

# Digital Technologies Applied to Music Therapy in the Information-Semantic Approach

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**Abstract.** The paper presents the rationale for the use of information-semantic approach to the study of music therapy issues in the context of the challenges of digital technologies. At present, the information theory and the basics of semantics in relation to art, including music, are becoming more relevant and popular in society. The value of the informational-semantic approach to music in the modern world is growing with the advent of new technological processes, the increasing role of computerization and the development dynamics of the Internet. Modern music therapy in the context of the informational-semantic approach can become an effective method for diagnosing, preventing, treating and teaching both adults and children with neuropsychiatric disorders and intellectual disabilities. The aim of the work is to theoretically substantiate ideas about the methodological significance of the information-semantic approach to the study of music therapy in the context of information technologies. The subject of the research is the specificity of the therapeutic opportunities of information technologies in music therapy. This work is of an interdisciplinary nature and is designed for information technology specialists in developing software for music therapy, specialists in cultural studies, psychology of music perception and music therapy.

## 1. Introduction

Music therapy is a psychotherapeutic method that uses music as a therapeutic agent [1]. Music therapy develops as an integrative scientific discipline at the interface of neurophysiology, psychology, reflexology, music psychology, musicology, Chinese medicine, etc. [2]. In works devoted to the study of the influence of music on a person, musical phenomena are usually considered as the result of the effect of musical harmonic signals on a person's hearing apparatus with further processing of the data obtained in the auditory center of the cerebral cortex.

The hearing apparatus, irrespective of its structure, is considered to be some non-linear medium through which the sound signal passes. After passing through the hearing apparatus, this signal is converted into an output signal of electromagnetic nature. The input signal in this case is a periodic acoustic signal coming to the auricle. The output is a signal that arrives at the auditory center of the cerebral cortex from the hearing apparatus. In such a nonlinear system, when a pure tone (sinusoid) is applied to the input, a spectrum of weak tones is produced at the output, which are called harmonics. The number of harmonics depends on the degree of nonlinearity of the transfer characteristic (the higher the degree of nonlinearity, the more harmonics), and the magnitude of the amplitude depends

on its particular shape. To study the harmonics, spectral analysis methods are used, which can be applied not only to periodic signals, but also to signals presented in digital form.

For some values of the frequency ratio of harmonics to each other, part of the harmonics coincide, forming the nodal points located vertically (the amplitudes of the harmonics are added together). This leads to an abrupt decrease in the number of harmonics several times and, consequently, the amount of information coming from the hearing aid to the cortical center of the brain. In addition, the coincidence of harmonics leads to an increase in their “loudness”, thereby facilitating the processing of information. As a result, the human brain begins to perceive sound signals at a qualitatively higher level and colors them with positive emotions. This phenomenon is what is called musical intervals, and the values of the ratio of frequencies at which it arises are called interval coefficients.

When studying the effect of music on a person in the manner described, researchers usually come to the following conclusion: in the historical process, musical intervals are the starting material for endowing them with meaningful characteristics. This is a completely objective, physical phenomenon, subject to objective physical laws, which determine the laws of the musical language and its development in historical perspective [3].

However, with this approach to the study of the influence of music on a person, it is often not taken into account that there is a concept of musical cultures that interact with each other. The concept of “interaction of musical cultures”, in the opinion of Kayak, the author of this concept [4] implies a special kind of relationship in the field of music, which is formed at least between two nations. In the process of long-term interaction of musical cultures, the exchange of musical forms and the birth on this basis of new phenomena in culture take place [5].

In foreign and domestic science, the approach to music as an informational phenomenon has been developed for decades. Already in the 1970's and 1980's, many researchers have successfully applied the basic concepts of the information theory in analyses of music. At the same time, it became obvious that the academic thought is rapidly advancing in understanding the informational nature of music. If in the 1960's artistic information was mainly understood as the segment of the aesthetic message that for the perceiver was new, quite unexpected and original in content, then in the 1980's the music information was interpreted much more broadly – it was considered as “all sound matter acting on the sense organs of the listener” [6].

In this case, it is essential to take into account the levels of perception. For example, a well-known representative of the domestic musical and psychological science, Gotsdiner identified four levels in the process of musical perception: sensory, pitch-intonation, emotional-semantic, and integral-semantic. This scheme allows concluding that the deep level of research into the process of musical perception determines the need for its analysis within the framework of the semantic approach. It is the junction of the information approach, capable of ensuring the macroscale of research, and of the semantic, which provides tremendous opportunities for understanding the means of expressiveness and the system of mechanisms of shaping in music at the level of microscale measurements, that holds great potential for studying the therapeutic effect of music on the listener.

A good example of an effective use of the information-semantic approach is the study by Kayak of the interaction processes of musical cultures of the world's nations. In this study, the author considers these processes in the framework of cultural (social) anthropology (founded by Orlova [7]). In his study, Kayak applies both general scientific and socio-humanitarian approaches, fundamental cultural theories adapted to the study of processes, trends, phenomena and events occurring in the space of music.

Consideration of the musical interaction processes as a factor possessing the mechanisms of musical culture of ethnonational and civilizational communities allows using a number of humanitarian [5] and general scientific approaches [8, 9, 10, 11, 12] in their analysis. An important role in the study of musical interaction processes is currently played by cultural science's methods of cultural (social) anthropology and analytical procedures designed to study cultural dynamics [13]. Modern cultural (social) anthropology also actively develops a synergistic approach, which is used in studying the problems of music therapy [14].

All the above gives grounds to assert that the information theory rapidly developing in recent years and the informational approach to art, including musical art, are being worked out more intensively, becoming more relevant and sought-after by the academic community. This is facilitated by the fact that the value of the informational approach in the modern world is growing with the expansion of new technological processes, the increasing role of computerization and communication technologies, and the Internet dynamics of development. Thus, the combination of informational and semantic approaches to music and to the study of the processes of its influence on the human body ensures the level of analytics that is provided for by the requirements of the Newest paradigm of scientific knowledge.

## 2. Methods

In recent years, the interpretation of the synergetic process associated with the conceptualization of ways of self-organization of human communities within certain spatial and temporal parameters of social life is becoming more and more actively used in the interpretation of the topic “society-culture-information”. The conclusions obtained by researchers working at the intersection of biological, social and human sciences (studies by Kaznacheyev et al. [15], as well as the works by Tsymbal [16], Nefedova, Protopopov, Sementsova, Yashin [17], and others). The authors of scientific research develop and introduce into the circulation such ideas and concepts about information as “information field”, “information space”, “information relations”, “information flows”, “information needs”, etc.

## 3. Informational approach

Consideration of the cultural significance of different types of presentations about the music space allows recognizing that their understanding in the information field is of particular importance when studying social communication processes. It turns out that field forms of connections organize representations in a special kind of differentiated integrity, reflecting particular stable sets of connections of people with their surroundings. The field interpretation today extends to all levels of the development of biosystems, ranging from protein forms.

All this indicates that the field concept is of great importance not only in the interpretation of understanding, but also in cultural communication as a whole. Man, society, culture, nature – all these levels of ideas about being are interconnected by overlaying each other with appropriate fields, concepts, as well as different psychological and intellectual forms of their organization and many ways of combinations and recombinations.

At present, such ideas about the field are concretized by domestic researchers in relation to music and musical culture. In this direction, an intensive analytical search of adequate models is carried out, explaining the role of music in culture, which is reflected in the thematic and substantive nature of scientific conferences, as well as academic literature devoted to consideration of music in the framework of the information theory. Introduction to the analysis of musical culture of the concept of “information field” helps to understand the essence of this culture in the form of a sound-energy or spiritual-psychological space in the culture of a specific nation.

As an example of using the concept of a music-information field, consider the theoretical constructs by Minayev who develops heuristic methods of informational interpretation of music and musical culture, acquiring paramount importance in the study of musical interaction processes. As one of the most significant information bases of human adaptation to the environment, the author calls the sound, the sound of the voice, the information embedded in the intonation. Based on ideas about the field forms of people’s consciousness and emotions, Minayev interprets musical art as an adaptation-communicative experience of the human community, as the primary mechanism for the resonance of emotions [18].

Indeed, in music, idealized emotional information is as if condensed and compacted. Music and musical art give rise to the field effect of emotions encoded in rhythm-intonation and expressed in joint or solo music-making. At the same time, music performs imitative (mimetic) functions, leading to the movement of epidemic mechanisms for the dissemination of cultural information. In this case,

similar emotions, perceptions, and assessments, first forming in the minds of individuals, then begin to spread in social communication networks. This action of music manifests itself both on simple levels of information exchange, and on the most complex, embodied in many-valued symbolic structures. It corresponds to the organization of the entire system of forms and genres of music, music education, broadcast and transmission of musical experience.

#### **4. Semantic approach**

With the development of the informational approach to music, the formation and deepening of semiotic analysis takes place, an important direction of which is the study of the meaning and significance of musical works. Semantics as a direction of studying the relation of signs to what they mean, contributes to concretization and deepening of the informational trajectory of the nature of a musical work. In addition, the semantic approach clarifies an important circumstance related to the interpretation of musical information: this approach allows replying the question of how music can reflect some non-musical realities.

The concepts “musical language”, “musical thinking”, “musical speech” used in musicology acquire in the semantic analysis of music not a metaphorical character, but a character close to the literal meaning. Meanwhile, it is known that some experts in the field of linguosemiotics denied or underestimated music as the carrier of a semantic link. For example, Lotman considered that music among the arts stands apart due to the specificity of its language: “Music sharply differs from natural languages by the absence of obligatory semantic links ...” [19].

However, musicologists and aestheticians, engaged in the analysis of musical art from semiotic positions, showed the obligatory nature of semantic links in musical texts. The psychobiological “mechanisms” of combining semantic units in music were analyzed in detail by Medushevsky and Nazaykinsky [20, 21]. Kholopova puts that the analogy of iconicity, visualization in music is expressiveness, intonation, which determines the semantic stability of the “utterance” [22]. Applying to music the systematics of artistic signs, developed on the basis of the Pierce’s theory, she identifies the following musical signs.

1. Emotional signs: expressive (analogous to iconic), they model psychological processes – growth, tension, reaching a climax, recession, calm, etc.:

- a) voice – song, declamation;
- b) motor – rhythmic.

2. Subject signs are indexes. There exist in music as indirect reflections on some accompanying trait: the image of birds by transmitting one of the signs – chirping or movement of wings, etc.

3. Conceptual signs are symbols. They are conventional signs, acting as if by agreement of the author with the audience or, in other words, by virtue of fixation in the historical ethnonational musical practice:

- a) musical – associated with musical or non-musical phenomena;
- b) verbal – displayed in the names of musical works in the poetic text of the vocal work.

See also the typology of musical signs by Bonfeld, similar to the scheme proposed by Kholopova, but having a more philosophical nature [23]. In this case, the whole reality embodied in music is divided into three areas, each of which has its own sub-signs.

The extramusical area includes intonations of human speech (interjections, shouts, moans, crying), as well as “silent intonations” (gesture, facial expressions, dance, plastic). Intonation and plastic, transmitted by music, reflect a wide range of experiences, emotions, as well as marks that relate to reality.

Intra-musical area includes semantics related to extra-musical reality, but mediated by music, – signals indicating nature and the world around man: striking of clock, singing of birds, military signals, traffic, etc. Signs of this kind significantly expand the meaning and value of the musical fabric. For example, in Christian culture, imitation of bell ringing introduced into sounding music gives it an additional religious meaning.

The synesthetic area transmits not only auditory sensations, but also visual and tactile. Here, the expressiveness of the music itself acquires special significance – its timbre, loudness, tension, etc. So, they speak about gravity, weight, solidity or, on the contrary, about lightness, airiness, weightlessness of a musical text. Synesthesia is also contained in rhythm manifestations. It is primarily about the level of pulsation – a calm, feverish rhythm; a rhythm that refers to time and space, etc.

Summarizing the above, one can distinguish those semantic aspects that are of particular importance in analyzing the processes of musical interaction and are taken into account in this study. The authors speak about the following semantic elements, qualities and aspects of music:

- sensual-emotional and intonational;
- content-semantic – meanings, symbols, images and their evaluation;
- palm-tone and metro-rhythmic;
- species and genre;
- social and communicative;
- worldview.

It is quite obvious that the realization of the specified semantic qualities of music presupposes the presence of certain material-physical processes represented in the dance, in the instruments, in the voice of a singing person. Accordingly, these aspects of musical practice should be given special attention. The semantics of music is also inextricably linked with the broad context of sociocultural life. Here it is important to take into account the connection of changes in musical semantics with the dynamics of people's livelihoods, social relations, and transformations in other symbolic areas of culture, primarily in other areas of art. All these processes constitute a general concrete historical background, against which musical interactions usually develop and on which they largely depend.

Summarizing all that the information and semantic potential of music brings, it should be emphasized that this potential turns out to be the main component of the musical fabric. At the same time, it is important to take into account the fact that it contains the most diverse typological phenomena and elements: those generated by the previous stages of the development of ethno-national music, and those currently born; those inherent in a given nation, and those borrowed outside from other musical worlds; those inherent in the entire ethnonational (civilizational) community, and those representing only particular cross-sections and social strata of this community.

The main feature of the information-semantic analysis of music is to prove its clarity and the ability to be well perceived by culture bearers, i.e., by the people and those groups of the audience among which it is born and to whom is addressed. Also is becoming clear the fate of the new in musical culture. New elements may be present, but they should not suppress with their code and volume what is understandable and close to the audience. Otherwise, music cannot be deeply mastered.

Thus, the information-semantic analysis of the musical field involves the consideration of musical culture as a special sound space, possessing independent qualities, organizing stress, activity.

## **5. Results and Discussion**

Modern methods in the field of music therapy have found their most complete embodiment in digital technologies with their enormous potential of functionality, coding and visualization of information. Visual therapy for quite a long time and widely has been using computer tools in such sections as artistic development, phototherapy, color perception, creating compositions in traditional techniques (drawing, applique, collage, etc.). Armed with these tools, modern music therapy can also become an effective method for diagnosing, preventing, treating and teaching children with neuropsychiatric disorders, and more specifically, with intellectual disabilities.

Currently, computer technology in music therapy (MT) is most often used to register and process psychodiagnostic information, as well as the targeted choice of available musical patterns, based on:

- test data of the recipient, his/her national, religious, social stratification affiliation, age, level of education, etc.;
- possibilities of the heuristic method used for probabilistic forecasting and more accurate assessment of the impact of an arbitrary music sample chosen by the music therapist, taking into

account its generic specification (folk forms, liturgical music, classical heritage, popular music, musical aesthetic innovations, etc.), composer's mentality, style of presented music, genre, textural filling, instruments and compositional and expressive means used by the author.

Digital technologies expand the diagnostic capabilities of the music therapist, both in assessing the mental state of the recipient and in choosing a representative music sample, enabling to find out a lot of details, to quickly test the patient, and then, to identify associative relationships between color, musical patterns and correlates of various states, to create unique therapeutic compositions with targeted therapeutic effects on a particular patient.

However, it is possible to significantly expand the scope of application of digital technologies in music therapy. So, for example, in one of its main areas – active analytical musical and pedagogical field – the potential of digital technologies is enormous: here, in cooperation with the recipient, therapeutic and pedagogical musical work is carried out. It is generally recognized that “in medical pedagogy with disabled children with various developmental disabilities (autism, mental retardation, cerebral palsy, organic CNS lesions, Down syndrome, etc.), the patient must actively act (sing, play a musical instrument, embody music in movements) "[24].

Thus, methods of music therapy involve the activation of not only hearing, but also motor skills (gross, fine and of particular organs). The introduction of digital technologies in the medical-pedagogical methods will enable the use of visual images and other types of specific fine motor skills associated with working on a computer. Activation of motor skills will contribute to the development of thinking logic, coordination of muscular efforts when using a computer mouse while tracking the movement of the cursor on the screen and pressing keys on the keyboard. The touchscreens that appeared a few years ago also involve fine motor skills and coordination of muscle movements, being yet more accessible for young children and children with limited mental capabilities, since they do not require intermediaries, such as a computer mouse and keyboard, to interact.

Considering the possibilities of using digital technologies in such a field of MT as active analytical musical and pedagogical therapy. Of course, they are not infinite, and in some cases have very significant limitations. However, it should be noted that the experience of their use in teaching music to healthy children is so positive that it suggests the possibility of transferring into the sphere of work with disabled children with various developmental disabilities.

In correctional and pedagogical work, the music therapist usually works with the pupil individually, using one of the musical instruments, most often a piano, or a synthesizer. In this case, one can use all the developed methods of receptive (passive) MT. However, the music therapist must take into account all new research in the field of clinical practice, focused on the role of creativity at different levels of communication between the music therapist and the recipient. In addition, the music therapist is obliged to take into account the nature and diagnosis of mental disorders of the recipient. All this involves focusing the activity of the music therapist on the integrative role of musical elements in the treatment and pedagogical process and the ways of children's self-expression through musical improvisation directly during the performance of music. Learning the art of improvisation requires a qualitative study of musical literacy so that the student can coordinate the elements of the transmission of musical thought on the basis of: duration of sound, variability of loudness and tempo dynamics, size, harmonic tone, degree of tonal relationship, timbre-harmonic coloring, etc.

Now, considering in more detail the possibilities of digital technologies in teaching musical literacy to children with intellectual disabilities.

The first group of possibilities is the area of graphic visualization of sound, considering its duration, volume, timbre, location of the sound in a particular register, some or other octave.

A regular laptop can show the spectrum of sound and the duration of sound using special software. For children with developmental disabilities, the classic spectrum graph can be replaced with color graphic symbols that change their color and size as they sound. The loudness of the sound can be expressed in the form of resizing shapes, such as colored cubes.

Each note can have its own color. For children with disabilities, the number of notes should be added gradually, starting with two notes, while taking into account warm and cold tones of color. Major sounds can be described as warm tones, and minor sounds – as cold.

Symbols can be used to distinguish between the location of the octaves. Symbols used should be familiar to children of a certain age, for example, animals or plants. Since for children with disabilities the number of studied octaves is usually not large, it will not be difficult to select the necessary symbols to distinguish the location of the octaves. Notes of different duration can be displayed by figures of different proportions.

There are attempts to use similar visualization of sounds for teaching deaf people music in the form of videos using particular compositions [25]. In videos, each group of instruments is assigned a graphic image. They float across the screen, becoming brighter at the moment of the sound. However, these videos do not use symbols and do not reflect the volume of sounds. They help in the study of individual compositions and are not intended for children.

The second group of opportunities is animation. For children with disabilities, simple two-dimensional animation is sufficient. At the same time, musical symbols can be displayed in the form of video characters, which come together and organize octaves and combinations of sounds, or, conversely, disperse and change their size, for example, become an image of a giant or a mouse. An animated explanation of the simplest mathematical concepts used in music, such as proportions, is acceptable. At the same time, communicative social opportunities are demonstrated to the child along the way.

The third group of opportunities is gaming. Many actions on the synthesis of musical compositions can be represented in the form of a game, associated in children with well-known and favorite construction kits. In this case, with a touchscreen, the synthesis of music is even closer in technology to the construction process.

The fourth group of opportunities is that the computer is well adapted to work with the spectrum of sounds and their analysis at a professional acoustic level and can even visualize the timbre. The features of a person's hearing are such that often with a sharp change in the volume and frequency of sound, the sound perception is disturbed for a while, however, the computer continues to record all sounds in this case and analyze their spectrum. Thus, using a computer, it is possible to demonstrate the deficiencies of the game technique that cannot be heard by ear.

The greatest difficulties in the implementation of teaching musical techniques are learning to catch the tone and its recognition. A person is able to catch quite subtle tones, but is not always able to recognize them. In the computer, the main method of recognition is artificial intelligence. Using this method, one can "train" the computer to capture and recognize different tones. However, it should be emphasized that the creation of applications for the recognition of sound compositions for children with disabilities is a separate task requiring development of a special technique.

## **6. Conclusion**

Unfortunately, the computer is not omnipotent. Even the most powerful computer is not yet capable with a sufficient level of quality to recognize human speech, especially that of native speakers of various ethno-national cultures. Therefore, it is unlikely that the computer will help, for example, in learning to sing. The computer is also not able to work with the mechanism of illusions, both optical and musical-sound.

Nevertheless, this study showed that since music, unlike an image, is easier to be mathematically processed, the use of a computer in music therapy has good prospects. Within the framework of the informational-semantic approach, a computer is able to ensure the completeness of the analysis of any music therapy technology from the micro to macro scales.

Based on the theoretical conclusions of the conducted research, it is planned to create an electronic workbook on teaching music to children with disabilities in the future. This workbook will lay the teaching methodology, including the main theoretical conclusions of this study. The tutorial will provide various levels of presentation of multimedia material.

The main conclusion of this study is that the application of digital technologies to the study of the problems of music therapy within the framework of the informational-semantic approach is a reliable basis for the optimal use of the opportunities of computers and music for applied therapeutic purposes.

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