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Some cognitive and perceptual aspects of speech and music

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In this introduction to the fourth session of the MLSB symposium I will discuss some basic questions that concern psychologists interested in perception and cognition, and I will examine how these questions apply to speech on the one hand and to music on the other. In doing so, I hope to reveal commonalities and differences between these two domains of human expression and communication. Since it is impossible to provide an adequate overview of such a broad area in such a short time, I will touch only selected topics, and then only very superficially, in the expectation that the distinguished speakers following me will fill some of the voids I have left. For the purpose of stimulating discussion, I will point out several relatively neglected research questions.

Auditory Perception and Organization

The most obvious commonality between speech and music is that they are primarily conveyed by sound patterns. There are visual aspects, too, but the auditory information is surely primary. Thus, whatever general-purpose auditory mechanisms reside in a listener's brain will be engaged by both speech and music.

It goes without saying that the sound patterns must be *audible* to be perceived; sensory thresholds apply equally to speech and music. Given that a pattern is audible, it also needs to be *free of distortion and interference* to be perceived accurately. This, too, applies to both speech and music, though it has been given much more attention by researchers in the case of speech. One possible source of distortion is a listener's *hearing impairment*. Hearing-impaired persons' difficulties of perceiving speech have been the subject of extensive investigations, whereas their difficulties of perceiving music are rarely even mentioned. One is led to ask why. There are probably several answers: Speech communication is more important than listening to music in most people's lives; there is no clear criterion of perceptual accuracy for music, comparable to an intelligibility score for speech; and the essential components of music (melody, rhythm) can survive fairly severe distortion, as do the corresponding prosodic aspects of speech, and although the latter clearly do not suffice for speech intelligibility, the former may give the illusion of being sufficient for music perception.

It is interesting to contrast this asymmetry of research attention with a converse asymmetry when it comes to *signal quality*. Speech is often listened to in noisy, reverberant, or band-limited conditions; as long as its intelligibility is not much impaired, nobody seems to mind. For music, on the other hand, a substantial effort has been made in audio technology and architectural design to achieve the lowest background noise, the optimal reverberation, and the widest bandwidth. Clearly, it is widely assumed that maximum fidelity is extremely important in listening to music; certainly, noone would think of listening to a symphony over the telephone. It seems paradoxical, then, that so little attention is given, for example, to the deterioration in music perception incurred by hearing-impaired listeners. The exact role of signal quality factors in music perception deserves closer investigation by psychologists.

Let us assume now that we have a clean signal and a listener with normal hearing. The sound patterns of speech and music then should be perceived perfectly well. This is in fact the case. However, psychologists have lost their innocence in these matters through their *visual* examination of speech and music. Optic representations of sound patterns, such as spectrograms, do not readily yield the multiple components and impressions that our ears extract so effortlessly from the sound waves, and they often do show components that we do not hear consciously; hence it seems that our auditory system must be equipped with mechanisms that enables it to partition, organize, and interpret the physical information. Albert Bregman, among others, has devoted his research career to the investigation of these processes (Bregman,1990).

The two primary processes of auditory organization are *integration* (grouping, or fusion) and *segregation* (streaming, or fission) (Repp, 1988). Integration combines what belongs together (assuming that it arrives in segregated form), and segregation separates what does not belong together (assuming that it arrives in integrated form). How does the auditory system "know" what belongs together and what does not? And how can we, the investigators, know in what form the information arrives before the auditory processes act on it? There is a philosophical problem here. One possible solution is to assume that, through evolution, our auditory systems have become adapted to perceive auditory events as what they are; thus, the terms integration and segregation describe information structures to be discovered, not to be created or imposed by the listener. The goal of research on the perception of auditory organization then becomes finding the description of the stimulus structure that best fits the listener's percept. This is essentially the approach of ecological acoustics (Jenkins, 1985).

This approach works fine as long as we are dealing with relatively unambiguous sound structures resembling real-world events. For example, in the domain of speech perception, an important problem that can be understood through basic principles of auditory organization is the segregation of speech from other concurrent sounds, including the speech of other speakers (the so-called cocktail party problem). Similarly, in music perception the segregation of dissimilar instrument sounds as well as the integration of similar instrument sounds (as in a choir or wind ensemble) can be understood in this way.

The ecological approach encounters its limits in situations that permit the listener a choice of different auditory organizations and/or that engage special knowledge or perceptual skills. This is a familiar problem in speech perception research. There is a long tradition of explaining various speech perception phenomena by principles of auditory processing that do not make reference to the special structure of speech. If snippets of speechlike sounds are repeated over and over, as they often are in the laboratory, they may indeed lose their speech quality and be perceived as nonspeech, in which case their perception follows basic auditory principles of integration, segregation, masking, and so forth. When speech is heard in a more natural context, however, its perception is governed primarily by listeners' knowledge of the phonetics of their language.

As an example, consider the perceptual coherence of fluent speech. Speech is acoustically quite heterogeneous, consisting of complex harmonic sounds of varying intensity and spectral composition (vowels, lateral consonants, nasal murmurs, stop consonant closure voicing) interspersed with aperiodic noises (fricatives, stop consonant release bursts) and silences (stop consonant closures). According to auditory principles, the noises should be perceived as segregated from the voiced sounds, and the silences should be perceived as interruptions. This is rarely the case, though a listener *can*, for example, pay attention to recurring fricative noises in a speech stream and hear them as isolated sounds (probably missing the content of the speech message in the process). An extreme example are the click sounds of Zulu languages, which are not easily integrated into the speech stream by nonnative listeners (Best, McRoberts, & Sithole, 1988), though native Zulu listeners probably perceive them as speech segments. *Knowledge of speech structure* in general, and of ones's native language in particular, promotes coherence of the perceptual object, even when auditory principles suggest fragmentation. In certain situations, usually encountered only in the laboratory, listeners may have a choice of going either with their speech knowledge or with more elementary rules of auditory organization, and in one famous contrived situation (the "duplex perception" paradigm; see, e.g., Liberman, 1982), auditory segregation coexists with phonetic integration.

When listeners perceive speech according to their internalized speech knowledge, they are said to be in the "speech mode". It is usually not difficult to find objective criteria for when that is the case, and there is also a clear subjective distinction between speech and nonspeech. Is there a corresponding "music mode" in listening to music? If its definition, by analogy, is the application of internalized musical knowledge, the answer must be affirmative. However, it is much more difficult to determine when someone is listening in a music mode, and when not; and the distinction between music and non-music is unclear nowadays.

In the case of speech, some knowledge supporting its perception is universally shared, whereas additional knowledge is language-specific and acquired. All speakers of a language with normal speech and hearing presumably have in their heads a virtually perfect representation of that knowledge, which is acquired in infancy and early childhood. The situation is rather different when we turn to music. There is no reason to believe that there is a universally shared, innate basis for music perception. Although the possible survival value of music has often been speculated about (e.g., Roederer, 1984), music has not been around long enough to have shaped perceptual mechanisms over thousands of generations. Clearly, music is a cultural artifact, and knowledge about it must be acquired. Moreover, in contrast to speech, this knowledge is acquired relatively slowly and not equally by all individuals of a given culture. Although all individuals with normal hearing are exposed to music at one time or another, we may assume that the knowledge acquired through mere passive exposure differs considerably from that acquired through active attention, participation, and musical training. The nature and extent of these *individual differences* is an important topic that pervades the whole field of music psychology. This is in striking contrast to the study of speech perception, where individual differences are rarely even mentioned by researchers.

Nevertheless, there may be a parallel between the acquisition of perceptual skills in speech and music. There is one class of speech perceiver whose perceptual skills exceed that of the ordinary language user: the professional phonetician. Although this has rarely been demonstrated formally, it may be assumed that trained phoneticians possess the ability to process speech more analytically and with greater sensitivity to its sound properties than the ordinary listener who just pays attention to the message. It is generally understood that this ability is useful only for scientific purposes or for correcting faulty speech; it does not help, and may actually hinder, the extraction of the communicative content. Similarly, in the domain of music perception there are individuals who have acquired highly analytic listening skills, namely, professional musicians, especially teachers, composers, and conductors. The status of these skills as regards "normal" music perception is less clear than in the case of speech. Speech is *not meant* to be listened to analytically; to do so is an uncommon strategy reserved for special purposes. Is music meant to be listened to analytically? There are probably many who would emphatically answer "yes", and indeed most psychological and musicological research seems to be based on this assumption. Nevertheless, while the ability to listen analytically is necessary for accurate music performance, it may be argued that it, too, can get in the way of getting the musical message. Of course, opinions may differ about the nature of the musical message. If it is taken to be the sound structure per se, then the most analytical listener will receive the most information. However, if the message is taken to be the emotional content, then synthetic, unreflecting listening may yield maximum returns. Rather than focusing attention on a particular aspect to the neglect of others, such a synthetic listening mode might enable listeners to take in structural relationships at many different levels in parallel, and it might enable them to make better use of analog, gradual information that otherwise may fall "through the cracks" between the cognitive categories invoked by conscious, focused attention. This leads me to consider more closely the role of categories in speech and music.

Categorical and continuous information

Categories are the elements on which our cognitive processes operate. Because we scientists need to think and communicate about the subject matter of our studies, we need to classify natural phenomena into categories. Therefore, the structures of language and of music are regarded as made up of categories at different, hierarchically related levels. This must be so in theory; however, do our brains actually generate these categories in the act of perception? Whenever we focus our attention on a particular level, this seems to be the case: Our ability to describe in terms of language categories what we have perceived, be it speech or music, seems to prove the extraction of the corresponding perceptual categories from the acoustic medium. However, are these categorical decisions made automatically, or are they the consequence of our having invoked the cognitive conceptual apparatus pertaining to the attended level? In other words, does categorical perception occur without attention?

There is a large literature on categorical perception of phonemes in speech (see Repp, 1984). In all of these studies, listeners were presented with speech stimuli and were asked to report the phonemes or (minimally contrasting) syllables they heard. That phonemic categories are perceived in this situation seems obvious; researchers' interest has focused instead on listeners' difficulties in discriminating subphonemic, acoustic signal properties--a psychoacoustic task that is fundamentally irrelevant to speech perception. Listeners' tendency to remain locked into a categorical speech mode despite the experimenter's efforts is what is generally referred to as categorical perception in the literature. It is a testimony to the functional significance of speech: Listeners want to continue doing in the laboratory what they do in real life. If subjects had their way, however, they would just focus on the meaning of what is being said, and not pay attention to the phonemes, syllables, words, and phrases. In doing so, would they *categorize* these unattended subunits? According to many models of speech and language perception, the answer would be "yes" because these units are represented as stages in the models. Models, however, are just abstractions that enable us to comprehend structural relationships (cf. Uttal, 1990). They are categorical because we need categories to think in. Perception not reflected upon may well be noncategorical, a continuous accumulation of information, without any loss of structure. On the contrary, without the constraints of preordained structural units, the perceptual information retains a vast richness.

This idea opens the door to a fuller appreciation of the information in both speech and music. Both speech research and music psychology have long been dominated by a cognitive orientation that emphasizes categorical processes, in part because they mirror the thought processes we are aware of, in part because they lend themselves to computer modelling, and in part because much theorizing is done on the basis of a written record of speech or music that is in discrete rather than in analog form. This has led to a focus on the segmental structure of speech and on the pitch structure of music, as the closest analogues to a segmental structure, but has resulted in a relative neglect of information that is less easily categorized or indeed gradual in nature. This point is well worth making about speech research, because the focus on linguistic structure has overshadowed research on the prosodic aspects of speech, and has virtually precluded a scientific investigation of speaking as an art, as in public oration, poetic declamation, and drama.

While speech is not inherently an art form, rather a practical means of communication that can be put to artistic uses, the opposite is true for music. Music is, first and foremost, an art form; only secondarily, and perhaps unfortunately, it may be put to practical uses, such as in films, dance halls, and department stores. Nevertheless, most music perception research is parallel in many ways to research on speech perception, and in some instances directly inspired by it. To be sure, there is more attention given to prosodic dimensions, especially melody and rhythm, because they are what music is made of. The "segmental" structure of music is imposed on what is a prosodic dimension in speech, viz., the fundamental frequency contour; musical pitch categories are prosodic, not phonetic segments. Even though psychological music research is thus concerned with some of those dimensions whose relative neglect in speech research I have just deplored, there is relatively little attention given to the artistic message conveyed by these dimensions. Rather, they are commonly treated as purely physical, psychoacoustic aspects of often artificial rather than artful sound structures, and subjects are expected to report on their sound impressions, but rarely on their aesthetic or emotional reactions to the music, which in the circumstances of the typical psychological experiment may indeed be minimal. Yet, musicians, composers, critics, and philosophers of art generally agree that the purpose of music is to convey feelings (see Langer, 1953). Music that is emotionally impoverished is generally unpopular; listeners want to be "moved" by music. It seems to me that one of the highest priorities of music research should be a search for the means whereby good music accomplishes that. This is largely uncharted territory for the psychologist, though there is no shortage of interesting hypotheses (e.g., Cooke, 1959; Clynes & Nettheim, 1982).

Knowledge and memory

In speech and music alike, new events are processed and interpreted in the context of what is remembered about past events in these domains. In the case of speech, this is the norm; rare exceptions occur in the laboratory, when speech stimuli have been distorted or repeated beyond recognition. A listener's tacit knowledge about speech and language is vast and ranges from language-specific phonetic detail to phonemes, words, phrases, grammatical structures, and facts about the world. The processes by which new input gains access to stored knowledge have been of great interest to psychologists, and later in this session Uli Frauenfelder will discuss the topic of word recognition. I will turn to music instead, which has been much less thoroughly researched.

Musical knowledge, too, is potentially vast, but it differs in some ways from linguistic knowledge. First, as already pointed out, it varies a great deal among individuals. Even for the musically sophisticated, it is substantially incomplete and is being augmented all the time. The historical changes in music are more rapid than those in language, and they have accelerated in this century, so that listeners are constantly exposed to new sounds and forms. Second, and more importantly, musical knowledge is acquired passively by most listeners. Language knowledge is solidified by constant productive use, but few people compose or improvise on an instrument. Most people have not learned to use their musical knowledge productively, and as a result this knowledge probably remains fragmentary. Almost everyone, however, has sung childrens' songs or folk songs at some time; this, in combination with extensive exposure to popular music, probably accounts for the relatively solid tacit knowledge people in our culture have of the tonal system that underlies most of our music. Among the numerous studies that have probed this knowledge experimentally, Carol Krumhansl's elegant research is most notable (Krumhansl, 1990).

Knowledge about the sound pattern and the grammatical structure of a native language is acquired in infancy and early childhood. Learning a foreign language becomes increasingly difficult with age, and there tends to be interference from one's native language in second-language perception and production. It is interesting to consider whether the acquisition of musical knowledge might be subject to similar limitations. Does it become increasingly difficult to understand foreign musical idioms as age progresses? Or does, rather, extensive musical knowledge in one idiom facilitate the understanding of others? These questions are intriguing but difficult to answer because, unlike different languages, the musical styles of different cultures often differ radically in complexity. Analytic techniques such as those developed by Krumhansl, however, make it possible to tackle such questions in a meaningful way. The same questions may be raised within our culture, in which very diverse musical styles coexist. One of the facts that music psychologists need to come to grips with is the failure of much 20th century music, especially of the atonal kind, to attract a wide audience (Smith & Witt, 1989). Is it because the knowledge necessary to understand this music is not acquired early and thoroughly enough (e.g., through atonal childrens' songs), or is it because the music makes demands on listeners that exceed their perceptual and cognitive capacities (Lerdahl, 1988)? With few exceptions, music psychologists tend to follow popular taste and restrict their attention to folk tunes and the serious music of earlier centuries. I believe one of the most important contributions music psychologists could make is to spell out the kinds of musical knowledge that can be acquired, and the conditions that promote such acquisition. The rift between the freewheeling aesthetics of contemporary music and the conservative tastes of the public, including many professional musicians, is a deplorable situation that should concern us all.

Musical *long-term memory* is a fascinating topic that has received little attention by researchers so far. In long-term memory for linguistic material, listeners usually retain the gist of what has been heard or read, plus perhaps who said it under what circumstances, but little about the exact words or their sound. If music were remembered the same way, since it is nonreferential in character, there would be little left except perhaps some emotional connotations tied to a particular place and time. Indeed, many musical memories are of that evanescent kind. Musical memories that count, however, are more literal and may include tunes, fragments, or whole compositions. These memories become very impressive in the case of professional musicians, who may remember many hundreds of lengthy compositions in great detail, including their precise orchestration. In the case of language, the analogous memories are those for idioms, quotations, poems, and ultimately for whole literary works such as religious texts, epics, or dramatic works. The retrieval of a work of art from memory is an act of re-creation, which can be covert, or overt as a vocal or instrumental performance, and in contrast to memory for ordinary conversation or prose, it makes a lot of difference if one word or a single note is changed. There has been very little research on the acquisition, organization, and deployment of literal memory for either language or music; yet it seems a challenging topic, and one that is of considerable practical importance to literary scholars and professional performers.

There is another topic that has been hardly investigated at all in music, though it is an important research area in language, and that is the productive use of the knowledge base. Language, of course, is used productively all the time, and by nearly everyone, in speaking and writing. Even though a detailed analysis of the psychological processes of language production is a relatively young enterprise, important progress has been made in recent years (see especially Levelt, 1989). Musical knowledge, on the other hand, is used productively by only a very small group of people: composers, and performers who improvise. Although their output has been studied intensively by musicologists and ethnomusicologists, very little is known about the psychological processes underlying their activities. An added complication is that the work of composers does not take place in real time, like speaking, or, if it does, it does not yield any immediately observable output. Therefore, what little information we have about the processes underlying composition and improvisation comes from introspective reports (see Sloboda, 1985, Chapter 4). An interesting constraint on creative activities, which also include those involving language (such as writing poetry), is the need to produce novel structures. The potentially vast long-term memory for literary works or music heard in the past thus exerts censorship over new formulations; yet the even vaster long-term memory of fragments and traces of past experience decisively shapes an artist's imagination. Literal memory thus may be a burden to the creative artist, whereas it is essential for the re-creative artist--that is, the performer.

Reading and performance

Although actors and performing musicians need to memorize great quantities of materials, in our culture they usually acquire this information through reading rather than through listening only. This raises the dual issues of the reading process itself, and of the conversion of the printed information into a vocal or instrumental performance.

In a literate society such as ours, the reading of printed text is an extremely important activity. The process of reading has been intensely investigated by psychologists, and there are hundreds of studies of letter, word, and sentence perception. Also, the problem of dyslexia is a matter of great concern and has been given much research attention. Many studies have investigated purely visual processes involved in reading; one of the most impressive research programs in that area concerns the control of eye movements, carried on by Keith Rayner and his colleagues (see, e.g., Rayner & Pollatsek, 1987), among others. Another recurring and hotly debated topic is the involvement of speech recoding in silent reading; although rapid visual recognition of familiar words can occur, many findings indicate that read materials are automatically converted into an internal speechlike representation (e.g., Van Orden,1990), and also that it is a deficiency in this process that underlies reading disability (Shankweiler & Liberman, 1989).

Considering this wealth of information and controversy about reading text, it is pitiful how little we know about the reading of music. John Sloboda has done pioneering work in this area in the 1970s (see Sloboda, 1984), but little work has been done since. The availability of computer-controlled music displays and eye movement monitors opens new possibilities for such investigations of the visual processes involved in music reading. In contrast to reading text, which is usually done silently, music reading is usually done in conjunction with playing an instrument. However, silent music reading is an important activity for composers and conductors, and the questions of whether the read symbols are automatically translated into an auditory image of the music and how complex that image can be, particularly in the reading of orchestral scores, are fascinating and well worth intensive study. Finally, despite widespread musical illiteracy, or perhaps because of it, we know little about musical reading disabilities, though they do exist and can be a serious handicap to professional musicians (Wolf, 1976). As far as translating a musical score into an auditory image is concerned, all musicians are probably handicapped in various degrees, and only the most proficient can achieve anything approaching completeness. If it only were easier to lure professional musicians into the laboratory, there would be many interesting experiments to conduct.

Written text and music have in common that they specify only some of the parameters for an oral or instrumental realization. In reading aloud, the speaker needs to supply prosodic variation that is barely or not at all indicated in the text: word stresses, emphasis, sentence intonation, tempo, etc. This is true for the laboratory speech that psychologists usually deal with; it is even more true, of course, when the text is of an artistic nature, as in reciting poetry or drama. The on-line choice and construction of these prosodic parameters in reading, and the help provided by punctuation and similar graphic devices, is an interesting but rather neglected question for language production research, mainly addressed so far by the curious group of researchers known as "pausologists" (see O'Connell, 1988).

At first glance, it might seem that printed music is much more specific than printed text in this regard, since it provides precise instructions about pitch and duration, plus some indications of tempo, relative intensities, and phrase structure. However, performers not only must make decisions about vaguely specified performance parameters, but also are not expected to follow precise instructions literally. Rather, the notated values must be modulated by performers according to their understanding of what the composer may have intended the music to sound like. This complex process, which engages a musician's highest skills and is fundamental to musical communication, has barely begun to be investigated, though analyses of the so-called expressive microstructure of performances and of its perception have been conducted in recent years (see Clarke, 1985; Repp, 1990).

I would like to conclude with a general observation. Speech and language research has largely proceeded from mechanistic assumptions about the nature of psychological processes, in accordance with computer technology and applied goals such as automatic speech recognition and language understanding. Most music research is in a similar vein, which probably reflects more the Zeitgeist than a drive towards applications such as automatic composers and music processors. Psychologists have been very reluctant to tackle questions related to the vital, organic, expressive aspects of speech, language, and music, which have been the focus of philosophers of art (e.g., Langer, 1953). It behooves us to be modest in the face of artistic subtlety, lest we be the proverbial elephants in the porcelain store. Yet I believe that empirical approaches to these issues are possible, though they require an intimate understanding of verbal or musical art on the part of the investigator. Perhaps, as we move towards a more peaceful future, the current obsession with the conceptual derivatives of computer technology will subside, and psychologists will give increased attention to the organic phenomena and processes that enhance the quality of our lives.

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