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Psychophysiology and psychoacoustics of music: Perception of complex sound in normal subjects and psychiatric patients

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Abstract

Perception of complex sound is a process carried out in everyday life situations and contributes in the way one perceives reality. Attempting to explain sound perception and how it affects human beings is complicated. Physics of simple sound can be described as a function of frequency, amplitude and phase. Psychology of sound, also termed psychoacoustics, has its own distinct elements of pitch, intensity and tibre. An interconnection exists between physics and psychology of hearing.

Music being a complex sound contributes to communication and conveys information with semantic and emotional elements. These elements indicate the involvement of the central nervous system through processes of integration and interpretation together with peripheral auditory processing.

Effects of sound and music in human psychology and physiology are complicated. Psychological influences of listening to different types of music are based on the different characteristics of basic musical sounds. Attempting to explain music perception can be simpler if music is broken down to its basic auditory signals. Perception of auditory signals is analyzed by the science of psychoacoustics. Differences in complex sound perception have been found between normal subjects and psychiatric patients and between different types of psychopathologies.

Review

Perception of complex sound is a process carried out in everyday life situations and contributes in the way one perceives reality. Both nature sounds and sounds in most everyday situations are complex sounds composed of basic sounds. Basic sounds are most often produced and heard in laboratory situations. Attempting to explain sound perception is complicated. Sound has a physical and a psychological component. Physics of sound has its origin in the pressure changes as a result of the vibration of an object. Such changes are perceived by the human outer ear, propagated and amplified through the ossicles of the middle ear and the area difference between the tympanic membrane and the oval window. Psychology of sound is based on the perception of its characteristics. It starts in the motion of the basilar membrane in the coch-

lea of the inner ear and proceeds to the cochlear nuclei and to the central auditory pathway to reach both hemispheres of the human brain.

Physics of simple sound can be described as a function of frequency, amplitude and phase. Complex sounds according to Fourier analysis can be broken down into a series of simple sounds. The frequency components of the complex sound are known as harmonics. Psychology of sound seems to correspond to the analysis of sound according to Fourier. Psychology of sound, also termed psychoacoustics, has its own distinct elements of pitch, intensity and tibre. Perception of sound and music is such that humans are able under certain circumstances to distinguish the harmonics of a complex periodic sound wave. The hearing sense provides human beings with data concerning their environment.

An interconnection exists between physics and psychology of hearing. Blowing of the wind, sea waves, birds singing are more than audible sounds; they have the ability to interact with the emotions and mood of a human being and create feelings. Music is the human effort to express emotions. It has the ability to influence mood, to remind us of a certain moment, to create feelings. Music contributes to communication and conveys information with semantic and emotional elements. These elements indicate the involvement of the central nervous system through processes of integration and interpretation together with the peripheral auditory processing [1].

In order to study music perception and the way it influences human beings, different approaches have been used involving the types of music, the emotional experience, psychosomatic and physiological changes and psychoacoustical characteristics of music. In certain cases music has been thought to enhance brain functioning [2]. Data evaluation reveals the fact that listening to a Mozart's Sonata for two pianos in D major (K448) lead (according to one study at least), to a subsequent enhancement in spatial-temporal reasoning. However other researchers have investigated the effect with conflicting outcomes [3-5]. The above results highlight the difficulty of comprehending music influences in human brain, particularly since it is composed of complex sounds.

The way music changes blood pressure and heart rate was investigated by several studies with different results. There are studies showing increased heart rates as a result of stimulating music and decreased heart rates associated with sedative music [6,7]. Other studies document increased heart rate as the result of listening to sedative and stimulating music [8] and Shatin [9] notes an increase in long term schizophrenics. Gerra et al [10] found that the type of music can influence heart rate and stress-related hormones. Specifically Techno-music seemed to produce a significant increase in heart rate, systolic blood pressure and stress-related hormones. Classical music produced no significant changes in these parameters.

Psychophysiological reactions in students due to exposure to a distorted sound of 400 Hz frequency, 109 db intensity and 0.5 sec duration are documented as follows [11]. Systolic and diastolic blood pressure were increased 4–11 seconds after the intense auditory stimulus. Afterwards blood pressure was decreased and reached the normal level a minute after. This study shows a temporarily increased blood pressure.

An interesting study documents the psychological and physiological effects of sound [12]. Monitoring of the subjective perception and the heart and respiratory rate took place during three different sound conditions, the first source being a synthesizer, the second bird twitters and the third mechanical sounds. Inhibition of the parasympathetic nervous system as a result of listening to mechanical sounds was documented together with promoting an unpleasant and alert feeling. This study suggests that the heart rate variability changes according to subjective perception.

Loudness and annoyance are two subjective parameters that can be influenced by age, personal preferences, previous musical studies and exposure to different kinds of musical pieces. Two studies by Fucci et al [13,14] are concerned with the preference of loudness for rock music. It seems obvious that a sound distorted with noise produces unpleasant feelings. Judging the annoyance of a musical piece produces different results than judging its loudness. Annoyance scale appears to be more context-dependent.

Listening to music can be emotionally arousing. Disclosing personal information is beneficial both from a physiologic and physical point of view. Jensen [15] examined the effect of music in 85 students within a disclosure setting. The study involved speaking of the most significant event of the subject's life with and without background music. The results confirmed the effect of music on the disclosure topics, enhanced cognitive expression and enjoyment of classical music.

Emotional experience due to music exposure is difficult to evaluate and study in a systematic way. In a well-organized work [16] 50 normal hearing persons with no special interest in music were studied. Their task was to rate each of the 13 pieces of newly composed music according to 20 semantic scales. Differences in emotional experience have been documented between women and men, with women experiencing more tension in music and between

different age groups and with older people experiencing more attraction to music than younger ones.

Psychiatric patients may experience music differently than normal subjects and this fact can be helpful in monitoring hearing perception in the different psychopathologies. In a comparison of normal subjects and psychiatric patients [17] music was experienced in the same way with only small differences. However, when evaluating each psychiatric group independently several differences were demonstrated. Schizophrenic patients may experience music as more attractive than normal subjects. Depressive and anxiety neurotics experience music as less attractive than normal subjects. Obsessive compulsive patients are more sensitive to music than normal subjects. In a different study by the same researchers [18], a comparison of two pieces of music with different tempo, slow and fast, revealed a difference in experiencing of music between normal subjects and patients with mania. Patients with mania associated fast tempo with positive emotions and declared attraction to it, with the control group having the same emotions with slow tempo music.

In an interesting and well-designed study on the perception of complex sound in schizophrenia and mania [19]; complex nonverbal sounds with 3 s duration were used. They were used instead of music as they are more simple to analyze. They were chosen to represent variation in frequency, amplitude spectrum and envelope. The patients were selected from a ward department with classification according to ICD 9. Testing was performed no later than 1 week after admission as a general rule. The main result of the study was that short complex sounds give rise to different emotional experiences in the two psychopathological groups as compared to the normal subjects. Patients with mania experienced the complex sounds as less tense and schizophrenic patients as more tense and more attractive. These statistically significant differences are supposed to be due to the short stimuli used as opposed to previous studied were musical pieces were used. These kind of auditory stimuli can more easily be grouped according to their different psychoacoustical characteristics.

Music is highly complex sound. A simple sound has the psychoacoustical characteristics of pitch, intensity and tibre. Music has the additional element of rhythm, which is time-dependent. Simple units of sound combine into highly complex patterns [20]. Basic units of sound containing the elements of pitch, intensity, timbre and rhythm progress into larger units and form musical melodies. Both time and frequency are important for perception of sound by the primary auditory cortex [21]. The auditory cerebral cortex occupies the dorsal surface of the temporal lobe and has at least 15 subdivisions. Neurons in the core region of the auditory cortex are responsive to pure-tone stimuli and those in the periphery are better activated by more complex sounds [22]. This opens up the discussion of whether there may be a neural network dedicated exclusively to music perception [23]. There is a study with subjects presenting disorders of musical perception with no linguistic disorders and no difficulty on prosody. The researchers of this study proposed the hypothesis that the observed deficits were the result of a deficit concerning pitch perception. It is difficult to support such an explanation. Neuroimaging studies may contribute in revealing characteristics of music perception [24]. This research has mainly focused on normal subjects being musicians or non-musicians. An interesting study has been published on a patient with central auditory processing disorder [25], with documentation of increases in cerebral blood flow in the lateral prefrontal cortices, the middle temporal cortices and the cerebellar hemispheres as a consequence of attentive listening. This research in central auditory pathology is only recently developing as the complexity of the auditory cortex with its 15 known subdivisions is starting to be appreciated.

Conclusion

Perception of music in normal subjects and psychiatric patients is reported to be different. Analyzing the way music affects human beings may be easier and better when using simpler and shorter sound stimuli. All psychoacoustic elements of sound are represented in the human auditory system starting from the cochlea, the cochlear nuclei and the central auditory pathways all the way up to the temporal lobe. Future research is important in order to document normal responses and reveal patterns of perception in different psychopathologic groups.

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