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THE PITCH CODE IN MUSIC AS COMPARED WITH THE NATURAL LANGUAGE CODE

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Comparisons are drawn between the formal features of language and music. Basic phonological universals of language and music are compared. Attention is drawn to specific properties of sound material and the general features of human perception mechanisms in the process of aural communication. The general common rules are described gqverning the organisation of communication codes in language and music.

Dokonano porównania funkcji i cech formalnych języka i muzyki. Zwrócono uwagę na uniwersalny charakter podstawowych zasad tworzenia kodów komunikacyjnych mowy i muzyki. Ukazanie przez autora psycholingwistycznych analogii pomiędzy mową i muzyką przyczynia się do lepszego zrozumienia praw rządzących doborem i organizacją materiału dźwiękowego w muzyce.

1. Introduction

The aim of the present paper is a comparison of language and music as far as their basic communicational functions are concerned. The comparison results in conclusions concerning some features occurring generally in both fields. The considerations are scarce in the detailed part due to the fact that among other limitations, the analysis of musical phenomena has been limited to the way of organizing pitch without mentioning organization in time, loudness and timbre. Also, only those organization systems are discussed which employ the discrete division of pitch continuum, i.e. musical interval systems. Finally, in discussing these features only the basic problems of organizing the material are considered remaining within the field of music phonology. The detailed analysis concerning phonological universals in music is preceded by more general discussion of the relations between language and music.

2. The comparison of functions and formal features of language and music

Before we start to discuss the functions and formal features of both fields compared, let us dwell for a moment on the problem of definitions of language and consequences they may lead to in respect to analogies in question.

Let us show it in the following example; if we define language broadly as "a system of communication or the means by which humans exchange meanings and values" RUWET [23], then its main universal feature (i.e. being "a system of communication etc...") clearly overlaps with those of some other selected systems of communication. On the basis of this definition we can speak of music as a "language", however, we cannot use the expression "the language of ants". If we adopt any other definition of language, the situation may look quite differently.

2.1. Language

According to the trends adopted by various authors, the following definition of a spoken language may be formulated: Language is a device for *transmitting* and *processing* information, using signs which are composed of elementary meaningless units produced by human articularly organs.

Besides the basic function of processing and transmitting information, three other important functions of language can be listed:

Representation (substituting phenomena of the environment by signs);

Expression (expressing the feelings of a speaker); and

Impression (making an impression on listeners and inducing them to take up attitudes or to undertake action).

Finally, three important formal characteristics of language can be mentioned:

Arbitrariness of language signs, held by DE SAUSSURE [24] to be a basic property of language, directly connected with its function of representation. Some doubts have been raised about the phonological aspect of language arbitrariness (JAKOBSON [11]). It should also be remembered that the conventional character of language is in some cases replaced by a more natural one (onomatopeic phenomena). Therefore perhaps it is more correct to understand arbitrariness as an extremely important, but not fully universal, feature of a language sign.

Double articulation of language. We can specify two broad classes or types of articularly systems effective in the process of conveying semantic information. The first type may be described as "systems with single articulation". Here information is transmitted by a series of single, unanalysable units, each having its own meaning. These systems are mostly natural, (i.e. their signs have a direct, biological or physical relation to represented phenomena). Typical signs of this kind are: cries of pain, caresses, raising, voice in anger, the speed and timing of movements etc. Natural signs of single articulatory systems are, to a large degree, universally understood among human societies at very divergent stages of development. They are also more or less universal in the communication of humans with animals and/or between animals. However, many signs of single articulatory systems are purely conventional. A good example of such a conventional sign is nodding the head in approval (in most societies) or in negation (in some others).

In contrast to the situation described above, double articulatory systems use signs which are constructed from a limited number of smaller, meaningless units. The human language, while incorporating some features of natural articulation, may be taken as a representative of the conventional, double-articulatory system. This is perhaps its main and most important formal characteristic. The structure of language as a combinatory-type device utilizing a code of a limited number of elements and rules for combining them, stems from the fundamental properties of the human mind and is effective in overcoming the limitations of memory.

Generative properties of language. This extremely important aspect of language has been forcefully demonstrated by CHOMSKY [4]. Its essence is the innate ability of the users of language to generate an infinite number of new, meaningful utterances. The generative properties of language are perhaps the most "human" feature of this system of communication and best reflect the power of human creative thinking (ROEDERER [21]).

2.2. *Music*

The basic assumption accepted in this paper was that both natural language and music take part in the process of human communication. This assumption, however, may seem to some degree controversial. Though it is obvious that language plays an essential role in communication by transmitting semantic information the question immediately arises: *what is being transmitted in music*? Music is constructed differently than language and we cannot say that its elements are simply and directly signs representing elements of the outer world, as the elements of language are. Then, it may seem doubtful whether any important similarity between language and music really exists.

The problem requires serious consideration. It cannot be considered at length within this paper, however some important facts should be mentioned. Similarity between language and music within the domain of communication stems from the fact that differences in the role played by them in that domain are quantitative rather than qualitative in nature. Let us first consider language. As it has been said its elements are signs representing the reality outside the language itself. They are used for transmitting information about the outer world. However, though most important, it is not the only information that language can transmit. The other information considers not the outer world but the language itself: the form in which its elements have been organised, the logic and beauty of this form, even the beauty of the elements themselves. The above kind of information is of great importance in poetry, particularly in modern poetry, but it is also present in language outside poetry. We may call it "internal aesthetic information".

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We can easily find analogous situation in music, though both the surface structure of events and the relative importance of the two processes are quite different. The counterpart of the "outer" semantic language information is vague, though extremely important system of musical connotations. These connotations, mostly of subconsious and emotional nature play important part in music appreciation and apprehension. Music brings memories, evokes feelings, generates emotions; in some way music tells about or originates phenomena that are outside it, using structures that are mostly conventional and partly natural. The role of music in that process may be understood as that of a system of signs used to convey information from sender (composer, singer, instrumentalist) to receiver (concert listener).

But that is not all, and, as some say, it is not the most important part of information contained in the musical message. Music is the art which comes into being through the organisation of sound structures. The imposition of this organisation on sound is conditioned by highly specific properties of human mind (probably related to those which laid the foundations for the development of language). By structuring sound, creatively inclined individuals acquire satisfaction through feelings of "beauty" and "perfection". As this satisfaction is intended to be shared by listeners, it is necessary to transmit information about the structure imposed on sound. And this "inner" information on the structure of a musical message contributes to the essential, aesthetic value of music. Similarly as mentioned earlier, secondary information contained in language, it may also be called "internal aesthetic information".

Now, if the transmission of information about the structure imposed on sound has to be efficient, several conditions must be fulfilled, very similar to those which govern the transmission of information in language. First, there must be a code known, or at least to some degree familiar to both the sender and the receiver of the information. This code may be arbitrary, or at least partly arbitrary, with limitations imposed on arbitrariness by the properties of the sound source, the auditory discrimination functions and the capacity of human memory. Then, over some degree of complexity, the code should have a permutational (hierarchical) structure. Some of these and other detailed conditions imposed on the pitch code of music by physics and physiology will be discussed later as "basic phonological universals of musical scales". Before that let us compare some of the functions and formal characteristics of language and music to find which of them may be understood as universal in both systems and which are typical of only one of them.

As we have shown, the first of two main functions of language, that of transmitting information, may be considered universal for both language and music. However, the second one, *mental processing* of information, facilitated by the use of language, cannot be attributed to music, because elements of music are derived of a direct representative function in relation to other phenomena. The mental processes of music composition and appreciation are of specific character and cannot be directly compared to those activated by language.

Though not capable of *representation* (except in marginal cases) music is particularly well suited to fulfill two other functions characteristic of spoken language; those of *expression* and of *impression.* According to popular opinion, the function of expression in music is more important than any other function. This is directly related to strong emotional connotations of music. Thus, the ability to express the feelings of the sender and to activate the mind of the receiver, may be considered a common universal of language and music.

Arbitrariness in selecting the details of a code for transmitting information is characteristic of both speech and music. (Limitations imposed upon this feature at the phonological level will be discussed later).

Double articulation, as commonly understood in language, cannot be attributed to music because the latter is deprived of meaningful units and conveys no semantic information. However, another important formal feature of similar character should be mentioned at this point. This feature is universal for all highly developed communicational systems, language and music included. It may be called the *permutational structure*. Following the rules of this structure, smaller units that are limited in number may be used to compose a more numerous, or even unlimited set of larger units. In music, as in language, the permutational structure may be observed on both phonological and syntactic levels.

In spoken language small units are combined to form a vocabulary of signs and signs may be composed into a practically unlimited number of meaningful communications. In music, limited sets of frequency and time ratios are used as the fundamental material for the creation of melodic structures. The combinatory, permutational character of both language and music is their important common feature.

There is another problem worth considering. It illustrates some aspects of the important analogies between language and music, and shows where "creative thinking" in music is really active. In his description of the specific features of language ("langage") DE SAUSSURE [24] explained how virtually all individual acts of speech ("parole") raise the possibility of interferring with established language rules. A single utterance, understandable but not exactly following the rules of a code, may initiate a slight change of the rules, which then, in turn, spreads out through imitations and finally becomes a fixed part of the standard rules itself. As a result, detectable changes can appear in a living language after only a few decades of its use, and after some hundreds of years the language may undergo very serious transformations.

There is an important analogy to this process in music. A musical composition produced in a definite style, (i.e. according to definite rules) combines some elements which are purely schematic or conventional and some which are entirely new (sometimes even breaking the established rules and thereby not accepted by more conservative listeners). The proportion of new elements in a given work is often taken as one of the measures of the talent of the composer and/or of the value of the composition itself. The new formal "inventions" found in masterpieces of great composers enter into the basic set of rules for musical composition and form definite changes in the existing code.

Important conclusions may be drawn from the analogy described above. As far as the formal communicational aspects of language and music are concerned, each new utterance in language corresponds to the creation of a new composition in music. This analogy is surprising! Perhaps it would be more easily accepted if a comparison were made between written musical compositions and works of literature. However, the above analogy correctly illustrates the mechanisms active in the temporal transformation of both language and music.

3. The basic phonological universals of musical scales

In some linguistic literature one may find the opinion that languages of the world differ in unpredictable ways and that in various languages, except for the fact of their double articulation, "everything may be different". However, such an opinion is not shared by the majority of linguists. HALLE [6] points to the invariance of the fundamental set of distinctive features in speech. HOCKETT [8] states that similarities of all known phonological systems of the world are much greater than could possibly be predicted from the physiological limitations of speech organs.

The above statements are reconciliations of the evident fact that all natural languages of the world are constructed according to some universal rules imposed by nature. Three groups of factors seem to be limiting the arbitrary character of language at the phonological level. They are related respectively, to the anatomy and physiology of speech organs (source of sound) to the discriminating power of the ear and to specific properties of the human brain (particularly to the accuracy of memory).

Having this in mind let us now look at the basic phonological system of music; that of pitch organisation in the form of musical scales. The universal features, similarly to those of language, are determined here by three elements:

— The sound source (physical properties of musical instruments).

— The analyser (frequency selectivity of the ear).

— The central processor effective in the formation of the code (typical features of a human mind; specifically, properties of the auditory memory).

3.1. The source. Sound material

The physical properties of musical instruments imposed essential limitations of a seemingly "universal" character upon the construction of a musical code long before these limitations could have been scientifically explained. Their manifestations were either purely spontaneous (as in the acquisition of simple scales based on fifths) or highly sophisticated (as in late Pythagorean or Arabic mathematical systems).

However, the fundamental question still remains: is the construction of musical scales really natural and universal, or rather is it conventional and based on arbitrary assumptions?

HELMHOLTZ [7], who first approached this problem from the scientific point of view, strongly emphasized the concept of a natural basis for the organization of pitch material in music. In his opinion, if physical properties of musical tones were such that between their component frequencies definite harmonic relations were preserved, then these harmonic relations constituted a natural basis for all frequency relations in music. Therefore, according to Helmholtz, the musical scale should employ only "natural" intervals with frequency ratios 2:1, 3:2, 4:3, etc. The immediate consequence of this assumption is the prominence of the harmonic interval system in music with its "natural" superiority over all other musical systems and the condemnation (as "unnatural") of the equally tempered scale.

There are several arguments in favour of the above mentioned "naturalness". The auditory sensation created by two simultaneously sounding complex tones, whose intervalic relation changes continuously from the unison to the octave, contains several distinct salient points. They occur at frequency ratios 1:1, 5:6, 4:5, 3:4, 2:3, 3:5 and 1:2 and correspond to the minima of acoustic beats between the harmonics of two component complex tones. The existence of such perceptually salient points is the usual basis for the formation of categories, for which these selected points can be used as cognitive prototypes (ROSH [22]). It is, therefore, easy to explain why the musical system of a Western culture is based primarily on intervals with simple or almost simple frequency ratios. There are, however, some restrictions which may spoil the picture of such a "natural" system as being universal in music.

As may be obvious from the above description, the appearance of salient points at natural frequency ratios along the interval magnitude continuum requires that two conditions be fulfilled. First, the tones must have a harmonic spectrum; second, they must be heard simultaneously. However, it must be admitted, that the fulfilment of such conditions is not a universal feature of music. Therefore, the question arises as to whether the interval categories based on natural standards may function in music without the constant presence of their cognitive prototypes. The answer should be given separately for two different cases; first, for the case when cognitive prototypes are available for learning, second – for the case when they are absent altogether.

For the first case the answer is obviously "yes". Natural musical intervals whose salience is easily tested by listening to simultaneous complex tones, become overlearned in the social process of the formation of a musical code. They can be reproduced with some accuracy and the categories which form around them are easily recognized (also in monophonic music). Even the secondary properties of simultaneous tones, such as their dissonance character due to the acoustic beats become generalized and may function not only in chords but also in succesion of tones.

The second case, that of music being composed and performed without the constant reference to natural intervals as specifically sounding consonances raises some doubts. There are three hypotheses concerning this problem; we may call them: "the hypothesis of innate factors", "the hypothesis of spectral learning" and "the hypothesis of incidental standards". The first two hypotheses give affirmative answer to the question of the universal character of natural intervals in music. The answer given by the third hypothesis is "no".

According to the "Hypothesis of innate factors", the human brain is genetically prepared to prefer combinations of tones in which frequency ratios correspond to natural intervals. This hypothesis had strong advocates among physicists and philosophers of the past (see PLOMP and LEVELT [13]) and is also held by some present writers (BOOMSLITER and CREEL [2]). Nevertheless its experimental verification was practically impossible for a long time (see Levelt et al. 1966). Only recently some published results of psychoacoustic experiments seem to be in favour of the hypothesis of innate factors to some degree. It was found by DEMANY and ARMAND [5] that 3-month old infants discriminate the melodic interval of an octave as leading to much greater similarity of component tones than the interval of a seventh or a ninth. This experiment leads to interesting conclusions concerning the role of innate and cultural factors at the formation of musical scales.

In the "Hypothesis of spectral learning" (TERHARDT [26]), it is assumed that since natural intervals are constantly present in the spectrum of musical tones and of vowels, so they may become overlearned through listening to such sounds.

The third one, "Hypothesis of incidental standards" is based on the fact that in some non-Western musical cultures the intervalic structure of music bears no relation to the natural overtone order (HUSSMAN [10]). However, in those cultures music has an exclusively monodic character and most of the instruments used are primitive idiophones with nonharmonic sound spectra. The lack of perceptually salient prototypes of natural intervals appears to be an evident reason for the fact that no corresponding categories are formed. Instead, some other incidental standards are accepted and corresponding categories overlearned.

The process of imprinting standard intervals in the long-term memory of musicians and music listeners closely corresponds to learning sounds of speech. From the point of view of auditory perception, simultaneous complex-tone intervals show some analogy to those syllables in which "salient points" are provided directly through the interaction of physical and psycho-acoustic phenomena (e.g. stop-vowel combinations). Melodic intervals are more similar to vowels. In those intervals, like in vowels, no physically salient prototypes are provided for recognition. Their standards may be imagined as arbitrarily chosen isolated points along smooth perceptual continua.

As a conclusion, it could be argued that the hypothesis on the universal character of "natural" harmonic intervals has no full confirmation. Instead, the elements of musical scales may be considered as being partly natural and partly arbitrary.

One thing should be explained as being a constant source of misunderstanding.

The formation of a musical scale can be understood as the division of the perceptual continuum of the pitch difference (or pitch ratio), into discrete, step-like categories. These categories tend to be formed around the salient points along the perceptual continuum. However, the salient points themselves *are not* units of a code. They are prototypes or standards employed in the formation of such units. The units of the perceptual code in music, similarly to those in speech, are categories. The perceptual categories, that are units of the pitch-difference code in music, correspond to segments on the frequency-ratio scale. Within each category various, perceptually different frequency ratios may be accepted as "intonation variants" of the same musical interval (RAKOWSKI, MIŚKIEWICZ [9]). The "within-category" discrimination of musical intervals is inhibited through the mechanism of categorical perception, however, through proper training of listeners in a specific experimental arrangement, this inhibition can be removed (BURNS, WARD [3]). The intonation variants of musical intervals are very important in playing some musical instruments (i.e. the violin). Musicians use these variants for raising or lowering pitch of some notes in order to increase harmonic tensions (RAKOWSKI [16]) The intonation variants in music are counterparts of phonetic variants in speech. Their existence may be considered an universal for the above compared domains.

3.2. *The ear*

The human ear is particularly well suited to discriminate frequency. At frequency 1000 Hz, the number of tones of different frequencies that a trained listener can discriminate within a semitone is more than a hundred (Rakowski [14]).This high selectivity revealed in laboratory conditions decreases significantly during practical listening to music. Still, it is sufficiently high to enable hearing the within-category deviations of musical pitch in a 12–semitone system of a Western music. These are two restrictions which limit this high ability. At first, the frequency selectivity of the ear drops down considerably at low frequencies.The pitch of low contrabass tones is estimated much less accurately than that of violin tones. Secondly, pitch selectivity may be lowered for very short musical tones, particularly when those are presented in rapid sequences. In such cases the additional effect of a pitch shift may occur (RAKOWSKI, HIRSH [18]).

However, frequency discrimination alone is not sufficient for the functioning of a musical pitch code. Equally important is the accuracy in estimating differences in the musical interval magnitudes or frequency ratios. Here the accuracy of the ear is significantly smaller (e.g. see HOUTSMA [9], ATTNEAVE, OLSON [1], RAKOWSKI [15]).

3.3. *Memory*

Some musicologists complain about the lack of interest of avant-guarde musicians in composing and playing quartertone or other microtone music. One of the arguments in promoting microtone interval systems, as the important enrichment of musical language, is the statement the quartertones and even smaller intervals can easily be detected by the ear. Although this statement is true, the reasoning is incorrect. The main obstacle in using microtonal divisions of an octave is not poor auditory discrimination, but limited capacity of the memory. It is very difficult to store in the memory a large number of intervals as units of the same level, e.g. after the division of an octave into 24 or 53 parts. The situation here is quite similar to the one in natural languages which all, due to memory limitations, use quite limited number of phonemes. These limitations are even more severe in the domain of musical pitch than in the language because here the units to be remembered are differentiated only through the unidimensional change of auditory sensation. George A. Miller, in his well-known paper about "the magical number seven" (MILLER 1956) gave the summary of a number of psychological experiments concerning memory. He concluded that the memory for changes of the magnitude of any single-dimensional sensation is limited to a very small number of separate steps of this magnitude: seven plus or minus two. There is no reason why such a unidimensional sensation as "magnitude" of pitch should be an exception to this rule.

There are, however, two important additional phenomena effective in overcoming the limitation of pitch memory in music. These two phenomena were gradually exploited in the long process of the formation of the fully-developed musical code, as means to overcome the contradictions between the great pitch selectivity of the ear and the limited capacity of pitch memory.

The first and most important phenomenon effective in the development of the musical code was the octave similarity of musical pitch. The second phenomenon was the hierarchization of structure into sets of units of various order. A good example of this effect is the acquisition of the chromatic scale through enlargements of the primarily acquired diatonic material.

The role played by the octave phenomenon in music requires some additional explanation. Due to the harmonic structure of most musical sounds, tones separated by the interval of an octave or its multiplicity seem "similar" or, in some aspects, "the same". The octave similarity of tones resulted in a cyclic or "spiral" character of the musical pitch scale (SHEPARD [25]). Such spiral changes in the domain of a given sensation may be regarded as a superposition of two movements, a periodic movement and a steady movement within the sensation area. Under such conditions musical pitch no longer suffered the limitations typical of all unidimensional sensations. It could be organized and memorized along two separate scales: the unprecise — "tone-height" or pitch-range scale covering the total range of pitch used in music and a within-octave scale that could be structured more precisely. The first one corresponds to the steady increase of the sensation magnitude within its full range. The second one corresponds to a periodic movement within the octave range.

The two-dimensional scaling of musical pitch concerns both relative and absolute pitch. There is however an essential difference between the way in which the magnitude of relative and absolute pitch can be fixed in the memory. The within-octave steps of relative pitch (musical intervals) can be fixed in long term memory and their sequences easily recognized as familiar melodies by most people. On the contrary, the within-octave steps of absolute pitch ("chromas", corresponding to the names of musical notes) can be permanently memorized only by a very small percentage of people, the possessors of "absolute pitch". All other people have the ability to assess absolute values of pitch very accurately but these values can be only kept in the short-term memory lasting for about 1–3 minutes (RAKOWSKI MORAWSKA-BÜNGELER [20]).

It results that only the memory for relative pitch memory for musical intervals can be used as the base for the pitch code in music. The vocabulary of this code is subjected to basic limitations of memory concerning the number of units that can be memorized. Here we see the far-reaching analogy with the limitations typical of the codes in all natural languages which, as a rule, use severly limited number of phonemes.

Limitations imposed by the basic properties of long-term memory are important universal feature, common for such codes of human communication as language and music.

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