Inserm

French National Institute of Health and Medical Research

The voice

and its disorders in teachers

Collective expert review

Synthesis

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This document presents the review and recommendations of the expert group convened by Inserm in the context of the collective expert procedure to reply to the request of the French National Education General Mutualist Association (MGEN) relating to the voice and its disorders in teachers. The document is based on the scientific data available as at the second half of 2005. Some 570 articles constituted the document base for this expert review.

The Inserm collective expert review center ensured coordination of this collective expert review.

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Foreword

The voice is essential to the exercise of the teaching profession. The voice, which may be qualified as a 'professional instrument', is frequently put to rude use. Teachers express themselves in a noisy and frequently poorly sound-proofed environment for several hours every working day.

A voice disorder may have mental, physical, emotional and communicational repercussions and thus have an impact on professional and social life. Teachers' awareness of the importance of the voice as a tool with which to capture their listeners' attention and communicate effectively should sensitize them to the acoustic conditions of their working environment and encourage them to consult as of the initial signs of vocal fatigue.

The French National Education General Mutualist Association (MGEN) asked Inserm for a critical and synthetic analysis of all the international scientific data available on the various disorders encountered by professionals using their voices in their work, particularly teachers. In order to respond to that request, Inserm convened a pluridisciplinary group of experts in the field of ENT medicine, phoniatrics, wave and signal physics, speech therapy and spoken communication.

The group's scientific expert review addressed the following questions:

- What concepts underlie analysis of speech? How do the various methods adopted, types of measurement and progress achieved in elucidating the fundamental processes of speech evolve over time?
- What mechanisms are involved in the production of sound, voice and speech?
- What forms of disease are associated with voice disorders? What is vocal fatigue? What is a strained voice?
- What prevalence and incidence data on voice disorders in teachers in France and abroad are available? Do prevalence and incidence vary with age or gender?
- What exacerbating etiological factors are linked to the subject him/herself and which are linked to the conditions of voice use?
- How can risk populations among teachers be defined? What screening methods are available? What instruments are available to measure the quality of the voice?
- How is a vocal assessment to be conducted? What methods are implemented to diagnose voice disorders?
- What medical and surgical treatments are used for voice disorders?
- How can the voice be rehabilitated? What is the proportion of relapses after voice rehabilitation? What are the roles of occupational physicians and speech therapists in teacher information?
- What preventive programs are available? How effective are those programs?

The international bibliographic database search led to selective retrieval of over 570 articles. During eight sessions held between March 2005 and April 2006, the experts presented an analysis and synthesis of the international published work, each in his/her field of expertise. In addition to the analytical proceedings, hearings were scheduled during which presentations on the psychological management of voice disorders and on pilot studies in the field of acoustics were delivered.

Synthesis

Voice disorders are frequent in the teaching profession. A third of teachers consider that the disorders interfere with their ability to teach. A historical epistemological approach to speech and the voice was thus a natural component of the literature review.

Voice disorders are the consequences - experienced, perceptible or audible - of an anomaly or organic lesion, acquired or congenital, of the vocal cords. Deficient control of the respiration, or laryngeal articulation or a psychological difficulty may also be involved. Acquired organic lesions may reflect straining or overworking the voice. Physical, chemical and infectious agents present in the environment may play an important role in the good or bad functioning of the vocal cords.

Voice diseases are subject to medical or surgical treatment and usually necessitate discontinuation of vocal activity. Rehabilitation, an integral part of treatment, is to be adapted to the subject's personal situation and the context of the dysphonia. The preventive approach involves information, awareness promotion and training exercises. Prevention may also address the acoustic environmental conditions, particularly for teachers, and act on the environment to enhance the effectiveness of communication.

Analyses of speech and the voice have a long history

How can speaking man who has the impression of being at one with his language detach himself for its use in order to make it an instrument for knowledge or for acting on others? Did reflection precede the action or did action precede reflection? The need to answer those questions and take into account, in the present day, the simultaneous existence of original scientific analyses and know-how transmitted through preceding generations fully legitimizes this historical epistemological approach. What should the subject be?

Speech, through the material references associated with it, would appear to be an appropriate Ariadne's thread. However, a material analysis of the linguistic phenomena by appropriate methods does not dispense one from resituating speech studies in the underlying theoretical contexts. In fact, the generic term 'speech' should be better defined in order to reflect the early historical differentiation of speech and voice.

The first human graves, clothing and cave paintings reflect the emergence of symbolic thought in man and may perhaps be related, indirectly, to the existence of language. With the advent of writing, at least 25,000 years later, the first direct evidence of reflection and/or action on language emerged. That thinking became clearer, a few centuries before the Christian era, with the articulatory analyses conducted on Sanskrit by Hindu grammarians with a view to preserving their language with its sacred function (reviewed in the 4th century before the Christian era by Panini). It was also in a religious context, that of the advent of the first religion of the Book, with the Bible, as of the first verses of Genesis, that the concept of language as nomenclature emerged: the world was created by the word of God.

The Greek philosophers addressed language in depth but their curiosity was restricted to a single language. We are indebted to those Greek philosophers for the first definitions of the voice and speech. Thus, Aristotle (384-322 BC) clearly distinguished the voice produced in

the region of the trachea which is 'the sign of the passions of the spirit' (he observed that that voice was also found in other animals). In contrast, 'man is the only animal which nature has endowed with the gift of speech'. Aristotle even stated that 'speech is natural for man who is by nature a political or civil animal'. Galen, much later (130-200), as a philosopher-physician, contributed additional anatomical and physiological knowledge by associating the voice with the function of the 'vocal organs' and speech with organs such as 'the tongue […], nose, lips and teeth.'

The Greeks were not content with a partial analysis but went on to develop a veritable synthesis, a general theory of reasoning, from two major techniques, dialectics, the art of controversial discussion (of which the masters were Socrates and Plato), and, above all, rhetoric, the art of public speaking (so important in a democracy).

Objective argumentation uses logical arguments intended to win the auditors' adoption of the new proposals presented by the orator on the basis of common sense or *doxa*. The second argumentation, subjective argumentation, in addition to the choice of words and arguments, uses the tone of voice and the rate of speech but also gestures, expressions and posture. This approach combines *ethos*, the moral image that the orator projects through his discourse, and *pathos*, the passions that the orator elicits in his auditors and through which he elicits their acceptance.

Adaptation to the audience involves the judicial (at the origin of rhetoric), deliberative (on addressing citizens) and epidictic (praising or blaming) genres. The latter genre was to be allocated to literature.

In the various phases of elaboration of the discourse, *heuresis* (*inventio*) and *taxis* (*dispositio*) concern the search for and ordering of the arguments, the organization of the discourse, *lexis* (*elocutio*), the style, the rhythmic figures and also the period. The latter, a true partition updated by the intonation, presents the audience with an argument that it can follow orally from one end to the other promoting continuity of speech that is itself sustained by a sort of vocal *legato*. This fully reflects the ideal verbal fluidity that was dear to Greek orators. It led them to stigmatize, using a detailed vocabulary, all the cases of constitutional or accidental dysfluency or disfluency. Lastly, the *hypocrisis* (*actio*) refers to delivering a speech that has been prewritten and memorized before being carefully enunciated. The voice is then advantageously deployed as a component of a motor set in which expressions and gestures also play their role.

In a different social and political context, the Romans were above all to contribute an improvement in techniques aiming to optimize exploitation of the speaker's vocal and gesture potential. The *pronuntiatio* mainly concerned the voice and the *actio* the gestures. The orators were practitioners of an effective speech whose esthetic aspect was stressed: eloquence (*bene dicere*). Thus, Quintilian (30-100) in 'On the oratory institution' developed a program of teachings. Several passages of the text are devoted to working on the voice, breath, facial expressions and body gestures, without overlooking the hygiene and training of the memory (*memoria*) on which good restitution of the discourse depends.

The teaching of rhetoric was to ensure both the transmission of the knowledge acquired with respect to the function of speech and the voice (in particular the projected voice) but also the uninterrupted transfer of experience accumulated first by the masters of the declamatory art, the 'phonasques', then by educators and trainers (for both the speaking and singing voices). Thus, the experience acquired crossed the centuries and remains available to voice professionals: singers, actors, lawyers, preachers and teachers.

All the philosophical reflection of Greek and Latin antiquity, harnessed in the works on rhetoric and grammar (with their phonetic classifications), was to be resumed and developed continuously until the 18th century, and even later, but in a more critical manner.

The Christian Middle Ages attempted to reconcile the heritage of the Romans with the Christian message. The first sentence of the Gospel according to Saint John 'At the beginning was the Word and the Word was with God and the Word was God' gave rise to considerable reflection on language, first of all by the Fathers of the Church (Saint Augustine compiled a whole theory of signs), then by the theologians of the Middle Ages. In the 13th century, Saint Thomas Aquinas set up a distinction between the intellectual processes: 'the word of the heart' and 'the word which includes the image of the voice' (the word thought with syllables) differentiated from the motor processes of speech: 'the word of the voice' (the word pronounced with its syllables).

At the start of the Middle Ages, poetry also assumed functions fulfilled by the spoken voice in primarily oral cultures. The other oral form, the oratory art, was incarnated by preachers who were to obey new constraints: the preacher places his voice at the service of the word of God in order to convince his congregation (and threaten his flock when the dangers of sin are to be evoked).

The most direct access to the works of the Greek philosophers was via Arab letters. But the Arab grammarians were also to develop a study of their own language, classical Arabic, which, as was the case with Sanskrit, is a sacred language, that of the Koran. It is thus important to pronounce the language correctly and a fine analysis of the articulation sites was intended to control the pronunciation. The importance attributed to chanting the Koran led to a review of the vocal categories, some of which were considered incompatible with chanting the sacred Text. In particular, it was important to be attentive not to lose the melodic line when the sound was softened.

In the Renaissance, the printed word was rapidly to assume dominance but reading out loud and the art of correctly pronouncing continued to be valued in cultural practices in which orality was necessary: oration, poetry, theater. A degree of suspicion emerged: while a well delivered text affected the audience, the vocal effects were not to supersede the content.

Increasing attention was paid to the 'vulgar languages' even though Latin remained the model for grammatical description. The first phonetician grammarians were stimulated by the projected reform of spelling. In addition, curiosity with respect to the anatomy of the human body developed: Leonardo da Vinci drew a series of diagrams of the larynx. During the Renaissance, research on language tended to distance itself from the speculations of the preceding centuries and increasing importance was attributed to the analysis of hard facts.

In the 17th century, while eloquence continued to be displayed in church and at the theater, the first salons, in which speech was exchanged in the intimate context of a relationship involving a small number of selected people, opened their doors. The art of conversation thus developed in a social environment that was privileged in terms of birth or wealth. It was appropriate to respect the proprieties. The correct use of language was regulated: eloquence was an art. Pronunciation of the language continued to be a subject of the grammars (although one of the most prestigious, that of Port Royal, innovated little in that field). Phonetic analyses 'for themselves' and classifications of both vowels and consonants were modified and refined. Thus, in 1694, Dangeau published a classification of the consonants which was a precursor of French phonology. Even more so, the 17th century was that of the scientific study of the voice which Marin Mersenne suggested calling 'phoniscopy'.

As Patrick Dandrey stressed, 'the analysis of the voice in the 17th century was entrusted to the natural philosopher and physician, on the one hand, and to the grammarian and priest, on the other, to the specialist in the human body and to the specialist in the spirit or soul, combining their complementary qualities in the person of the orator who cultivated his voice in order to place it in the service of God or the world.'

The 18th century was marked by a great curiosity with respect to language and, in particular, the origin of language. Philosophical reflection was of primary importance and the most essential works on 'the origin of understanding' were those of Locke, Hobbes, Hume, Leibniz and, in France, Condillac, who, in 1746, clearly formulated the theory of the arbitrary nature of the linguistic sign. The clear distinction between the speaking and singing voices, although supported by strong arguments, was called into question by Jean-Jacques Rousseau, author of a veritable anthropological concept of the voice: music and, more accurately, singing were considered to be the origin of the spoken language.

Salons continued to play the role of 'resonance chambers' for artists and the learned but the latter could also meet in the Academies, which had almost all been created (the last, the Academy of Medicine, was created at the start of the following century).

Linguistic research progressed with the publication of grammars for an increasing number of languages. The latter development also resulted in the first major attempts to relate languages (Gyarmathi was the first to call attention to the close relationship between Hungarian and Finnish). Persistent discussions on reforming spelling continued to stimulate phonetic analyses which became increasingly independent of the grammars.

The anatomical and, above all, physiological studies of the larynx advanced. The production of the human voice was described by analogy with musical instruments by Dodart, in 1700, and Ferrein (to whom we owe the terms 'vocal cords') in 1741.

The first experimental phonetic studies were launched and Abbe Mical and Von Kempelen built the first 'speaking machines', the first great mechanical simulations of the phenomena of the production of human speech combining the vocal source and supraglottic resonance chambers.

Speech and the voice subject to specialization

In the 19th century, speech and the voice became the subjects of specific scientific studies. Two main analytical models interacted at first, then opposed one another. The first, the historical model, ensured the independence of linguistics as a historical science. The second, the physiological model, initially used by numerous different disciplines, including comparative grammar, gave rise to the major medical specialities which were to take charge of the hygiene and then pathology of disorders of the speech and voice (without overlooking language disorders).

The 19th century was the century of in-depth reflection on history conducted in the context of German philosophy (Hegel and the different interpretations of his theses). Again in Germany, two major research currents derived from the 'discovery' of Sanskrit succeeded each other. Comparative grammar resulted in a number of languages being grouped in the Indo-European family. Subsequently, the neo-grammarians identified, in that evolution, the 'phonetic laws without exception'. Profoundly influenced by Charles Darwin's theory of evolution ('The origin of species' was published in 1859), a comparative grammar specialist, August Schleicher, came to consider all languages as organisms and linguistics as a natural science. However, opposition to that point of view mounted increasingly throughout the

century, culminating in the idea that 'the only method for scientific study of language is the historical method' (the peremptory affirmation of Herman Paul).

The 19th century was also a century of physiology. In the fields of speech and the voice, a new term, phonation, with physiological orientation, led to reappraisal of the voice as the first indispensable stage in the production of speech. Speech was no longer reduced to articulation but put into relation with thought and, thus, with the function of the brain. Broca defined the major brain centers for language (in 1861) and Wernicke defined the centers for oral and written language understanding (in 1874) in relation with various types of aphasia. Thus, a new research avenue came into being, that of neurolinguistics. The research investigated the relationship with the clinical characteristics of acquired speech and language disorders and their repercussions at linguistic level on the basis of an increasing number of cases. In a complementary perspective, the study of hysteria led the neurologist, Sigmund Freud, pursuant to cooperation with Doctor Breuer, to develop the 'cure by speech'. Taking into account Freud's complementary thinking on the role played by sexuality and the importance of transfer in treatment, that period (the last years of the century) may be considered those of the birth of psychoanalysis.

In France, the grammarians remained much attached to the 'general grammar' (on the Port-Royal model) and were influenced by the ideologists' school, which remained very potent at the start of the century. This delayed the commitment of French grammarians to comparative research (particularly as conducted in Germany). French grammarians preferred more practical tasks such as the compilation of school grammars. Comparable concerns led to the pursuit of research with a view to developing phonetic transcription. At first, this was the work of the 'phonographs of vocabulary', dictionary writers who wished to indicate how words whose spelling was likely to induce incorrect pronunciation should be pronounced. But the research also moved further into other fields: the teaching of living languages (beginning with English) with Paul Passy, then Daniel Jones, and dialectology. Dialectology consisted in collecting the spoken forms of the regional languages of France, which were threatened with extinction, particularly with the acceleration of the political centralization movement following the French Revolution in 1789. Two phonetic transcription alphabets were created with two different points of view. That of the International Phonetic Association (created in 1886) was pedagogic in aim and used a limited number of characters. It was more oriented towards the characterization of invariant units. The other alphabet, that of the 'Romanists' was intended to reflect the variability of the oral forms of 'patois'. The new 'instrument' was to renew the attention paid to 'aural phonetics'. In a manner complementary to historical linguistic research, 'aural phonetics' addressed the phonetic description of the languages then spoken in Europe but with an orientation that remained orthoepic in that it was designed to promote a standard. Phonetic transcription was then endowed with a role (which had long been, in part, that of orthographic writing) of conserving the data on spoken languages. Edison's invention of the phonograph in 1878 called into question transcription. Dialectology, by collecting speech on the very sites of its pronunciation (the French countryside), appeared to be a linguistic 'field' study based on observations of subjects speaking and was thus differentiated from speculative linguistics which frequently had an ideological cast. The question as to whether an accumulation of facts can replace a theory remained, however.

Throughout the century, technical innovations enabled enhanced physical and physiological analysis of the phenomena of speech and voice. This was the case, for instance, with the laryngoscope, a mirror enabling *in vivo* examination of the vocal cords. The instrument , used in 1854 by Manuel Garcia, was mainly promoted by Johan Nepomak Czermak, thanks to the complementary contribution of artificial light. In the field of speech production, the

kymograph, invented by Karl Ludwig in 1847, strengthened the development of the graphic method in France under the impetus of Jules Étienne Marey.

Elsewhere, acoustic analysis moved further in two directions which continuously competed with each other. One direction, more mathematical, was derived from the work of Joseph Fourier on the analytical theory of heat (1822) while the other, more physical, was derived from Von Helmholtz studies on the timbre of musical sounds, then speech, using resonators.

The scientific and technical progress was conducive to the creation of experimental phonetic laboratories, one of the first of which was that of Abbé Rousselot. The laboratory was first housed at the Catholic Institute in Paris, then at the College of France in 1897. The laboratory rapidly became a meeting place for phoneticians, teachers, physicians and rehabilitators. Suzanne Borel-Maisonny, a student of Abbé Rousselot, specialized in rehabilitation with respect to disorders of language, speech and voice. Although the term 'orthophony' was created in 1828, it was not until the 20th century that 'orthophonic rehabilitation' (speech therapy) in an office under medical control was officially recognized. The term phoniatricians appeared in Germany in the context of experimental phonetic research directed by H. Gutzman. The latter was named professor of phoniatrics in Berlin in 1905.

Abbé Rousselot, who had defended a thesis on dialectology and who had a solid training in historical linguistics, consistently presented experimental phonetics as a means of acquiring more refined knowledge of the processes of phonetic evolution in languages even though linguistics were becoming independent as a historical science. Rousselot succeeded in convincing the dialectologists of the value of experimental analyses of their speech but other linguists and even some 'oral' phoneticians such as Paul Passy were very reticent and even critical of the use of instrumentation that was considered superfluous (for them, the ear remained the best instrument for analyzing speech and the voice). Even though Abbé Rousselot continued to plead in favor of linguistic phonetics, the various phonetic practices appeared too different to be wholly incorporated in linguistics (particularly as the latter was then conceived).

The first schism was the work of the two most prestigious representatives of the 'Kazan school' (Poland), Baudouin de Courtenay and Kruzewski. They proposed splitting phonetics into two independent parts: one, 'anthropophonic', considering sounds from the objective viewpoints of physics and physiology, and the other, phonetics in the strict sense of the word or in a 'morphologico-etymological' sense, addressing sounds in relationship with the meaning of words. In the latter case, the term sound was rejected and Kruzewski proposed replacing it with the term phoneme (borrowed from Ferdinand de Saussure, who had in turn borrowed it from Dufriche-Desgenette, 1873).

In France, with a different perspective, Michel Bréal (with Baudry) was at the origin of the term phonetics, 'science of the sounds of language', created in 1897, with an eye to the term semantics, 'science of meanings'. As G. Bergougnioux was to remark in his work entitled '*Aux origines de la linguistique française*' (1994): 'language has a dual status - material by its sound component […] and mental by its meaning – […]. Linguistics has some difficulty assuming the heterogeneity.'

Whatever the case may be, the experimental phonetics laboratories that developed in France and worldwide over the next century pursued the example of their illustrious forerunner and continued to bring together the various specialists in the analyses of speech and particularly the voice: phoneticians, dialectologists, teachers, physicians, therapists and engineers. All came together with a shared commitment to interdisciplinary research that was all the more laudable in that it would be difficult to maintain over the following century with the increasing independence of the disciplines, their increasing specialization and the institutional consequences of those trends.

New 'instruments of reflection' and accelerated technological developments contribute to deepening and broadening the understanding of speech and the voice

Linguistics became increasingly independent with the decisive contribution of Ferdinand de Saussure whose 'Course' was published in 1915. Linguistics, for which de Saussure clearly distinguished two approaches, one historical, diachronic, and the other current, synchronic, addressed 'language', a social phenomenon defined as a code. 'Speech', a set of phenomena rather related to more individual use of language (in that sense, 'speech' includes a large proportion of vocal phenomena) moved into the background. The insistence on the formal nature of the linguistic object was taken up by Noam Chomsky with 'generative grammar' privileging 'skill', an indispensable prerequisite in order to account for 'performance', i.e. that which is directly observable in the acts of speech. Many of the phonologists who came afterwards, from structural phonology to the theory of optimality, considered the separation between phonetics, a (natural) science of the substance, and phonology, a science of the form, to have been established. Nicolas Troubetzkoy, to whom we owe that fracture (1939), had set up a research area, phonostylistics (developed later and mainly by Yvan Fonagy), to take account of the expressive and appellative functions of language and no longer only the representative function. Ferdinand de Saussure, whose theses have recently been reevaluated (in particular the dichotomy between language and speech, pursuant to the discovery of new manuscripts), had left a possible opening by making linguistics a field of semiology, a 'science of signs at the heart of social life'. The research related to the sciences of culture (Rastier) was to be oriented in that more symbolic direction.

Attempts to develop a typology of voices (speaking and singing voices) via ethnolinguistics and ethnomusicology expanded our understanding of the fundamental mechanisms of the voice and moved study beyond the narrow framework of the cultural restraints of Western civilizations only.

The 20th century and start of the 21st century gave rise to unprecedented expansion of research into language, the various languages spoken worldwide and speech and the voice replaced in a more general context of spoken communication. All the studies are characterized by their increasing profoundness thanks to the use of technological resources that progressed throughout the last century and in the beginning of this one: mechanical analyses were transformed by the development of electronics, itself superseded by information technology. Computer workstations equipped with software that is continuously updated to more or less successfully adapt to researchers' and practitioners' ceaselessly changing requirements have profoundly modified the context of scientific studies of speech and the voice and circulation of the results with respect to both basic research and applications. It would be tedious to list all the technical resources for acoustic and physiological analyses that have succeeded each other. It should be stressed, however, that we owe to those resources a refined understanding of the processes of speech and the voice. Computers enable a single real-time representation of synchronous analyses from different sources. This has culminated in multimedia through which gestures, expressions and exchanges of looks can be related to acoustic analysis of the signals of speech together with perception (giving rise to fine phonetic transcriptions). The analyses are supported by rigorous designs in order to control the extreme variability of linguistic phenomena. However, they may be criticized in that they address a 'laboratory speech (and voice)' whose artificial character has frequently been criticized. However, although the value conferred on certain phonetic parameters is debatable, it is possible to simulate speech and the voice

through analog synthesis of the vocal tract by a source that is itself simulated. In addition, analytical recognition of speech has been a remarkable tool for elucidation of the crucial processes in acoustic and phonetic decoding (from the acoustic signal to the meaning). Research is continuing on a more mathematical basis currently, in order to ensure reliability, with regard to the various applications of speech recognition.

European 'continental' philosophy remains greatly influenced by phenomenology and has addressed intentionality, a concept frequently applied to language conducts. A broadening of the scope of the study of language activity occurred pursuant to the philosophical reflection on 'ordinary language' initiated by Wittgenstein and pursued by several representatives of analytical philosophy, particularly in the English-speaking world (with Austin for the pragmatic approach). Conversational analyses focus on everyday language and study, for example, the succession of speakers in usual communication settings. The analyses also address the relative share of individual skills and the social context in the organization of language exchanges. The subject of conversation analysis is then the discourse in the interaction with its system of turns of speaking (the listener is more than a simple foil in the active communication). Thus, a fine description of the organizational forms specific to conversations based on detailed analyses of authentic interactions leads to a search (which may often appear mythical) for a 'spontaneous' speech whose vocal components, the prosodic and, above all, melodic and rhythmic phenomena, but also the gestures, play a major role in the meaning of the statements. The studies have shown the disfluency which can characterize conversational speech with its pauses, hesitations and false starts, etc., which it would be good to distinguish (but is that always possible?) from the dysfluency that is more related to language disease.

The separation between speech and voice as two very distinct stages in the production of the phonic units of language is no longer so assured. This is, moreover, the conclusion reached by speech therapists when they target the placement of the voice which is largely affected by supraglottic phenomena. In the same perspective, a complement to the International Phonetic Alphabet was compiled in 1994 to transcribe pathological language. Not only speech is concerned by the extension (extIPA) but also vocal quality thanks to the use of specific characters. A system of labeled markers enable isolation, in the phonetic transcription, of the particular vocal sequences of the enunciation.

A new stage was reached, particularly in the last third of the 20th century, with the development of cognitive sciences which analyze the function of the brain in the production of speech using brain imaging (generally speaking, this is a new stage in the *in vivo* use of medical imaging that has ceaselessly developed over the century). Prior neurolinguistic research had already shown the fascinating complexity of brain function in the pathological changes in language characterizing the various types of aphasia.

Integrating the data derived from cumulative experience (frequently of a holistic nature) over more than 2000 years, from the Greek 'phonasques' to the speech therapists, logopedists and phoniatricians, and scientific laboratory analyses, also fragmentary, remains a complex undertaking. The increasing profoundness and widening scope of the analyses of speech and the voice are not devoid of new epistemological questions: How can the complexity be managed? By using an interdisciplinary approach? Experimental design enables control of the variability of linguistic phenomena but is necessarily frequently accompanied by a simulation or more generally a modeling that is more synthetic (hence the crucial role played by formalization).

And what about speech and the voice in the classroom? The teacher's position with respect to the students has profoundly changed, as can be readily observed today, at the beginning of the 21st century. It would appear increasingly difficult in teaching, at all levels, to deliver

lecture-like courses. The need to introduce a significant amount of interaction in the spoken communication in class is now widely admitted. The need necessitates regulation of speakers' turns and organization of discussions that must itself be judiciously regulated. The heterogeneity of the student groups may give rise, for an increasing number of students, to a feeling of linguistic insecurity and a malaise in teachers who are frequently situate their 'public'. In consequence, not only must sociolinguistic factors, which are frequently stressed, be taken into account, but also, and above all, the sociocultural factors in the new relationships between students and teachers.

The sketch of the historical epistemology of speech and the voice has frequently disclosed a strong ideological investment: what is in question is what is specific to man with, in the background, the opposition between nature and culture. Another major separation reinforces the first dichotomy: the speech of reason responds to the voice of passion. But has man always mastered his speech and, to an even greater extent, his voice? Pathological psychology research results, particularly those of the 'master of suspicion', Sigmund Freud, provide grounds for doubt. Moreover, the voice characterizes, in itself, human experience. Have we not then overestimated the meaning of speech to the detriment of that which, drawing on the philosophers of the Middle Ages, we might call the significance? All meaning transits through a particular speaker whose voice takes on the personal resonances of his experience.

From glottal sound to speech

The vocal fold or *plica vocalis* is a composite fleshy fold. Two vocal folds are positioned inside the larynx, at the juncture between the trachea and the pharynx. They are oriented in an anterior-posterior direction. Toward the front, they rest on the thyroid cartilage (Adam's apple) and toward the back on two small cartilages known as the arytenoid cartilages. The speaker controls the inter-fold gap, as well as lengths, shapes and tensions of the vocal folds by contracting them and changing the relative positions of the laryngeal cartilages. The 3-dimensional space between the vocal folds is known as the glottis.

The sound produced by the pulsed airflow through the oscillating glottis is called voice. The voice is produced via the transformation of aerodynamic into acoustic energy. This transformation depends on several aerodynamic and biomechanical factors (subglottic pressure, mass, stiffness and viscosity of the vibrator, tension and contraction of the intrinsic and extrinsic laryngeal muscles). The laryngeal sound propagates through the resonating supraglottic cavities of the vocal tract, whose morphological and parietal characteristics (energy losses, resonances) determine speech timbre and contribute to voice quality.

Each vocal fold consists of a mucous membrane, ligament and vocal muscle. The mucous membrane is separated from the vocal ligament by a slippage space known as Reinke's space. The mucosal wave is caused by the subglottal air during expiration, separating the closed vocal folds. The undulation occurs along three axes: from bottom to top, anteroposterior and lateral. The chemical constitution of Reinke's space, in particular the presence of hyaluronic acid, plays an important role in favoring the flexibility and slippage of the mucosal membrane over the vocal ligament and contributes to the efficacy of the laryngeal vibrator.

Vocal fold vibrations are self-sustained. They result from a circular chain of causality, which relates elastic and viscous forces generated by the movement of the vocal folds to the aerodynamic forces in the glottis. The latter derive from the flow of air from the lungs. By regulating the manner in which the vocal cords vibrate, the speaker determines the timbre,

pitch and loudness of his vocal emission, controls sentence intonation, accentuates syllables and switches between voicing and non-voicing of the speech sounds.

Voice disorders are the felt, perceived or audible consequences of an anomaly or acquired or congenital organic lesion of the vocal folds. Disorders may also be due to defective control of the respiration or the laryngeal articulation or a psychological problem. Acquired organic lesions may reflect vocal abuse or overuse.

Several physiological and environmental factors may contribute to impairing the vibrator. A subglottal pressure that is too strong, in the low register, at high intensity, will increase the amplitude of the mucosal wave, which may become excessive and give rise to microtraumata that cause tissue changes and the appearance of nodules. Aging affects individuals unequally and may have an effect on the flexibility of the vocal folds. Voice training appears to slow the aging of the voice. Dry air is reported to increase the viscosity and rigidity of the mucous membrane with, as a consequence, changes of the voice acoustic and efficacy (more effort is required for the same result). Adequate fluids intake contributes to correct laryngeal function. Finally, the environment has an influence on the function of the vocal folds: physical factors (inhaled substances), biological agents (viruses, bacteria), irritant chemicals, and pharmaceuticals (hormones, drugs) may all play a role.

Acoustic analysis of the voice contributes to the vocal assessment

The physical etiologies of voice disorders are various: abnormal vibratory modes of the vocal folds, excessive turbulence of the air, amplification of vocal tremor or 'jitter', parasitic vibrations of laryngeal structures that normally do not vibrate, uncontrolled transients between different vibratory modes. Irrespective of the exact etiology, rapid disturbances in the durations and amplitudes of the speech cycles are frequently referred to as vocal jitter and shimmer (or shimmy). Other vocal symptoms include dysprosody and deficient coordination of articulation and voicing.

Frequently, the effects of voice disorders on speech are described using acoustic, mechanical or aerodynamic cues, which are quantitative data obtained from the speech signal or other signals (e.g. electrolaryngography, contact microphone or measurement of the air flow rate) that are recorded in a non-invasive manner. These cues summarize properties of the speech signal that are clinically relevant. They are selected on the base of the laryngeal disorders that are investigated, the vocal symptoms described, the searched-for correlations with other levels of description, the tasks requested from the patients, the linguistic performances involved as well as the instrumentation and type of the recorded signals.

Voice assessment includes an acoustic analysis and perceptual evaluation of a patient's vocal emission. Often, acoustic indices are obtained using dedicated software. Software that is available in clinical practice is based on research that has been performed 10 or 20 years ago, and which does not include recent analytical methods meeting clinicians' current requirements.

Expert assessment concerns the evaluation of vocal handicaps that are considered to be the consequence of a voice disorder related to the practice of a profession or exposure to a vocal risk. The assessment of the handicap of a professional speaker may be problematic because intensive and prolonged professional use of the voice is difficult to simulate under clinical or laboratory conditions.

Currently, few analysis systems are available that are suitable for use in the field. Those that are have been purpose-built. As a consequence, little experience has been accumulated and use is not widespread. There is no consensus on the cues that must be recorded.

Few studies are available on the use of acoustic cues of voice quality during vocal rehabilitation. Such an application of acoustic cues would consist in informing the patient on his voice and the time course of its quality. Use in rehabilitation is legitimated by the observation that only acoustic cues carry relevant information on the patient's voice, which is the same for the caregiver and the patient (biofeedback). The speech signal propagating in the air is the only signal that is shared by listener and speaker, who does indeed not perceive his voice in the same way as the listener. Moreover, the speaker, obviously, cannot directly observe his/her glottal articulation or vocal folds.

Perceptual evaluation and acoustic analysis of voice disorders are components of voice assessment. In practice, clinicians expect a feeble or moderate correlation between perceptual evaluation, acoustic cues and patient self-assessment. In general, clinicians are resigned to observing that voice assessment requires a multilevel representation of the voice with a moderate correlation between the perceptual features, acoustic cues and subjective indices.

This is the situation that currently prevails in clinical practice. However, it is not easy to determine to what extent it reflects listener cognition or lack of understanding of the perceptually relevant acoustic cues. Perceptual and acoustic voice analysis combined with acoustic voice synthesis might contribute to a systematic investigation of the acoustic disturbances and clinically relevant percepts.

Perceptual evaluation by the caregiver and self-assessment by the patient also contribute to the vocal assessment

The voice is multidimensional. Multi-parametric analysis is therefore required for diagnosis and in order to orient disorder management. Among the various determinations available, perceptual evaluation plays a special role. Perceptual evaluation consists in determining, on the one hand, the timbre of the voice and its esthetic qualities, while, on the other hand, determining the articulatory and prosodic behavior, and the intelligibility of the speech. Numerous perceptual scales are available and vary as a function of the evaluation criteria targeted (timbre, intelligibility, linguistic criteria). The GRBAS scale consists of 5 components (grade, roughness, breathiness, asthenia, strain) and 4 severity grades for each component (0, 1, 2, 3). For instance, a very dysphonic, moderately rough, slightly breathy and somewhat strained voice would be scored: $G_3R_2B_1A_0S_2$. It mainly evaluates timbre and phonatory behavior. It is the most widely used scale and does not depend on the user's language or professional skill. In addition to perceptual evaluation, the subject's own experience of his/her voice disorder, and its repercussions and consequences on the subject's everyday life is to be incorporated in the assessment of voice disorders. Several instruments measuring quality of life are available. The most widely used scale is the 'Voice Handicap Index' (VHI) which comprises 30 items divided into 3 subscales: physical, emotional and functional. An abridged version consisting of 10 items is used in the United States.

A voice disorder may have a markedly greater impact than its solely acoustic expression because of its repercussions on the subject's professional and social life. It can as well have consequences on the mental, physical, emotional and communicational life.

The medical criteria used to evaluate a voice disorder do not reflect the degree of communicational handicap. It is therefore important to allow the patient to evaluate that

handicap, particularly since the assessment may not always be correlated with the objective reality of the dysphonia.

The WHO international classification of handicap considers handicap to be the consequence of a disorder that limits an individual's activities both through the objective disorder and through the personal and environmental factors that may modify the patient's perception of his disorder. The definition is thus multidimensional and admits that two people with similar disorders may experience different limitations of their activities due to personal and environmental differences. "The classification takes into account the social aspects of handicap and proposes a mechanism for determining the impact of the social and physical environment on an individual's function. The environment is to be adapted to the person, not the person to the environment."

The US FDA has estimated that voice disorders cost between USD 30 to 150 billion per year in terms of losses of productivity, treatment and education. In France, no public health study has yet evaluated the financial cost of voice disorders for voice professionals.

Different forms of the disease are associated with the professional use of the voice, particularly for teachers

A number of laryngeal lesions, particularly of the vocal cords, are related to tissue reaction to biomechanical overload (supraphysiological phonatory conditions, phonotrauma). The lesions consist in erythema and edema of the vocal cords (concept: 'laryngitis'), vocal polyp or polypoid forms (acute phonotrauma), vocal cord nodules and, to a degree, contact ulceration and dorsal granuloma on the vocal cords (chronic phonotrauma). However, some of those manifestations are not specific in the sense that phonotrauma is not necessarily the only etiologic agent. For example, laryngeal erythema may in part derive from environmental factors (dust, dry air, etc.). Vocal cord polyp (in particular the angiectatic form) preferentially occurs on a mucosa that is already congested (for example, due to cigarette smoke). Contact ulceration and dorsal granuloma may in part result from gastroesophageal reflux. Vocal cord nodules may be considered the most specific lesion of chronic phonotrauma at an early stage when the symptoms are still mild. Nodules are identified at a significantly higher frequency in female primary school teachers than in a paired homogeneous group (nurses). For some other laryngeal diseases, intensive use of the voice (which may be accompanied by straining) is considered a possible etiologic cofactor: this is the case for Reinke's edema (polypoid corditis) and hyperplastic chronic laryngitis in which smoking and alcohol are the main etiologic agents. Minor congenital anomalies (sulcus, mucosal web in the anterior commissura) may play a promoting role as may diathetic factors (allergy of the upper airways and treatment by inhaled steroids) or chronic diseases such as gastroesophageal and gastropharyngeal reflux.

The etiology of vocal cord nodules appears to be associated with a particular vibratory mode of the vocal cords which limits the contact (collision, then detachment) between the free margins of the vocal cords at a particular site: the union of the anterior third and posterior two thirds. The vibratory mode requires three biomechanical conditions: incomplete dorsal adduction, a curved resting position (rather than rectilinear) around which an oscillatory movement occurs, and a sufficient oscillatory amplitude (without which contact does not take place).

Voice disorders in general and vocal cord nodules in particular are very largely preponderant in women. The main factor is the mean vibration frequency of the speaking voice and hence the frequency of potential microtrauma (115 Hz in men and 210 Hz in

women). In addition, incomplete dorsal glottal closure is almost to be considered physiological in women (2/3 of normal subjects). The slight curving of the free margin develops with vocal fatigue and the sufficient oscillatory amplitude required to induce microtrauma naturally accompanies voice projection and the need to raise one's voice. The tissue reactions are initially reversible but subsequently become definitive.

Environmental factors are also important: the acoustics of the classroom, outside background noise, the noise of the class, excessively dry air, etc., together with the stress that accompanies speaking. Stress exerts various physiological effects, generally negative, but with a few exceptions. Those effects include dryness of the mucosa, postural rigidity, undifferentiated increase in the tone of the laryngeal intrinsic muscles, changes in respiration, etc.

Screening methods and aptitude tests remain little developed. A few attempts have been made based on case history-taking and perceptual evaluation of voice quality, laryngoscopic clinical examination or certain physical voice tests such as maximum phonation time (MPT) determination or study of the dynamics of the fundamental frequency of speech as a function of imposed sound intensity levels. At present, the sensitivity and specificity of those tests are not sufficient for their widespread use to be advised.

Voice disorders occur more frequently in female teachers

Most of the studies that should enable estimation of the prevalence and incidence have exploitation and interpretation limitations, in particular due to the absence of a consensus definition of the functional disorder. There is no clear medical nosologic classification. In the International Classification of Diseases (ICD), voice disorders are listed under several headings (ENT, neurology, psychiatry).

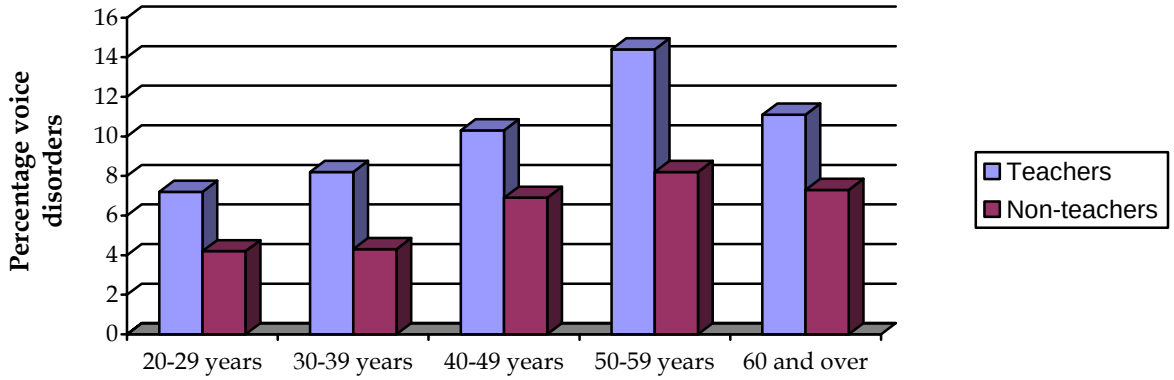
From a methodological point of view, most of the studies of voice disorders are based on:

- self-assessment questionnaires (frequently differing between studies) but which enable statistically adequate recruitment;
- specialized investigations (video laryngoscopy, recorded-voice evaluation software) limiting the size of the samples and for which result interpretation depends on the operators. These difficulties explain the great diversity of the published figures.

In the overall population of the United States, the prevalence of voice disorders was estimated to be between 3 and 9% in the most recent studies.

With regard to teachers, epidemiological studies of voice disorders have been conducted in European countries (Finland, United Kingdom), the United States and Australia. Several studies show that voice problems occur more frequently in teachers than in the overall population and that the difference is significant. Thus, in the United States, the prevalence is about 12% in teachers and 6% in non-teachers. A recent Finnish study showed that the prevalence of vocal symptoms in teachers had significantly increased over 12 years (1988-2000).

Studies have also shown that in teachers who remain in the profession, the prevalence of voice problems increases with age, peaking in the age group, 50-59 years. The prevalence is very markedly higher for women.



Voice disorders as a function of age (after Roy et al., 2004)

In France, voice disorders are not clearly identified as an occupational disease despite the large number of teachers who account for 2.7% of the country's working population. Very few studies have been conducted in that occupational sector. However, voice disorders are beginning to be taken into account in the teacher-training establishments (IUFM), which are attempting to set up awareness promotion and prevention programs.

In a study of the French National Education General Mutualist Association (MGEN) conducted in 2005, (10,288 survey respondents of which 3,904 working teachers), among the teachers, 26% of the men and 50% of the women reported always or frequently having voice disorders. The trends observed show that the prevalences of voice disorders are markedly higher in female nursery-school teachers.

In the teaching profession, an increase in voice-related complaints has certainly occurred over a few decades. The increase is probably related to the greater number of women working in educational professions, particularly in nursery and primary schools. Female gender is a risk factor for teachers. Certain types of teaching are associated with a higher risk (music, nursery school, primary school, sport). The studies to date have not evidenced a higher risk in language teachers.

In the United States, voice disorders give rise to 2 days of sick leave per year and per teacher for an estimated total annual cost of USD 638 million and a substitute teacher cost of USD 220 per day. In Finland, 5% of teachers have their professional capability called into question due to voice disorders.

Environmental conditions are risk factors to be taken into account

Ergonomic factors are to be taken into account among the risk factors for voice disorders. In the first place comes acoustic pollution of classrooms, amphitheaters and gymnasiums which constitutes a major factor for straining the voice. Recommendations exist in France but only cover new buildings and they are perhaps inadequate compared to the WHO recommendations. Based on the acoustic recommendations, the French recommendations do not sufficiently take into account the sensory difficulties in auditory perception that are frequent in children and the need for additional acoustic power from the speaker. This may be necessary with children whose mother language is different from the language used for teaching (signal/noise ratio of about 15 dB). External acoustic pollution (urban environment, airport, etc.) is a recognized factor with regard to learning difficulties in younger children.

Acoustic standards in classrooms

Standards or recommendations	Maximum ambient noise (dB(A))	Reverberation time (seconds)
United States *American Speech Language Hearing Association* (2005) ANSI S12-60 2002	30 dB: empty room 35 dB: ≤ 566 m^3 40 dB: > 566 m^3 Leq dB(A) over the noisiest continuous 1 hour	< 0.4 over 500-2 kHz bands 0.4 < RT60 ≤ 0.6
Great Britain *Building Bulletin* 93	35 dB: classrooms and lecture rooms < 50 people 30 dB: lecture rooms >50 people Leq dB(A) over 30 minutes	< 0.6 elementary school < 0.8 secondary school < 1 lecture room >50 people
WHO WHO Recommendations	35 dB Leq dB(A) over the class	< 1 s < 0.6 or less for the hard of hearing
France Decree dated April 25, 2003	Continuous noise : 33 dB: library, music room, rest room, infirmary 38 dB: teaching facilities Intermittent noise: 38 dB: library, music room, rest room, infirmary 43 dB: teaching facilities Noise due to the building's technical equipment	0.4 < RT60 ≤ 0.8 room ≤ 250 m^3 0.6 < RT60 ≤ 1.2 room > 250 m^3

RT60: time taken for the sound pressure to decay by 60 dB after the source has stopped emitting; Leq: level equivalent

Other factors are to be taken into account:

- the duration of the teacher's phonation; complaints are more frequent in the afternoon;
- the relative humidity of the facility air, a factor frequently mentioned in studies and correlated with good hydration in order to ensure good quality mucus which is necessary for the correct vibration of the vocal cords;
- the quality of the air in order to ensure, in occupational facilities with non-specific pollution, the required number of air changes, taking into account the number of students in the class;
- air pollutants. Dysphonia due to chemical pollutants (ammonia, welding fumes, solvents, diesel fumes, mold, ozone, formaldehyde) has been identified in a few studies conducted in occupational environments. In a single recent study, physics and chemistry teachers were shown to be at vocal risk. Teachers in vocational high schools are also possibly at risk, particularly when facility ventilation is inadequate.

Some teachers do not complain of voice disorders. This raises the question of between-individual differences in the emergence of disorders. The variability may be due to constitutional factors but also perhaps to the development of more pertinent vocal adaptation strategies whose recognition and implementation would be a simple means of prevention. The need to adapt to different categories of students and to different facilities is a requirement of the teaching profession and may explain the occurrence of voice disorders in subjects without vocal disorder history, sometimes at the start of the career, or even sporadically throughout the career. European directive 89/391/EEC dated June 12, 1989, is a framework directive that defines the fundamental principles for the protection of workers and provides a template for priority implementation of collective solutions: necessary

information for teachers on the vocal risk (giving appropriate instructions), a priori assessment of risk factors (acoustic risk, chemical risk), combating risks at the source by ensuring the absence of degradation, the improvement of the acoustic characteristics of classes by judicious location of establishments (external acoustic pollution), improving ventilation, replacing hazardous products (felt-tip pens containing solvents, dry effacement of boards). Individual preventive measures may be adopted by teachers suffering from voice disorders by adaptation of the work to the subject taking into account technical progress (use of amplification systems, creation of a vocal rest room for dysphonic teachers). With regard to reducing noise levels in classrooms, it is possible to attenuate intrusive noise by enhancing sound proofing and to limit the relative disturbance induced by technical equipment by modifying its installation. With regard to reverberation control, it is possible to position semi-absorbent acoustic panels, taking care not to excessively decrease the reverberation time. That type of arrangement also enables absorption of the noise generated by the students. A last type of treatment, which is very important, consists in strengthening the initial reflections (those which take less than 50 ms to reach the ears) whose role is to naturally strengthen the voice and the intelligibility of the message and thus decrease the teacher's vocal effort.

It should be noted that in other occupational settings different from teaching a vocal risk is also present. In modern societies, for one third of the workers, the voice is the leading tool. This applies to call-center operators, reception personnel and workers who communicate in noise-polluted settings.

The diagnosis of speaking voice impairment requires functional and etiological assessment

The diagnosis of a speaking voice impairment or dysphonia is conducted in the course of a phonation assessment. The assessment includes a functional assessment and an etiological assessment.

The functional assessment is clinical and instrumental. The interview is undoubtedly the longest part since it is important to elucidate the complaints (vocal fatigue, straining, respiratory difficulties), the results of vocal straining or overwork, professional constraints and working conditions, and identify the associated symptoms and all 'exacerbating' factors. This enables assessment of the subject's psychological status and the potential impact of vocal disorders, assessment of 'vocal behavior' (respiratory technique, posture, muscle relaxation), patient's self-assessment of the quality of his/her voice and perceptive analysis. The GRBAS scale is increasingly used.

All the acoustic parameters of the voice may be impaired: frequency (or tone), intensity, timbre, rate, articulation. Objective acoustic analysis enables measurement of all those parameters. The difficulty resides in the absence of a consensus with regard to the pertinence of the indices measured, their correlation with the subjective evaluation and the anatomical findings. This is due to the instability of the voice as a signal from a physical point of view, the manner in which the signal is acquired (acoustic or microphone, electrolaryngography), the phonetic material analyzed (vowel or continuous speech), vocal emission conditions (mean intensity, high intensity, usual frequency, speaking voice, singing voice, etc.). All the analytical systems are computerized with dedicated programs ranging from the most simple to the most sophisticated. The programs concomitantly analyze one or several parameters. There is thus a question of choice and resources.

Acoustic measures determine the usual tone or fundamental frequency of the voice, its irregularities or jitter, and its mean intensity and intensity irregularities or shimmer. An examination frequently conducted by phoniatricians and speech therapists is the phonetogram, or dynamic range of the voice, which correlates two acoustic parameters: frequency and intensity. The test protocol has been standardized by the Union of European Phoniatricians.

The analysis of timbre is more complex and the interpretation of spectral analysis data is difficult except for trained specialists.

Aerodynamic measurements determine air pressures and flow rates. Some are easy to conduct such as the maximum phonation time (MPT). Others require more sophisticated apparatus with flow rate transducers.

Etiological assessment is conducted by a specialist physician, an ENT specialist or phoniatrician. The physical examination studies the quality of the resonators (mouth, teeth, tongue, soft palate, temporomandibular articulation). Laryngeal examination is an essential and indispensable component since it addresses the morphological aspect and dynamics of the vocal cords. The examination is conducted with flexible (nasoendoscopy) or rigid endoscopes enabling good quality imaging and enabling adjunction of a stroboscope. In general, digital video recording is conducted during the investigation. The morphology of the vocal cords (color, length, lesions) and their mobility are studied, while the stroboscope enables determination of the quality of their contact and the amplitude and symmetry of mucosal undulation. A standardized examination protocol recommended by the European Laryngological Society is available.

Following the vocal assessment which is to at least include a functional assessment (conducted by a phoniatrician or speech therapist), acoustic determinations (fundamental frequency, intensity), MPT determination and laryngeal endoscopy, dysphonia may be diagnosed: the dysphonia may be purely dysfunctional with anatomically normal vocal cords, or vocal cord lesions may be present in a context that is frequently dysfunctional. Bilateral nodules, unilateral polyp or edema of the vocal cords are the lesions that are most frequently encountered, particularly in teachers.

The prognosis is assessed and treatment prescribed: simple medicinal treatment for laryngitis or gastroesophageal reflux, speech therapy or phoniatric rehabilitation to restore the 'correct vocal practice' in the context of dysfunction, surgical treatment, if necessary, which is given concomitantly with or followed by rehabilitation since the dysfunction frequently 'creates' the lesion, over time.

Further investigations may be necessary for more accurate diagnosis or in order to prescribe particular management: hearing assessment, respiratory function tests, imaging (laryngeal CT-scan or MRI) for a mobility disorder or trauma, laryngeal electromyography in the event of a disorder of mobility or if spasmodic dysphonia is suspected (laryngeal dystonia). The latter enables both diagnosis and treatment by botulin toxin injection.

Vocal rest is the best anti-inflammatory for the acute phases of dysphonia

In the acute phases of dysphonia, most frequently in the context of a chill with laryngitis but also in the event of pharyngeal or bronchopulmonary inflammation or an acute episode of vocal straining, resting the voice is the best anti-inflammatory. This means that the teacher requires a few days of sick leave. Optimal anti-infective treatment indication is outside of the scope of this expert review since treatment depends on the clinical situation. In certain cases

of severe dysphonia not resolving on rest or in the event of particular occupational requirements, anti-inflammatory treatment with systemic corticosteroids (prednisolone: 1 mg/kg/day) may be prescribed. The treatment is of short duration and dosage tapering is not required. Patients with peptic ulcer require concomitant gastric demulcents.

The efficacy of aerosols, particularly in the event of medicinal combination therapy, has not been demonstrated. With regard to drug administration by aerosol, in line with the recommendation of the consensus conference on pneumology, it is preferable to use only normal saline aerosols (with a view to moisturization) possibly with a steroid (anti-inflammatory). Corticosteroid sprays are intended for the treatment of bronchopulmonary diseases, particularly asthma, and are not appropriate for the vocal cords. Their use has even been suspected of inducing dysphonia related to the propellant gases in some cases.

Vocal cord surgery is one option for voice disorder treatment

The surgical procedure consists in treatment of lesions that have become established over time. Most of the time, the specific lesions following voice straining in teachers are responsive to rehabilitation and surgical treatment is only used in the event of failure of the latter.

Overworking and straining the voice are the key factors in the emergence of dysfunctional lesions. Lesion management must thus focus on the dysfunction and vocal cord surgery is always to be accompanied by vocal hygiene measures such as the use of an amplification device, medicinal treatment of concomitant diseases and, above all, rehabilitation measures. In all cases, speech therapy is to be prescribed at least post-operatively. It is preferable for the patient to meet with the speech therapist before the surgical procedure.

For the chronic phases of dysphonia, there is no specific treatment having demonstrated its efficacy with regard to improving the voice. A number of patients have nonetheless been treated for diseases considered promoting factors for dysphonia. This is particularly the case for gastric antacid treatment in patients presenting with gastroesophageal reflux.

Surgery consists in insertion of a laryngoscope (metal tube) into the oral cavity with the patient under general anesthesia. Orotracheal intubation is usually conducted. The tube enables imaging of the vocal cords directly or via a surgical microscope. The procedure is short but in most cases the patient is hospitalized at least for a day or one or two nights depending on the healthcare establishment's regulatory regime. As with any surgical procedure, the patient is to be warned of the risks associated with the procedure.

Surgery is conducted using specific instruments enabling the basic surgical procedures: retraction, detachment, gripping, section. Some surgeons use a CO2 laser whose beam, coaxial with the microscope view, enables the mucosa to be sectioned and microvessels to be coagulated. With the more recent laser systems, the unwanted thermal effects (burning of the mucosa around the section site) are minimal and currently there is no documented reason for recommending section by microsurgery rather than laser section or vice versa.

The treatment of nodules and polyps consists in gripping the polyp and retracting it from the vocal ligament plane in depth so as to implement excision with minimal healthy tissue damage. Some surgeons conduct infiltration of Reinke's space in order to implement a 'hydro-dissection'. Excision may be implemented by microsurgery or by laser. After excision, it is not necessary to suture the excision margins. The wound bleeds very little. The excision specimen is systematically forwarded to the histology laboratory for analysis. On returning

to consciousness, the patient generally does not suffer at all. Although there is no consensus, absolute rest of the voice for a few days is usually recommended.

The other surgical procedures are variants on the foregoing. Edema is sometimes very similar to a polyp from the point of view of appearance and consistency. Excision is conducted in accordance with the same principles. In other cases, the edema is more 'fluid' and may be aspirated after practicing a longitudinal section of the mucosa at the superior surface of the edema. Granuloma of the vocal apophysis is usually treated by laser excision. At the end of the procedure, some surgeons conduct a complementary procedure consisting in mitomycin application or cortisone infiltration *in situ*. Other surgical procedures are not specific to teachers and will not be considered here.

For teachers, surgical treatment is most frequently combined with sick leave. During the post-operative period, authors recommend suspension of vocal activity for at least 3 to 6 weeks, depending on the surgical procedure conducted. Resumption of professional vocal activity fulltime will only take place after assessment of the quality of the voice and its potential since there is a strong risk of relapse in the event of work resumption before complete cicatrization of the vocal cords. In certain cases, if possible professionally, resumption of teaching part-time is suggested.

Rehabilitation is to be adapted to the subject's personal situation and the context of the dysphonia

The laryngeal organ which ensures vocal vibration also has other roles: a sphincter to protect the upper airways, contribution to deglutition and sometimes a degree of regulation of the respiratory rate.

The voice is intended not only to be heard but, through speech, to have an action on the interlocutor (voice projection and projectional act). This points to the role of the voice in speech, i.e. in the verbal exchange relationship. The role of vocal projection in the verbal exchange is thus to be defined. Speech contributes to psychological dynamics. The great concepts of modern psychiatry enable illustration of the psychological functions of the voice, which define it as the founder of a vocal identity.

The voice is produced through the synchronous functioning of several systems that have functions that are usually independent: the oral cavity and tongue, the larynx, the respiratory system and the abdominal and diaphragmatic muscle system. These systems when acting in conjunction are subject to constraints in the implementation of their movements or combinations: if the respiration is excessive and very energetic, it is associated with a cervical muscle contraction which tightens around the larynx and reduces its mobility; excessively low or high laryngeal pressures reduce vibratory efficacy; the latter may be offset by linguopharyngeal tone modifying the vocal timbre. The constraints thus have a limited margin for adaptation beyond which symptoms will develop, clinical then organic.

When the constraint margin of the system is exceeded, dysphonia occurs. The voice is thus not univocal and management needs to be organic, functional and psychological to ensure complete coverage of the crucial role of the human voice.

The management of vocal symptoms is generally conducted by ENT specialists, phoniatricians or speech therapists. They consider the patient overall and are able to distinguish the organic, somatic, functional and psychological factors. This calls for receptiveness, empathy and professionalism. Management by rehabilitation calls for the

personal maturity of the caregiver in order to comply, first of all, with the cultural identity and vocal requirements of the social group to which the patient belongs, while taking into account the psychological dimension specific to the voice and to the principles of communication. Rehabilitation is thus to be tailored to the patient and conducted at the patient's rhythm in compliance with the diagnostic indications and the medicinal or surgical therapeutic orientations.

Singing teachers and coaches manage vocal problems that may be encountered by teachers. Management is not a question of therapy but of optimizing vocal potential. The teaching is intended to enhance the vocal gesture for esthetic aims, at the rhythm of the musical group or choir or in accordance with the requirements of the score.

Specific voice research has markedly developed since the start of the 20th century through the actions of numerous learned societies and research laboratories. Training is given to teachers through teacher-training colleges (IUFM) but still remains too rare, although teachers are convinced of the benefit of voice training, particularly since 60% of teachers have already experience vocal symptoms (fatigue, aphonia, loss of strong voice, change in timbre).

Rehabilitation is based on the organic and functional diagnosis insofar as rehabilitation will have specific features depending on the disease considered. The main organic lesions to which teachers are exposed are lesions due to straining: polyp, nodule, edema. Dysphonia of a functional etiology includes vocal fatigue, changes in timbre, loss of strong voice and aphonia. Psychogenic aphonia requires a specific approach targeting the context of occurrence and specific management.

Rehabilitation is to be adapted to the teacher's personal situation and to the context of dysphonia (junior school, nursery school or university, noisy facilities, disruptive students, etc.). Immediate assistance is to be offered, such as voice amplification, which is particularly effective. The caregiver must also take into account the stress factors which are particular for teachers. The caregiver must be attentive to resolving them in as far as possible. The objectives of vocal rehabilitation take into account the nosologic context: pre- or post-operative, isolated dysfunctional dysphonia or dysphonia associated with a laryngeal disease, psychogenic dysphonia.

In order to orient the 'treatment program', caregivers use particular instruments. The caregiver first defines the treatment aim with the patient by assessing voice quality (GRBAS scale, study of posture, patient's ability to modify his vocal production, patient self-assessment of voice). The acoustic measurements are mainly used to strengthen the patient's self-assessment and enable the patient to assess progress. The acoustic measurements also reassure and encourage the patient. They also demonstrate the state of the voice and constitute forensic documents. Stroboscopic examination generates crucial information for the caregiver but also acts as a visual aid enabling the patient to understand his/her dysphonia. Initial care addresses the information and advice given to the patient with respect to eradicating irritant factors, voice misuse and the responsibility of environmental working conditions.

Care then addresses the conditions of vocal projection and the situations and dynamics thereof. The various styles of voice, related to intention, are addressed: reflective and confidential voices, vocal projection voice (containing both spontaneous speech and prepared speech), the voices of opposition, insistence and distress. Voice placement work thus takes into account the overall bodily dynamic: laryngo-pharyngo-buccal, the sites of vibration, pressurization and articulation. Voice placement also takes into account breathing and its use in phonation. There are two main poles: the superior tension triangle (laryngeal, pharyngeal and buccal region) and the inferior tension triangle (low back and abdominal

region) which are particularly involved in voice straining and require relaxation, depending on the case, to regulate and re-equilibrate the tensions.

Rehabilitation training is of two types:

- during rehabilitation, the patient may learn or further elucidate the manner in which he/she articulates or makes a sound or syllable resonate. This study isolated from the context of communication and only centered on implementation technique may be considered mechanical;
- when it is necessary to reintegrate the mechanical implementation of vocal production within a verbal chain, rehabilitation addresses the truly functional aspect, i.e. re-associating speech with its semantic content and linguistic values with the intention of the speaker acting on his/her interlocutor. The vocal and socio-phonatory code modify the mode of implementation, which moves from the mechanical to the functional.

Traditionally, in France, speech therapists offer on average 30 half-hour sessions once per week, frequently with two sessions per week to begin with. According to the international literature, the number of sessions is often more limited. No comparison of the efficacy of different rehabilitation session durations for a given disorder is available.

The criteria for resolution of dysphonia are as follows:

- a voice present at all times and under all circumstances of life, enabling what is usual with the voice: talking quietly and loudly, shouting, calling, singing;
- no tiring of the voice or, if there is tiring, tiredness that rapidly and spontaneously resolves;
- auditor understanding at syntactic, semantic and pragmatic level: the voice reflects the feeling experienced thanks to the prosody that it confers on the speech;
- a voice considered an integral part of the user's personality and identity.

The assessment of the therapeutic efficacy of rehabilitation techniques is based on numerous studies comparing and contrasting the results of various investigations such as the GRBAS, phonetogram, laryngeal stroboscope, acoustic and aerodynamic data, handicap self-assessment and listening tests. The assessments have confirmed the value of voice rehabilitation in the event of symptomatic impairment of the voice due to straining mechanisms.

Voice rehabilitation uses deliberate attention to transform the pathological vocal gesture. The aim is to confer, through that learning, a vocal automatism, the correct vocal gesture.

Training is an essential component of a preventive program

Under the European legislation, various organizations are responsible for identifying voice problems. The organizations take into account the health risks and consider whether voice problems require recognition as an occupational disease. The European Committee for Standardization has defined the ergonomic criteria which may be applied to the field of the voice and speech. The organizations have proposed the term 'vocoergonomics' for a multidisciplinary field which combines both the scientific and practical aspects. The European Agency for Health and Safety at Work (EAHSW) recommends that the employer should take measures to ensure the safety and health of the employee. This is documented in European directive 89/391/EEC which has been incorporated into French labor law.

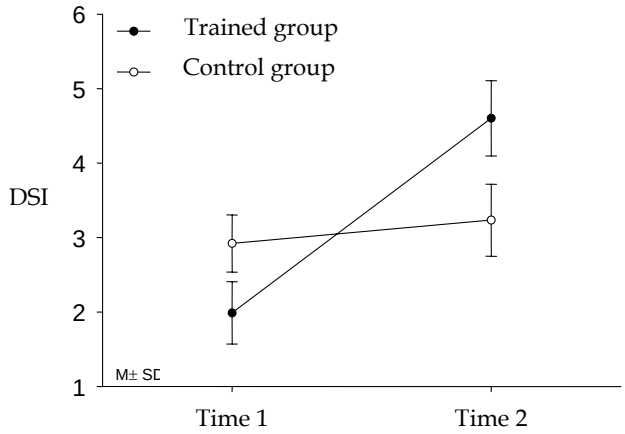
However, there are no preventive measures. Nonetheless, various countries are currently addressing research on voice disorders with a view to compiling preventive programs.

Preventive programs consist of two approaches: the indirect approach and the direct approach. The indirect approach stresses vocal hygiene and the understanding of the anatomy and physiology of the larynx and vocal cords. Vocal hygiene recommendations consist in a list of instructions on how to avoid vocal disorders. The literature stresses a list of 'to do's and don'ts' for voice care. The don'ts are frequently stressed more. The explanation of the anatomy and physiology of the larynx and vocal cords must be comprehensible for a non-specialist public. In consequence, audiovisual programs are used to show the functioning of the vocal system in a readily understandable manner.

The direct approach stresses voice exercises but also insists on vocal hygiene. Voice exercises address various parameters: the position of the body, breathing (learning the various techniques), resonance, articulation, the voice (quality, timbre, intensity) and voice projection. In order to meet high requirements, the functions of the voice need to be increased and strengthened. Three techniques were developed in Antiquity: (1) the position of articulation, (2) the positioning of the voice in the mask and (3) the search for obstacles to strengthen the different parameters of voice and speech. Role playing exploiting the resources of the imagination are often used. It would seem that combining the direct and indirect approaches is the most optimal solution for obtaining the best possible results.

Various voice training programs have been designed to prevent voice disorders. These programs are beginning to be used in the training of teachers and other voice professionals such as radio broadcasters.

Recent preventive programs are based on the combination of the direct and indirect approach and incorporate a subdivision with the abbreviation TTTT: Test, Theory, Training and Transfer. The 'tests' are indispensable in order to identify the characteristics of the voice. The 'theory' may be considered the indirect approach. 'Training' consists in voice exercises. 'Transfer' aims to transfer what has been learned with regard to vocal hygiene and vocal techniques into everyday life. Group training has a positive effect on the function and the quality of the voice. After 18 months of training, a significant difference ($p < 0.001$) in voice quality was evidenced. The group that underwent training obtained a dysphonia severity index (DSI) of 4.3 while the control group had a DSI of 3.2. DSI is an acoustic index which reflects the quality of the voice: a score of -5 denotes a poor quality voice (G_3= Grade 3; bad voice quality) and a score of +5 a good quality voice (G_0= Grade 0: normal voice). DSI provides information on the time course of voice quality.



Time course of voice quality for a trained group and control group (taken from Timmermans et al, 2003)

A TTTT program, included in teacher training, contributes to structural prevention. At the start of the school year, the student teachers underwent a perceptual evaluation ('test') and, in the event of a voice disorder, the physician, speech therapist or phoniatrician was contacted. The 'theory' was imparted after the test and before in-school teacher training. Voice 'training' was conducted in groups in two phases. The first phase was given before teacher training and the other afterwards. The motivation for applying the voice techniques is stronger after teacher training when the student teachers have experienced the difficulties associated with adopting a 'teacher's voice'. 'Transfer' is necessary to consolidate the new vocal technique during or after the course.

For working teachers, the Training, Guide, Video (TGV) program includes training materials, a guide for the school administration, a guide with the schedule for voice assessments and a video explaining how the larynx functions, the diseases of the larynx and the recommendations for vocal hygiene. The program is implemented in the four TTTT stages.

Basic facilities are components of prevention: good classroom acoustics and the use of sound amplifiers. The latter are all the more necessary the greater the acoustic pollution: student behavior (talking increasingly loudly) and the style of teaching have changed. Moreover, according to the surveys, the number of students per class has increased.

It is thus important to prevent potential problems before they occur by daily action targeting vocal hygiene, awareness promotion and training.

Recommendations

Numerous studies have shown that teachers frequently experience voice disorders, which are strongly related to the exercise of their profession, during their careers. This finding should lead to teachers being better informed and trained with respect to the potential for prevention and management of that type of disorder.

In the context of training, a teaching module on vocal physiology, voice diseases and trauma, and the effects of stress and anxiety could be an initial approach to the instrument that the voice constitutes. Similarly, training in correct use of the vocal apparatus in a teaching context (addressing a class, capturing attention without increasing vocal intensity, disarming aggressiveness, etc.) and an awareness of the rules for vocal hygiene (fluids intake, warming up, pauses in prolonged phonation) and the risk factors (smoking, caffeine, poor room acoustics, etc.) are fully in line with a preventive approach. Future teachers should also learn to understand their vocal capability and its limitations better. The ideal would be recourse to a speech therapist in order to obtain early personalized assistance. Although preventive programs exist, their implementation for teachers requires adaptation to the profession in France.

At work in their educational establishment, teachers should also have access to information on the acoustics of their classroom and should be consulted on potential arrangements that could enhance the quality of their working environment.

Although frequent in teachers, voice disorders nonetheless remain poorly understood and poorly managed by healthcare professionals. They are frequently responsible for sick leave. The treatment modalities still remain very heterogeneous and call for reflection on the harmonization of medical practices and the efficacy of rehabilitation speech therapy under the auspices of the French High Authority for Health (HAS).

The analytical and synthetic review of the scientific literature conducted by the expert group has enabled identification of a number of gaps in our epidemiological and clinical understanding of voice disorders. The review has also drawn attention to working hypotheses for improvement of the instruments used to evaluate the voice in occupational settings and for improvement of the acoustic environment.

Furthering research

ECONOMIC STUDIES

Very few studies of the cost generated by absenteeism and voice disorder treatment have been conducted. In the United States, the absenteeism related to voice disorders due to noise pollution of classes was estimated to cost USD 2.5 billion per year and 2 days of sick leave per teacher per year. The cost of a substitute teacher was USD 220 per day. Those costs are far from negligible.

The expert group recommends that studies should be conducted in order to estimate the efficacy and cost of medical and voice therapist management of voice disorders and conduct a cost-benefit analysis of preventive programs.

EPIDEMIOLOGICAL RESEARCH ON VOICE DISORDERS IN TEACHERS

In France, only partial data on voice disorders in teachers are available.

In order to elucidate the situation in France, the expert group recommends initiating a multicenter study of teachers using the Voice Handicap Index or another scale with a view to collecting information on the number of cases of dysphonia with or without consultation (complaint), the number of sick leaves, their frequency, duration and reasons, and in order to monitor the time course of the prevalence of the problem with a view to enhancing prevention. The expert group also suggests conducting a prospective study over 5 years, then 10 years. The study would address teachers having received information on the voice during teacher training vs. those who did not in order to study the frequency of voice disorder occurrence in the exercise of the teaching profession. It is possible that correct information during initial teacher training would be sufficient to protect the teachers.

RESEARCH ON VOICE AMPLIFICATION SYSTEMS

Various studies of the use of portable individual amplifiers or the amplification system incorporated in the facility infrastructure have been published in the literature. The systems are reported to be highly effective, in particular with regard to reducing the vocal intensity of teaching and enhancing the signal/noise ratio. Moreover, a judiciously deployed loudspeaker system prevents the adverse effects of an intensity gradient (the back-row problem). The results of pilot studies conducted in the United States, unfortunately only over the short term, are reported to be extremely interesting with benefits for both the teachers and students. The concept of teacher comfort is clearly experienced by the interested parties.

The expert group recommends further research on voice amplifier prototypes. The main problems that have still to be solved seem to be of a technical nature (improvement in quality, need to prevent the teacher having to adjust the amplifier while teaching, siting optimization, maintenance of the wireless microphone, type and positioning of the loudspeakers, optimal adjustment of the signal/nose ratio, etc.). Once a prototype has been produced, it could be installed in a number of pilot classrooms.

DEVELOPING HIGH PERFORMANCE TECHNIQUES ENABLING FUNCTIONAL ASSESSMENT OF THE VOICE

Functional assessment and documentation of a patient's voice using a small number of numerical cues are widespread. Functional assessment is based on speech signals or other signals, which are acquired in a non-invasive manner. That is, their recording does not interfere with the speaker's performance. Methods of analysis that have been developed recently are more flexible and reliable than those available in the form of dedicated computer programs based on heuristic methods developed 20 years ago. Conventional clinical methods, for instance, are often exclusively designed for the analysis of sustained speech sounds.

It is conjectured that the quasi-permanent monitoring of the voices of speakers at risk in their occupational environment could contribute to both prevention and expert assessment of voice disorders. Currently, this is only a plausible hypothesis since the existing analyzers are not portable and the speech data they process are limited.

In consequence, the expert group recommends promoting research projects with the following objectives:

- development of prototype clinical workstations based on recent analytical methods which answer criticisms formulated with regard to existing methods. The aim is to let clinical practice benefit from recent advances in the laboratory;
- development of demonstrators of portable analyzers enabling monitoring of a speaker's speech in the context of his/her daily work and acquiring relevant data on vocal production. The aim is to test the conjecture that vocal dosimetry is an instrument for prevention and expert assessment of voice disorders in professional speakers.

DEVELOPING RESEARCH ON THE INDIVIDUAL CHARACTERISTICS AND SITUATIONAL ADAPTABILITY OF THE VOICE IN CLASS

The technical resources for voice analysis, in its various acoustic components, and the IT resources for data processing now enable specific research to be envisaged. The research would be designed to answer the question: Does voice adaptability differ over time as a function of the individual characteristics of the teachers? In order to answer that question, the time course of the prosodic phenomena of speech could be monitored over a fairly long-duration teaching task: acoustic parameters of the accent, intonation, rhythm (succession of durations and syllable stressing), elocution rate, tempo and speed, and pause distribution.

In order to ensure satisfactory recording of intonation, it would be appropriate to use a contact microphone (type: laryngeal microphone) which could be issued to volunteer teachers. A room microphone would also be necessary in order to promote the intelligibility of the words spoken.

An aspect of the question which is worthy of further investigation consists in the changes in the syntactic function of intonation in settings of prolonged use of the voice in front of a student public.

The expert group recommends studies to generate reference data on the use of the projected voice over a certain duration in the implementation of a teaching task.

DEVELOPING RESEARCH ON THE INTERFACE BETWEEN CLASSROOM ACOUSTICS AND VOICE DISORDERS

A gradual increase in the level of environmental noise to which a speaker is exposed induces a natural raising of the voice. The vocal effort of teaching is thus linked to the noise level in the classroom. The teacher wishes to use a volume that enables clear understanding of his/her message. Noisy and reverberating environments not only limit the understanding of the message but also limit the auditors' and speakers' endurances. In consequence, the probability of scholastic success is reduced in acoustically-unfavorable teaching environments and all the occupants of the classroom, teachers and students, suffer from the situation.

The expert group recommends studying the relationship between the acoustic conditions of classrooms and the emergence of voice disorders. All acoustic improvements targeting the teacher will have favorable repercussions on the students' receptiveness.