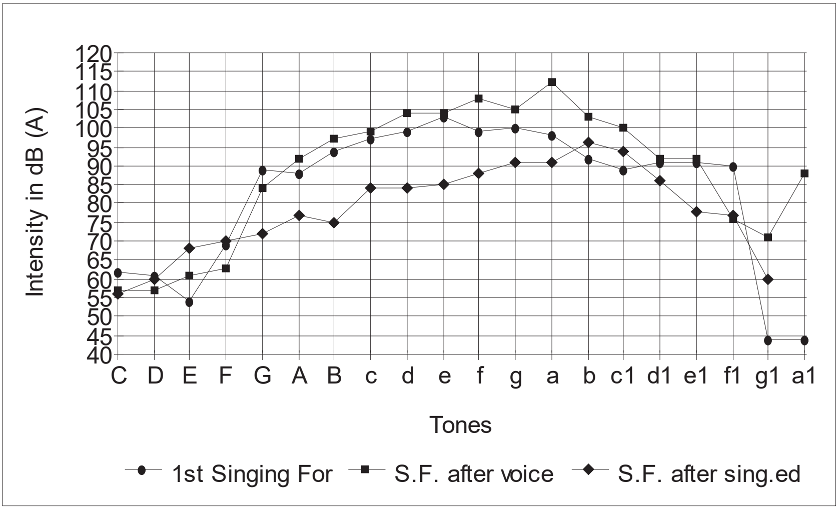


Figure 151: 3 longitudinal measurements of the value of the singer's formant of a young student of musical theatre.

9.3.2.5. Decreased maximum intensity of lowest pitches, after abuse of the singing voice

Another example of the *negative influence of abuse of the singing voice* is the case of a *16-years old boy*, a leptosome dancing student, length 1,84 m., and gifted with a beautiful, be it untrained, bass voice.

The next Figure 152 shows the maximum intensities, deducted from our first phonetogram, to be compared with the results of vocal abuse (*excessive singing with a high falsetto voice the evening before*). Maximum intensity of the lowest pitches is considerably decreased (4 to 18 dB (A) on the pitches C-D-E-F- and G), while his lowest pitch B1 is completely lost. It took 5 sessions of voice therapy to get the better result of the third curve of maximum intensity. Remark that his vocal range has much extended from A1 to c2, including acquired falsetto pitches from e1 to c2.

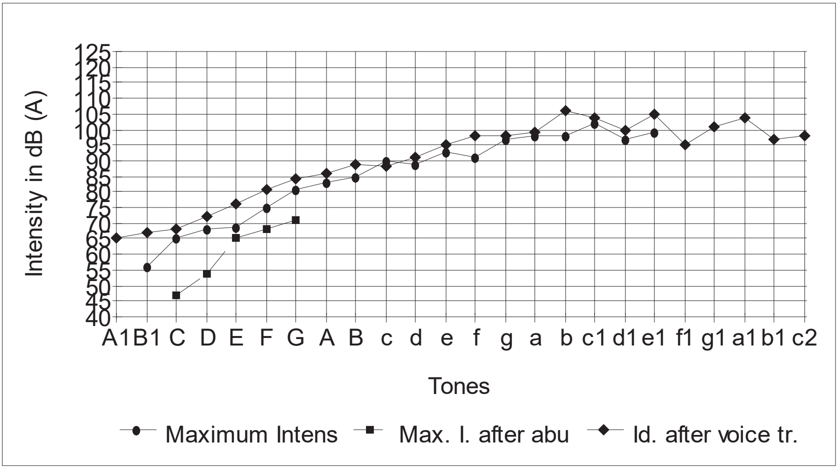


Figure 152: Influence of vocal abuse on the lowest pitches of a bass voice (dotted lines)

9.3.3. Longitudinal phonetograms of aging voices

At the beginning of this chapter, we mentioned the results of our (exceptional) gerontologic study[1398] of voice measurements of 54 choir singers after a period of 27 years. We concluded that the total range and the vocal intensity of our subjects were unchanged, lesser, or even greater, while the voice quality, in most cases, was deteriorated. Maximum intensity decrease was more pronounced in the head register.

Longitudinal phonetograms clearly demonstrate the **plasticity** of the human voice. All kinds of influences (voice training, singing lessons, vocal abuse and misuse, pathology …) change the morphology of the phonetogram and its parameters. The results of our longitudinal VRP's of elderly voices over a long period are too divergent to explain…

Conclusion: longitudinal phonetography proves to be an invaluable aid in voice analysis. Back in the seventies, Coleman[1628] carefully expressed the hypothesis that "young singers have a basic vocal instrument which is already capable of near adult dynamic limits".

Our longitudinal phonetographic results also prove the *versatility of the human voice,* as expressed by its parameters of frequency, intensity, and voice quality. In our opinion, phonetography combined with the analysis of the value of the singer's formant, offers a simple yet practical instrument of evaluation of voice quality.

Our results confirm Awan's statement[1629]: "Vocal training has extensive effects on voice characteristics and may maximize the potential of those who have exceptional voice characteristics prior to receiving vocal training". Our own results also show that *the results, obtained in the same person, strongly vary according to the kind and intrinsic value of the received training.*

CHAPTER 10

IDENTIFICATION OF THREE NATURAL VOICE GROUPS BY PHONETOGRAPHY: A DATA DRIVEN APPROACH[1128]

10.1. Introduction

The previous chapters were dedicated to the results of our lifelong involvement with every aspect of the human voice. *The huge importance of voice classification by phonetography was continuously stressed*. However, we had to wait many years, and after making several attempts, before being able to scientifically proof our point of view.

Surprisingly, there exists no generally accepted method for voice classification, let alone an algorithm, as there is no consensus about what voice parameters to use. This calls for an objective method for voice classification. When this proves infeasible, one may rightfully question the existence of three basic female and male voice types by nature.

The many conferences, workshops, with a sustained scrutinizing of scientific articles on voice, including often intense discussions, during my professional life as a vocal coach/speech and voice therapist, confronted me continuously with the many different and even contradictory opinions about voice classification (see the preceding chapters).

Let us have a look now at our personal research history over a period of more than 20 years, trying to solve the "riddle of voice classification".

After a year of preparatory activities, I obtained the admission by the Dean of the State University of Groningen (The Netherlands), to "promote as doctor in medical studies" with a thesis on '**The measurement of vocal performances in professional voice users'** (anno 1992). Next to my promotor, Prof. dr. Harm K. Schutte, a well-known phoniatrician, 6 other specialists from 4 European universities, were in charge for helping me with the statistical analysis of the many collected data. However, even after several years of involvement, the since long expected results could not be obtained.

A new team from the Catholic University of Louvain, with Prof. dr. Felix de Jong as promotor, and with the assistance of 11 specialists from 4 European universities, took over in 2006.

Voice is a multidimensional phenomenon and should be addressed as such. We mentioned already in the former chapters that Voice Range Profiling is acknowledged as a suitable method of establishing vocal capacities. The voice source varies along the phonatory dimensions of vocal frequency and intensity. Together with other features such as timbre, this yields a *multi-dimensional phenomenon.* A VRP is a combined graph of frequency and intensity measurements. *Voice Range Profiling can be considered as an appropriate method of assessing vocal capacities*.

In a first study, we hypothesized it was therefore tempting to verify whether frequency- and intensity parameters derived from the Voice Range Profile could discriminate between the three basic female voice types, alto, mezzo, and soprano. It looked plausible to assess if the combined measurement of frequency and intensity parameters could discriminate between the three basic female voice types, alto, mezzo, and soprano.

Voice classification has a great impact on a singer's life, but often "experts" disagree, and singers question the received label(s) and stick to their own opinions. In addition to this, singing teachers, conductors, scientists, physicians, speech, and voice pathologists, almost everybody (including the subject himself) feels entitled to express his opinion on this matter. However, a correct and preferably objective voice classification is indispensable to assess the physiological capacities of the human voice to develop and preserve them.

In traditional voice classification different parameters are considered, like the quality of the sound, the intensity with which the individual can sing, how high the chest voice can be used, and the comfort that the singer feels, and the frequency of the register transition points. The weight to be assigned to these parameters is not easy to define and requires great experience. Due to the subjective nature of these parameters, combination of these parameters or incorporation into an algorithm is not readily possible.

10.2. An unusual experiment

For many decennia, studies on voice were limited to studies in laboratory settings. Brodnitz[1630] cautioned:” The bigger the machinery, the more the artificiality there is with a patient”, and von Leden[1631] stated:” There must be careful study of the patient under conditions that are as close to his normal use of the voice as one can arrange. I could not stress this point too strongly”.

Kitch et al.[1632] stated that the results obtained from research in naturalistic settings may be more valid in singing pedagogy than in laboratory settings. They encourage investigators to explore the possibilities of taking the laboratory to performers and thus to consider larger groups of subjects for investigation.

According to Hoffman-Ruddy et al.[1633] clinicians must visit the performer’s stage so that there is a better understanding of detrimental environmental situations they are working in. However, in our experience, the access to stages and conservatories is not easy (Chapter 4). This limited access of scientists to the singing world could explain why so few studies are available in the literature, dealing with larger groups of singers and singing students outside the laboratory.

Schutte and Seidner[1634] stated that “audiometer cabins or strongly dampened experimental rooms might influence the auditive self-control of the subject’s own voice». This is certainly the case in singers. Schultz-Coulon[1635] and Wirth [1636] too prefer an ‘acoustical living room atmosphere’.

With the lingWAVES Voice Diagnostic Center we always performed our Voice Range Profile (VPR) measurements *outside laboratory settings*, in many different rooms situated in conservatories and theatre companies, with a level lower than 45 dB(A) and according to the recommendations of the UEP.

According to Dejonckere[1637] and Speyer and Dejonckere[1638], *voice is multidimensional and thus needs a multidimensional approach: no single measurement can reflect all aspects of the human voice.* However, the *taking of the voice laboratory to the “real scene”, “in naturalistic settings”, is seldom possible.*

To this end, we invited in our private cultural centre the participants at the 4th Conference on Voice’, at a special **Workshop on ‘The exploration of**

your own voice' with demonstrations (voice classification, F°SPL measurements, 'Durchdringungsfähigkeit' in acting and in singing) **on the stage of the Royal Opera of Ghent**.

Many participants (phoniatricians, E.N.T-specialists, speech therapists and students from European countries were hugely impressed, being for the first time in their life on a real opera stage, not as spectators, but trying hard to get heard in a big opera house, and this without the aid of a microphone.

Needless to say, that everybody immediately understood the need for trying to adopt specific laryngeal postures, formant tuning, producing the 'ring', and, most of all, trying to obtain a resonant and carrying sound, potentially being heard over a big fortissimo playing orchestra!

10.3. Own methodology

From the literature and our own inquiries among singing teachers, students, and professional singers it became clear that there exists no generally accepted method for objective voice classification. Frequency range is generally considered to be an important factor in voice classification, but our own exploratory studies indicated that this is not a panacea for voice classification by itself.

In Voice Range Profiling the melodic vocal range is measured, i.e., all producible frequencies. Tessitura was not considered because this is prone to a subjective interpretation. Scores for songs have always been written for specific voice types, depending on the range of frequencies (and not intensity). Therefore, frequency scoring is the most important procedure for voice classification by singing teachers. However, voice range / tessitura alone proved not to be a reliable voice classification parameter. At this point, one may question the existence of three basic female and male voice types by nature.

Some authors assume that VRP provides useful information for classifying a voice. However, no specific interpretation of VRP results regarding voice classification could be found in the scientific literature. This has not only to do with difficulties in interpreting the VRP, but also with the general conviction that voice classification belongs to the domain of singing teachers, conductors, and other people with musical training, who claim to possess a trained ear for assessing voice types. The many contradictions and discussions on this subject indicate the need of an objective methodology of voice classification. The objective measurement of voice intensity, combined with the objective measurement of the frequency vocal range as applied in VRP could be considered as an objective starting point for voice classification.

In an attempt to break out of the controversy, a new perspective is adopted in our study by letting the data speak for itself. Such an approach, called ***data-driven****, imposes minimal assumptions on the nature of the data, what elements to use for its analysis, and in our case even the existence of natural voice groups.* Voice range profiling is an objective measurement of minimum and maximum intensity at all fundamental frequencies that span the singer's range. Therefore, the voice range profile (VRP) reflects the capacity of the voice. The pertinent study uses VRP-derived parameters that are commonly applied in clinical practice.

The purpose of the first study was to verify the existence of individual- or combinations of commonly used and easily understandable VRP parameters (i.e. the lowest- and highest frequencies the subject's voice can reach, the minimum and maximum intensity of the lowest octave, and the intensity and frequency when entering and exiting the register transition zone) with which the data can be partitioned into a number of clearly separated clusters as a basis for discriminating between basic female voice categories.

In our study, trained and untrained, singing, and non-singing voices were included. The data from 327 females between 18 and 25 years (mean age: 20.8 years) from different conservatories in three European countries (Musical Theatre and Classical), was investigated. Subjects were recruited from our private practice and during auditions for Opera and Musical Theatre. Data entries that only measured part of the Voice Range Profile was removed. This reduced the data set to 268 subjects. In a second study, the data from 256 male subjects (18 – 52 years, mean age = 22, SD = 4.9), consisting of 9 young singing students, 17 professional singers, 61 professional choir singers and 169 with and without singing experience, was investigated.

A voice range profile (VRP) was performed according to the UEP recommendations16 using the ling Waves Voice Diagnostic Center, version 2.5; 2007, with a Center 322 Data Logger Sound Level Meter. Phonation was on the vowel /a:/ with a microphone distance of 30 cm. The minimum phonation time was 2 seconds. The data included maximum and minimum intensity measurements (in dBA) of a subject's voice taken at the fundamental frequencies that span the singer's range. At each pitch, subjects were encouraged to phonate as softly and as loudly as possible, regardless of the produced vocal quality.

An individual subject's VRP has, approximately, the shape of an ellipse. In order not to favor any frequency range in the analysis, the frequency axis was transformed from the non-linear note scale into a linear frequency scale (Hz). *In the VRP the maximum intensity increases with increasing frequency.*

The *register zone* (including the marked register dip) was measured as follows: the beginning of the register zone is marked by the maximum intensity before a drop of intensity occurs. The register zone ends when the maximum intensity (at increasing frequency) exceeds the maximum intensity of the beginning of the register zone. This avoids argumentation about the "exact" register transition (point) and the possible difference when singing up or down. The marked break points reflect the additively perceived voice sound, according to the used technique.

10.3.1. Statistical analysis and methods

After preprocessing the data, we applied Ward's minimum method to assess whether the data displays any natural clusters (groupings), this means without assuming their number and without using any prior voice classification (cf. *data-driven approach*).

However, Ward's method could not be decisive as it could return more than one statistically plausible cluster solution. To break the tie, we needed an additional method. Furthermore, we wanted to identify which parameter (or a small set of them) is crucial for discriminating between the voice clusters. We decided to use K-means clustering in combination with a selection procedure (i.e., forward, or backward feature selection) to define the discriminative parameters and the cluster migration index to decide which cluster solution is more consistent across discriminative parameter combinations identified and adopt that as the final cluster solution.

The analyses were performed using Statistical Analysis SAS/STAT ® software (release 9.2).

10.3.2. Results

At first, the female voices were examined. Ward's procedure indicated that there could be three or four clusters in the data. In using K-means clustering, both a forward and backward feature selection procedure was applied to both clustering options. Based on the migration index, the three-cluster solution turned out to be the most consistent one. The parameter that led to the best three-cluster separation was the ratio of the perimeter length of the chest voice part of the voice range profile versus the total perimeter length. In the case of this single variable, the overall R-squared is equal to the partial R-squared, and it is larger than 80% which is an indication of a high cluster separation degree.

Secondly, *male voices* were examined. Again, Ward's procedure indicated that there could be three or four clusters in the data. Because of the numerous options to combine parameters, only a backward selection procedure was applied in combination with K-means clustering. Based on the migration index, also for the male voices, the three-cluster solution turned out to be the most consistent one across all parameter combinations. The parameter that led to the best three-cluster separation in the male voices was the frequency of the register transition.

In this *pilot study* consisting data of 327 female singing students, we investigated if basic groups (clusters) can de distinguished by generally applied and easily clinically understandable frequency-intensity related parameters, derived from the voice range profile (VRP), and how much there are. The *Ward's minimum variance method* was used. Alas, *the result was negative*. This does not mean that there would not exist other, more "intelligent" parameter combinations, even non-linear ones, of the voice range profile, that could lead to a clear cluster separation, and that could serve as the basis to resolve the riddle of voice classification. Subsequently, *more "intelligent" parameters derived from the VRP* (combinations, or even non-linear ones) were used. *The data of 206 female conservatory singing students and 256 male subjects,* consisting of 9 young singing students, 17 professional singers, 61 professional choir singers and 169 with and without singing experience, was analyzed.

10.3.3. Feature construction

Then, it was decided to represent, in a more compact manner, each VRP by several parameters - called features in our context - in connection with:

the *geometry of the VRP* such as the surface area enclosed between the maximum and minimum intensity curves, their frequency ranges, and their perimeter lengths;

the *register transition zone* such as the intensity of the dip in maximum/minimum intensity curves between the chest and head voice parts of the VRP and the frequency at which it occurs;

the *geometry of the chest/head voice parts* of the VRP such as their surface areas and their perimeter lengths;

the *linear characteristics of the minimum and maximum intensity curves* such as the slopes of the regression lines through the maximum and minimum intensity curves.

Finally, a number of voice frequency and intensity ratios and differences were defined, based on some of the above features such as the ratio of the surface area of the chest voice to the total surface area enclosed by the maximum and minimum intensity curves. Another example was the ratio of the perimeter length of the chest voice part of the VRP to the total perimeter length, per feature dimension, taken between the cluster centers (averages, centroids) and the center (average, centroid) of the whole data. The total variability is the squared distance between each data point and the center (average, centroid) of the whole data. RS varies in the interval [0, 1]. "0" means that there is no difference, "1" means that there is a maximal difference between the clusters.

The same statistical technique now indicated that there were potentially two cluster solutions: 3 and 4 clusters. To resolve the latter, we applied a *clustering technique in combination with a parameter selection procedure* (to select the most discriminative parameters) and a test for consistency of the found cluster solutions. When applying Ward's minimum variance method, 3 or 4 clusters turned out to be possible. We, therefore, restrict ourselves to the 3 or 4 cluster cases: when assuming 3 clusters, the single, two and three feature cases are examined; the same was done when assuming 4 clusters. Note that no prior knowledge of the number of voice types is used in Ward's method or in the further evaluation of the 3 or 4 cluster options.

Now, the three-cluster solution turned out to be the most consistent one in both genders. *The parameter that led to the best three-cluster separation in females was the ratio of the perimeter length of the chest voice part of* *the VRP versus the total perimeter length. In males this was the frequency of the register dip.*

This means that the complexity of voice classification can be reduced to a more compact, yet adequate formula, easily obtainable from the VRP parameters. In fact, the "perimeter total" can be seen as an expression of the total frequency range, whereas the "perimeter chest voice" marks the boundary with the head voice/falsetto.

Klingholz et al.[1063,1069,1070] elaborated a method of analyzing ellipse parameters and conclude that the register transitions, visible in the VRP, at certain frequencies, illustrate clearly the different mechanisms based on pre-phonatory larynx positions and specific muscle activities.

Pabon[1075] prefers to talk about a region where modal and falsetto registers overlap. He acknowledges that, in general, register differences are accentuated by a greater effort (louder voice production, higher pitch) In previous publications automatic, computer assisted VRP registration is considered to be helpful to determine voice breaks and to indicate register contours, facilitating voice classification.[1076,1077] In another study, however, the author assumes that the register transition from modal to loft cannot be located with certainty from the VRP, nor by auditory perception.[1075]

According to Klingholz et al.[1073] and Airainer and Klingholz[1074], however, markers of the register ranges are the transitions which are indicated "by minima in the forte contour and maxima in the piano contour, and minima of the dynamics, at specific pitches."

The features that lead to a clear cluster separation in this study do not take *timbre* into consideration. This parameter has always been evocated as decisive in voice classification by many singing teachers. Perceptual evaluation of voice quality, however, proved to be highly subjective[789-791] and remains controversial because of poor correlation among raters.[792-795]

The results of this study demonstrate that different parameters of the VRP can yield a clear separation into three voice clusters for each gender. Such a result is remarkable since this may not be expected from biological proxies. However, many years ago, the French phoniatrician Garde[287] defined voice category already as "a biological constant, as important as the determination of the blood group. One can only wonder if ancient composers of vocal music had an innate feeling about the existence of three natural basic human voice categories.

Further studies are necessary to link the three statistically obtained clusters to the traditional three basic female and male voice classes.

10.3.4. Voice research and the register enigma

A second salient finding of our study is that the parameters that have led to the three-cluster separation in both genders have to do with *register transition*. The results of this study may provide *a basis for settling the issue of objective voice classification*.

Many textbooks on singing education stress the importance of the register transition in relation to the three basic female and male voice types. However, the results of our explorative study on voice classification (see Chapter 4) showed that only 9% of private singing teachers and only 54.5% (classical) and 60% (musical theatre) conservatory singing teachers use register transition as a voice classification criterion.

Although the register transition zone has often been a major concern in singing education textbooks, its objective location on the voice range scale has always been the subject of much debate. An extensive overview of the many divergent opinions and findings on register transitions has been given in Chapter 6.4. and in Chapter 8.7.

Obviously, frequency localization alone cannot be the sole characteristic of a vocal register. Based on the classification by 16 singing teachers of 3 European conservatories, classifying 99 of their female students, Lycke concluded: "Although voice classification based on frequency range is still very popular among contemporary singing teachers, the results of this study demonstrate that frequency range proved not to be suitable as a voice classification parameter, if used as a single parameter. While frequency range is an objective parameter, the combination with other, but subjective criteria make voice classification an even more subjective issue." (Unpublished study).

Lycke and Siupsinskiene[147] recently made a study on the effects of singing training duration and institution on basic Voice Range Profile parameters. VRP recordings were made of 162 females, taking individual singing lessons during 5 consecutive years (1st - 5th level) in Dutch, Belgian, English, and French public or private training facilities. Sixty-seven non-singing female students served as controls. The main location of register transition from chest to head voice was between h1 (494 Hz) and e2 (658 Hz) and included 91,3% of cases independently of the level of training.

Lycke continuously stressed the importance of the register transition as a criterion for voice classification. The finding of three natural clusters in female and male voices and the role that register transition related parameters play in clustering, is an indication that *clustering may be a new angle on the issue of voice classification. The eye casting dip(s) in the phonetogram at certain frequencies illustrate the different mechanisms based on the pre-phonatory larynx positions and specific muscle activities*.

According to our specific methodology, the region of voice instabilities, which can be spread over an octave, is accompanied by large SPL variations, even in classically trained singers, when trying to avoid pitch breaks or jumps. However, further studies are necessary to link the results of the statistically obtained cluster separation to the three basic voice categories as commonly interpreted by most composers of vocal music and singing teachers.

To this end, we presented in this manual the results of many phonetograms, schematized, and analysed in 152 figures and 72 tables, suggesting that the complexity of voice classification may be reduced to a more compact, yet adequate formula, easily obtainable from the VRP, and thus appropriate for clinical use.

10.3.5. Clinical implications

Our basic study applies to male and female singing students and singers, aged 8 to 88 years, who are or have been using different types of singing techniques in their educational (conservatories) and professional (stages and performances) environment. The results of our study concerning this mixed population of different gender, age, education, and occupation could open a new area of research and clinical applications.

We believe that our methodology can be applied to every kind of human vocalization, be it speaking or singing. After all, as we already mentioned in Chapter 1 on “Subject classification in voice research”, many authors consider that the acoustic principles of speaking, and singing are basically the same and do admit that the speaking and singing voice are strongly interdependent. Many verbal productions are intermediary between singing and speaking (cfr. Sprechgesang, “Parlando” singing, recitatives, and country singers use basically the same type of phonation when they sing and when they speak.

As Miller[108] stated: 'it is very confusing to singers and actors to think that they have two voices when they really have two vocal folds that will speak or sing or yell or laugh'.

The larger voice and intensity range in singing depends on the singing style, but even in an animated, expressive conversation, considerable extremes of frequency and intensity can be found. As we already mentioned, in pathology, dissociation of one's speaking and singing voice is a frequently occurring cause of voice problems in singers. These observations stress, again, the importance of the register transition zone, in direct relationship with the three basic vocal types, as shown in our study.

Our study indicates that there exist three basic voice types, corresponding with classic voice types or not. This indicates the need of voice classification, also in modern music, where not a similar vocal repertoire has been written like in classic music.

We assume that our methodology can be useful, not only in determining a basic voice type for singers of all kinds, but also in providing interesting cues for voice diagnosis and voice therapy in general (speaking and singing), considering the strong relationship of all different human vocalizations.

10.3.6. Conclusions

This complex long-time study demonstrates that parameter combinations of the voice range profile can yield a clear cluster separation to discriminate between three basic voice categories of each gender and may serve as the basis to resolve ***the riddle of voice classification.*** *Such a result is remarkable since this may not be expected from biological variables. One can wonder if ancient composers of vocal music had an innate feeling about the existence of three natural basic human voice categories. Most "intelligent" parameters that have led to the cluster separation, however, are not easily understandable in clinical terms. Therefore, it is not easy to link them to the clinical situation, nor can the difference between these parameters that have led to the clustering of female and male voices readily be explained. A second salient result of this study is the finding that each of these features has to do with register transition.*

CHAPTER 11

GENERAL CONCLUSIONS

The human voice is the instrument *par excellence* for oral communication. In day-to-day use the vocal load may not be heavy, in contrast to professional use. In singing, the vocal load can be extremely high, sometimes exceeding the physiological limits. To avoid damage and to optimize vocal performance it is important to know the possibilities and impossibilities of the voice. In other words, the vocal capacity must be estimated. Voice classification is a method to estimate the voice and composers of vocal music wrote and write repertoires that fit to the possibilities of the voice, in classical music indicated by voice classes.

The results of our explorative studies (Chapter 4) can be seen in the light of the remarks of Radionoff et al.[150] about the nomenclature disparity and the tremendous lack of consistency among curricula of commercial music degrees today. The answers we received to three different questionnaires showed a marked inter-individual difference in attitude towards voice classification by the various singing teachers and their students. Many different criteria for voice classification are applied today, even in classically oriented conservatories, while many singing students have their doubts on the correctness of the voice category as provided by their teachers.

Regarding contemporary music we found that many private singing teachers and their students do not feel the need of voice classification). Scores of commercial music are usually adjusted (= transposed) to the capacities of the individual singer who has been chosen to sing a specific song. Usually, it is not necessary to know your voice type if you are singing for your own enjoyment. However, if you have the ambition to sing professionally or to do some professional auditions, you must know your voice type. In most cases, at the audition, the candidate will be asked about his voice type. Usually, the singing teacher is not present here. The jury will often look for the most fitting (voice) type for the role, without considering voice classification. Estimation of the real voice type could enable to find out what songs are most appropriate to somebody's voice.

Classification is one of the major objectives of scientific endeavour. Scrutinizing the scientific literature reveals the many hidden biases when one tries to classify subjects and their voice. Surprisingly, there exists no generally accepted method for voice classification, let alone an algorithm, as there is no consensus about what voice parameters to use. This calls for an objective method for voice classification.

According to Brewer[414], in the panel discussing "The Integration of Voice Science, Voice Pathology, Medicine, Public Speaking, Acting, and Singing", "research teams should look at acoustic phenomena and their possible detectable correlates. *Further studies e.g., on voice categories ("accurate descriptions)" are necessary*. Obviously, the publication of our doctoral thesis (2013) gave rise to a new series of scientific publications, all based on phonetography.

During our long professional life as a vocal coach/speech and voice therapist, we were often confronted with the *negative influence of inappropriate singing lessons*.

Voice scientists too, often consider the voice as something elusive that must be cultivated, while even highly cultivated voices are puzzled when confronted with voice problems. In an interview, a famous French coloratura soprano, after several surgical intervention for vocal nodules and voice therapy, claimed she considered the whole thing just as an accident. "After all, football players have knee problems; why should singers not have vocal nodules?."[1639]

In an extensive article with a provocative title **"Why do stars like Adele keep losing their voice?",** appeared in The Guardian on 10 August 2017, Bernhard Warner acknowledged the fact that "more and more singers are cancelling big shows and turning to surgery to fix their damaged vocal cords. But is the problem down to the way they sing?" There is no precise data on the number of performers who have gone under the knife over the years. According to the same author, several surgeons told him they estimate that vocal cord surgery has been performed on thousands of pop, rock and classical singers, as well as on theatre and stage musical stars. And he continues:" In the west, vocal abuse is surprisingly common in all professions that rely on the voice, from schoolteachers to opera singers. Awareness of the problem is growing, but as Adele's case demonstrated, and separate studies conclude, *surgery is not necessarily a lasting fix*. There are few, if any, widely accepted standards for teaching singing, and many teachers complain that too many of their peers get jobs because of how they sound, not what they know."

With the arrival on the Internet of many **professional networks for scientists and researchers like Research Gate, Academia.edu, HAL, and so on**, making it very easy for researchers to share and access scientific output, knowledge, and expertise, we found out that, since the publication of our PhD thesis, many studies on the speaking and singing voice, have been inspired by our data and obtained results. We feel happy with this new phenomenon, hoping that the *officially claimed many thousands reads, and citations o*f our publications will also result in a *basic change in attitude from the artistic world toward scientific research on voice!*

To this author, voice classification always has been a primary concern before any education or treatment started. Phonetography helped him a lot to better understand the huge variability of human voices and accentuated the need to classify them in clearly distinguishable groups to provide a more practically directed therapeutic approach.

In our opinion, the criteria of voice classification we propose in this study are clinically useful, because they provide a *basic classification*, regardless of any level of training or (temporary) vocal status.

We hypothesized that every human voice can be classified according to six (well known) basic voice categories: bass, baritone and tenor for male voices, and contralto, mezzo, and soprano for female voices. This basic voice classification should be determined before any other (sub)classification takes place.

According to the conclusions of the U.E.P. (Union of European Phoniatrists) (1978), *soloist singers, choir singers and actors belong to the top three of the professions with special demands on the quality of the voice. That is exactly the major category of subjects in our study*. However, the results of our study can easily be generalized to a much greater population of voice users by introducing the proposed voice classification. Once subjects are classified into these basic voice categories, they can be ordered in (sub)categories like "normal voices", "voice patients", "singing students", "actors", teachers", or whatever category is felt as necessary to compare different people in any study.

Phonetography provides an easy solution to objectivate the most important parameters of voice and to discuss them on the spot with the subjects.

Phonetography provides an instant image of two important parameters of the human voice: vocal range and intensity. The location of the register zone and the measurement of the singer's formant offer additional information on the voice capacities of a given subject.

We hypothesized that phonetographic interpretation could provide the necessary information to classify every human voice, hoping to solve the age-old discussion on 'the 'riddle of voice classification'.

The elaboration of an age-related and gender-specific *pattern card of the human voice*, based on a step-by-step analysis of the phonetogram, enables a *basic voice classification of any subject*, providing a guideline with useful information for voice education and voice therapy.

The *interpretation of longitudinal phonetograms* offers direct cues for voice education and therapy. Regularly consulting these data have been very useful in my own private praxis with actors/singers/dancers. As a rule, the results of every phonetogram were thoroughly discussed with the subject, often in the presence of his/ her (often critical) singing teacher. I am convinced that, at the end, everyone learned a lot about individual vocal capacities.

As mentioned by Awan[201], the phonetogram enables the voice researcher and clinician with "*a powerful, yet easily accessible quantitative tool through which an extensive description of vocal performance can be obtained*".

The in this manual presented step-by-step procedure of voice classification by means of F°SPL-measurement, offers the possibility:

to objectively registrate the vocal function;

to provide an useful document within the overal phoniatric examination of the larynx;

to objectively classify every human voice;

to establish vocal capacities;

to provide voice selection criteria;

to indicate the demands which can be put on a voice;

to determine the 'speaking voice area';

to determine the ‘shouting voice area’;

to test and analyze singing voice potentialities;

to diagnose voice problems;

to provide a guideline for voice education and therapy;

to objectively demonstrate the phonetographic results before and after treatment;

to assess the results of voice lessons or therapy sessions by repeated measurements;

to provide an indication of the required voice capacities for specific voice professions, including auditions and conditions of access in music conservatories;

to predict vocal hazards;

to objectively determine register transitions;

to compare the obtained data for each frequency and intensity of an individual vocal range, for each gender and age group, with one’s own personal observations and/or measurements.

to easily predict the limits of the possible capacities of an individual voice by voice education and therapy, just by attentively scrutinizing the many figures of this manual..

Hopefully, the many data and advices in this manual can be helpful for all people involved with one of the most exciting expressions of mankind: **VOICE**.

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ADDENDUM: DESCRIPTION OF SUBJECTS

1 Abnormal speaking populations

2 Active-duty U.S. Army drill sergeants

3 Actively performed professionally and spanned a large range of experience

4 Active professional solo classical singers

5 Actors

6 Adult talkers

7 Adult women without voice problems

8 Adults randomly surveyed from the National Association of Teachers of Singing membership

9 Advances sopranos

10 Advanced vocalists

11 Altos

12 Amateur choral groups

13 Amateur musical experience, singing regularly in a church choir

14 Amateur singers

15 Amateur status

16 Appropriate to their age, sex and cultural milieu

17 Artistic level singers: advanced level singers who make their living in this manner.

18 Artistic-level singers who earn their living as singers but who are not “rock” or “pop” artists

19 Artist-level professional singers

20 Artists

21 Asymptomatic singing students

22 Attained a degree of proficiency which allows them to derive the major portion

23 Average speakers

24 Baritones

25 Bass/baritones

26 Basses

27 Beginning singing students

28 Beginning vocalists

29 Belting

30 Better/bad singers

31 Broadcasting

32 Cantor Contemporary

33 Cantor Historical

34 Casual experience in singing, such as participating in church or school choirs

35 Casual singing experience

36 Cheering related dysphonic episodes

37 Cheerleaders with a history of dysphonic episodes

38 Children's voices

39 Choir lay voices

40 Choir members

41 Choir singers

42 Choral singer

43 Choral singing

44 Choral singing females

45 Chronic vocal fold lesion

46 Classical singers

47 Classical" music

48 Classically trained

49 Classically trained singers

50 Clinical populations

51 Commercial singers

52 Concert

53 Contraltos

54 Conversational speech was considered to be acceptable to the investigators

55 Could sing but had no formal vocal education or special singing experience
56 Countertenors
57 Country music
58 Country music singers
59 Country singer
60 Country-and-western singing
61 Currently suggested by professional vocal teachers
62 Denied any history of voice disorder
63 Developing voice user
64 Dilettante voices
65 Dramatic soprano
66 Dysphonic patients
67 Dysphonic patients who had no pathological changes of the vocal folds
68 Dysphonic patients who showed a laryngeal pathology
69 Dysphonic students
70 Earn their income from singing
71 Earn their living by touring as concert and opera singers
72 Earn their livelihood from singing
73 Earning more than 50% of his income from singing
74 Earning more than 50% of his income from singing country music
75 Earning their living from singing
76 Educated at a musical conservatory
77 Educated singers
78 Educated voice
79 Elderly bass-baritones
80 Elderly tenors
81 Employed primary and secondary teachers
82 Excluding any cases of voice disorders
83 Experienced female singers
84 Experimental speakers

85 Female graduate and undergraduate voice students

86 Folk singers

87 Formal training

88 Formal training and experience in vocal music

89 Formal training in music or speech

90 Four major voice categories

91 Free from known laryngeal pathologies that might interfere with their singing or speaking

92 Free of any history of laryngeal pathology

93 Frequently using their voice as a hobby

94 Good singers

95 Good voices of lower tessitura (contralto and baritone)

96 Gospel singer

97 Healthy individuals

98 Healthy larynges and normal-to-better voices

99 Healthy normal speakers

100 Healthy subjects

101 Healthy trained voices

102 Healthy untrained subjects

103 Healthy untrained voices

104 Healthy children

105 Healthy voiced singers

106 Healthy voices

107 High voice register strongly pulled down, counteracting the evolution of a mid-voice

108 Higher voice positions

109 Highly effective speakers

110 Highly skilled professional operatic singers

111 Highly skilled professional singers from the classical Western tradition

112 Highly successful jazz artist

113 Highly trained singers

114 Highly trained vocalist

115 (High school) cheerleaders

116 Hyperfunctional and hypofunctional dysphonia

117 Ill voices

118 Immature singers

119 Inartistic or bad singer

120 Incidence and nature of dysphonic episodes

121 In all cases they were or had been, performers.

122 Individuals with a more restricted range

123 Individuals with a wider range

124 Individuals with formal singing training

125 Individuals with little or no singing training

126 Individuals with no vocal training

127 Intermediate vocalists

128 International soloists

129 Inexperienced nontrained singer subjects

130 Jazz singers

131 Judged to have a “normal” voice if they had no history of vocal pathology

132 Kindergarten teachers

133 Lacking training in singing

134 Large church choir with a director who spends much time on technique

135 Lay voices

136 Laymen

137 Less developed voices

138 Less trained voices

139 Locally in night clubs and bars

140 Logopedic therapy of the speaking voice

141 Logopedic training of the speaking voice

142 Lower voice positions

143 Lyric soprano

144 Master's level singers

145 Mathematical choir

146 Members of opera companies

147 Mezzosoprano-Alto

148 Mezzosopranos

149 Middle-aged bass-baritones

150 Middle-aged tenors

151 Minimally trained singers

152 More than casual experience in singing

153 Music, but not voice, majors who had never taken private voice lessons

154 Musical and theater

155 Musical theatre

156 Negative history with respect to vocal pathology

157 Nightclub singer

158 No audible vocal abnormality

159 No formal voice training

160 No history of any training in song or speech

161 No history of vocal disorders

162 No history of vocal fold pathology

163 No history of voice disorders

164 No history of voice or hearing problems

165 No history of voice or laryngeal disorders

166 No history of voice problems

167 No more than casual singing experience

168 No more than x sessions of voice coaching or training

169 No previous training in singing

170 No private voice lessons and never majored in voice

171 No professional singing or speaking training

172 No special training in singing

173 No speech or voice training

174 Nominated for national awards for performance and recording in the industry
175 Non singing tenors
176 Non-educated voices
177 Nonprofessional Baritone
178 Nonprofessional singers
179 Nonprofessional Tenor
180 Non-singer musicians
181 Nonsingers
182 Nonsingers (non-singers)
183 Non-singers: individuals with no vocal training at all
184 Nonsinging controls
185 Nonteachers
186 Non-trained singers
187 Normal sounding voices
188 Normal speakers
189 Normal speakers who had no singing experience or training
190 Normal speaking subjects
191 Normal subjects
192 Normal talkers with no singing experience
193 Normal untrained voices
194 Normal voice status
195 Normal voices
196 Normal voices, with no history of vocal pathology
197 Not had any previous voice training
198 Not had any training in voice or singing
199 Not had any vocal music training such as in professional choirs
200 Not the heaviest category
201 Not undergone systematic voice training
202 Older bass/baritones
203 Older tenors

204 Opera

205 Opera Contemporary

206 Opera Historical

207 Opera singers

208 Oratorio

209 Participated in any kind of organized singing group, such as church choirs

210 Particular pathologies

211 Pathological subjects

212 Pathological voice conditions

213 Pathological voices

214 Patients

215 Patients suffering from hyperfunctional dysphonia

216 Patients suffering from nonorganic dysohonia

217 Patients suffering from voice disorders

218 Patients with voice problems

219 Patients with voice professions

220 Performed professionally in opera and concert

221 Performer

222 Performers

223 Persons with speech and voice professions

224 Phoniatric patients

225 Pop singers

226 Popular ballad singers

227 Preadolescents and adolescents engaged in recreational (pre)professional vocal activity

228 Presented negative histories with respect to respiratory, vocal, articulatory, auditory

229 Private voice lessons

230 Professional actors

231 Professional country singers

232 Professional musical and theater tenor-baritone singers

233 Professional musicians and a few advanced students made up this group
234 Professional performer
235 Professional singers: they derive at least 50% of their income from concert or musical
236 Professional singing teachers
237 Professional tenors who earned their living by touring as concert and opera singers
238 Professional voice users
239 Professional voices
240 Professionals were further divided into the traditional categories of soprano and alto
241 Professionally but not on a full-time basis or for a long period of time
242 Received extensive training in vocal music.
243 Receiving individual singing lessons
244 Recording artist
245 Recording contracts
246 Recreational singers
247 Recurrens paralysis
248 Reported having been diagnosed as having a history of a voice disorder or hearing loss
249 Reported no history of voice or laryngeal disorders
250 Representing a variety of voice types, according to the report of the choir director
251 Retired singers
252 Self-identified
253 Semiprofessional singer earning part of his/her yearly income from performing
254 Serious singers
255 Singers in all of the voice categories
256 Singers of all voice categories
257 Singers in each vocal category ranged from novice to professional
258 Singers performing musical theater
259 Singers with training and professional performance experience

260 Singing according to the Western operatic style

261 Singing in a choir

262 Singing laymen

263 Singing ministry

264 Singing students

265 Singing students in alto field

266 Singing students with different degree of education

267 Singing voices

268 Skilled singers

269 Soprano singer

270 Sopranos

271 Sopranos and altos

272 Speakers

273 Speech-language pathology graduate students

274 Speech therapist students, receiving voice training during a period of 2 1/2 years

275 'Spinto-tenor'

276 Sporadical classical singing training

277 Stage and concert work

278 Stage singers

279 Student singers: advanced college students majoring in vocal music.

280 Students

281 Students of singing

282 Student-singers who were majoring in vocal music with enough talent in vocal music

283 Subjects

284 Subject performer

285 Subject who has had some training in choral singing

286 Subjects with no singing experience

287 Subjects with singing experience

288 Suffering from nonorganic dysphonia

289 Superior speakers

290 Superior vocal students just about to start their professional careers as singers
291 Talkers
292 Taught singing but may have sung or still sing
293 Teachers
294 Teachers with voice disorders
295 Tenor-baritones
296 Tenors
297 Theater activity
298 Train their voice according to the common principles and practices
299 Trained children
300 Trained performer
301 Trained professional female musical theatre singers, who stated that they could sing in belt,
302 Trained singers
303 Trained singers: individuals who, actively and formally for professional reasons, study
304 Trained singing voices
305 Trained sopranos
306 Trained soprano singers
307 Trained speakers
308 Trained subjects
309 Trained tenors
310 Trained vocal groups
311 Trained vocalists
312 Trained voices
313 Trained young adults
314 Training in singing
315 Training of the singing voice
316 Unexperienced singer
317 University female voice students
318 University graduate-level voice majors

319 University students

320 Untrained children

321 Untrained individuals

322 Untrained normal voices

323 Untrained persons

324 Untrained professional singers

325 Untrained singer: one who had never received formal voice training and seldom, if ever,

326 Untrained singers

327 Untrained speakers

328 Untrained subjects

329 Untrained vocal groups

330 Untrained vocalists

331 Untrained voice users

332 Untrained voices

333 Untrained young adults

334 Vocal exercises for his singers and who is quite concerned with quality of sound.

335 Vocal fold pathology

336 Vocal music teacher

337 Vocal training

338 Vocal training

339 Vocalist

340 Vocally healthy nonsingers

341 Vocally healthy singing students

342 Vocally healthy subjects

343 Vocally healthy untrained persons

344 Vocally trained music (voice) majors who were taking private voice lessons

345 Vocally trained persons

346 Vocally untrained

347 Vocally untrained boys and girls

348 Voice disorders and diseases

349 Voice disturbed patients

350 Voice patients

351 Voice training as part of their participation in the chorale

352 Volunteer choir groups

353 Well-trained voices

354 (Western) classical voice training

355 White females

356 White female professional singers

357 Without past laryngeal pathology

358 Without vocal complaints or history of vocal pathology

359 Young female singers who were active participants in a church choir program

360 Young singers

361 Young tenors

362 Young voice users

363 Younger bass/baritones

364 Younger voice users