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MUSIC PERCEPTION OF THE BRAIN AND ITS DEVELOPMENTAL EFFECTS

Müziğin Beyinde Nasıl Algılandığı Ve Gelişimine Olan Etkileri

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ÖZET

Among the many other different functions of human brain perception, production and developmental aspects of music has been the interest of many researchers. This subject has been the area of interest of not only the musicians but also the neurologists and the neuropsychiatries.

Throughout human history, in every human culture, people have played and enjoyed music. Thus music is a phenomen happening and practiced everywhere. Only humans can learn to play musical instruments, and only humans can play instruments cooperatively together in groups. Making music in a group is a tremendously demanding task for the human brain that engages virtually all cognitive processes.

Music education is a very important form of education with its instructive and motivational aspects to be educative, nurturing, developing, patient and disciplined. Throughout history, nations of the world have believed in the educational role of music, regarded it as an educational tool and attached importance. In today's modern life, the brain has become an indispensable principle of education with its role in interaction and work.

How does the brain perceive, compose and interpret music? Today these questions are still perceived as open-ended questions. What are the communication paths and centers responsible for composing and perceiving music? Is it possible to develop them with training? In this study, answers to these questions were sought by making an extensive literature review.

Key Words: Music, brain, music perception, music education.

ABSTRACT

İnsan beyninin çesitli fonksiyonları arsında müziğin olusturulması ve yorumlanması geçmisten günümüze birçok araştırmacının ilgi odağı olmustur. Bu konu müzisyenlerin olduğu kadar nörologların ve nöropsikiyatristlerin de ilgisini çekmistir.

İnsanlık tarihi boyunca, her kültürde insanlar müzikle uğraşmış ve müzikten keyif almıştır. Dolayısıyla müzik her yerde olan ve uygulanan bir fenomendir. Sadece insanlar müzik aleti çalmayı öğrenir ve sadece insanlar gruplar halinde ve iş birliği içinde enstrüman çalabilir. Bir grupta müzik yapmak insan beyni için neredeyse tüm bilişsel süreçleri devreye sokan müthiş zorlu bir görevdir.

Müzik eğitimi, eğitici, yetiştirici, geliştirici, sabırlı ve disiplinli olmayı öğretici, güdüleyici yönleriyle oldukça önemli bir eğitim biçimidir. Tarih boyunca dünya milletleri müziğin eğitsel rolüne inanmışlar, ona bir eğitim aracı olarak bakmış ve önem vermişlerdir. Günümüz modern hayatında beyin, etkileşim ve çalışmasındaki rolü ile eğitim anlayışının vazgeçilmez bir ilkesi haline gelmiştir.

Beyin müziği nasıl algılar, olusturur ve yorumlar? Bunlar bugün bile ucu açık sorular olarak algılanmaktadır. Müziğin olusturulmasından ve algılanmasından sorumlu merkezler ve iletisim yolları hangileridir? Bunların eğitim ile geliştirilmeleri mümkün müdür? Bu çalısmada geniş bir literatür taraması yapılarak bu sorulara cevaplar aranmıştır.

Anahtar Kelimeler: Müzik, beyin, müzik algısı, müzik eğitimi.

1. INTRODUCTION

Music is the art of combining different pitches into sequential patterns of harmonic configurations of diverse duration, intensity, and timbre. As such, it is a creation of the human mind. More correctly it is a creation of the human brain that made use of structures it inherited from evolution (Sergent, 1993). All aspects of human life, the physical, mental, emotional, ethical, spritual and musical aspects are functions of brain activity.

It is only normal that research on this subject is conducted in fields where special and different skills are used together and on people who work in these fields. Since music is one of the few activities where the brain's different functions are used together, it has been from the past to the present day the focus point of many researchers in how it is perceived, developed and interpreted by the brain.

There have been important advances in recent years toward understanding various brain structures and brain functions. A lot has been learned about the brain in the past years, but there is still a significant gap between such findings and their relation to life and the consciousness. (Reimer, 2004).

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Music and the brain, a subject that has been until recently more of a research topic for neurologists and neurophysiologists, has started to kindle the interest of musicians as well. Why should musicians and music educators care very much about present brain research? The musician's interest is so far removed from such work that even brain researches often seem to be either academic or even irrelevant to the musician.

The situation is somewhat different for neurologists. Since music requires many different perceptions and attributes, whether for performance or creativity, and also because it is one of the main and oldest socio-cognitive fields of human kind, musicians are for neurologists an ideal test subject group in order to observe brain development and plasticity. Plasticity, or neuroplasticity, is the lifelong ability of the brain to reorganize neural pathways based on new experiences. In oder words plasticity refers to how circuits in the brain change, organize and reorganize in response to experience, or sensory stimulation. The ability of the brain to change with learning is what is known as neuroplasticity.

Doing music involves evolutionary functions such as communication, cooperation, group coordination and social entirety. It is a multidimensional profession that activates almost all of the mental activities of the brain such as perception, movement, feelings, learning and memory. It is this richness that makes music an ideal tool for investigating how the brain works. In the last 30 years, thanks to technological progress the image of the way music happens in the brain has gone through lots of changes and music started to be considered as a different cognitive skills group.

Researches on the biological foundations of music have shown that the brain possesses areas in the anterior part of the right superior temporal cortex specific to music such as frequency analysis (pitch) and that it also brings together different mechanisms and fields to create new cognitive patterns such as sound and time organization. As a matter of fact, the way the brain functions when it comes to music shows lots of similarities with how music within itself works; music also embraces different components and can analyze these separately and can also bring them together to create a new formation.

Music, just like mathematics and chess requires high brain functions. Dealing with music lays the foundation of a well-developed "spatial" intelligence. Spatial intelligence is the ability to perceive the visual world, to form mental images of objects and the ability to conceive the differences they manifest (Boettcher et al., 1994).

Throughout history, nations all around the world have believed in the educational role of music, considered it as an education tool and gave great importance to it. In today's modern world, with its effects on the brain and how it works, musical training has become an indispensable element of the concept of education. This is still an early stage of knowledge but the discipline of neuroscience of music is developing rapidly.

2. MUSIC PERCEPTION

In recent years investigators have begun to have a firmer understanding of where and how music is processed in the brain. Collectively, studies of patients with brain injuries and imaging of healthy individuals have uncovered no specialized brain "center" for music. Rather music engages many areas distributed throughout the brain, including those that are normally involved in other kinds of cognition. The active areas vary with the person's individual experiences and musical training. Yet our mental response to music is remarkably adaptable. Even a little study can retune the way the brain handles musical inputs (Weinberger, 2004).

Neuropsychologists use scientifically validated objective tests to evaluate brain functions. While neurological examination and CT, MRI, EEG, and PET scans look at the structural, physical, and metabolic condition of the brain, the neuropsychological examination is the only way to formally understand brain function.

Imaging findings suggest that a region in the frontal lobe enables proper construction of the syntax of both music and language, whereas other parts of the brain handle related aspects of language and music processing. Imaging studies have also given a picture of the brain's responses to music. These results make sense when placed in the context of how the ear transmits sounds in general to the brain. Like other sensory systems, the process of hearing is arranged hierarchically, from the ear to the highest level the auditory cortex (Patel, 2006).

2.1. Localization Of Music Perception In The Brain

The response to music or our perception of music, though, is more complicated because it is the sum of essentially different musical elements. These basic elements pitch, intensity, duration, rhythm, and memory, are spread across many different parts of the brain – the basic primordial brain, the middle brain where emotions are located, and the most recently developed neocortex, where the intellect resides. The neocortex consists of the two brain hemispheres connected by the corpus callosum (Perry, 2002).

The frequency analysis of sounds takes place first in the cochlea in the inner ear, then they are transformed according to their qualities such as pitch, timbre, intensity into neural signals in the auditory area of the brain stem. These kinds of informations are sent via the thalamus to the primary auditory cortex. The thalamus is, at the same time, directly connected to the amygdala, which is related with emotions and emotional behavior. More specific information about acoustic qualities such as pitch level, color, timbre, and intensity get separated in the main auditory center and enter into the auditory memory; this is how is the auditory Gestalt phase or integration phase is achieved.

This auditory Gestalt formation necessitates melodic, rhythmic, tonal and spatial grouping. This acoustic elements' grouping is followed by similarity and continuity. Briefly, the Gestalt effect or formation is a much more delicate analysis stage that translates into a more detailed analysis of the relationship between the pitches of a melody or a chord - for example, whether the cord is a major or a minor chord - or of the rhythmic elements. In addition, researches done on damaged brains have established that melodic and rhythmic elements are being processed independently. Even though a damaged brain cannot differentiate between the pitches, it can differentiate the rhythmic elements flawlessly or vice versa (Koelsch, Siebel, 2005).

Music consists of a sequence of tones, and perception of it depends on understanding the relationships between sounds. In other words, in order for us to musically perceive the sounds we hear, the auditory stimulus is firstly broken down into its components; in this way, the two-sided, separate cortical areas come into play within an anatomical and functional hierarchy. This is a hierarchical system that starts from the ear, continues to the brain stem, thalamus and up to the auditory cortex.

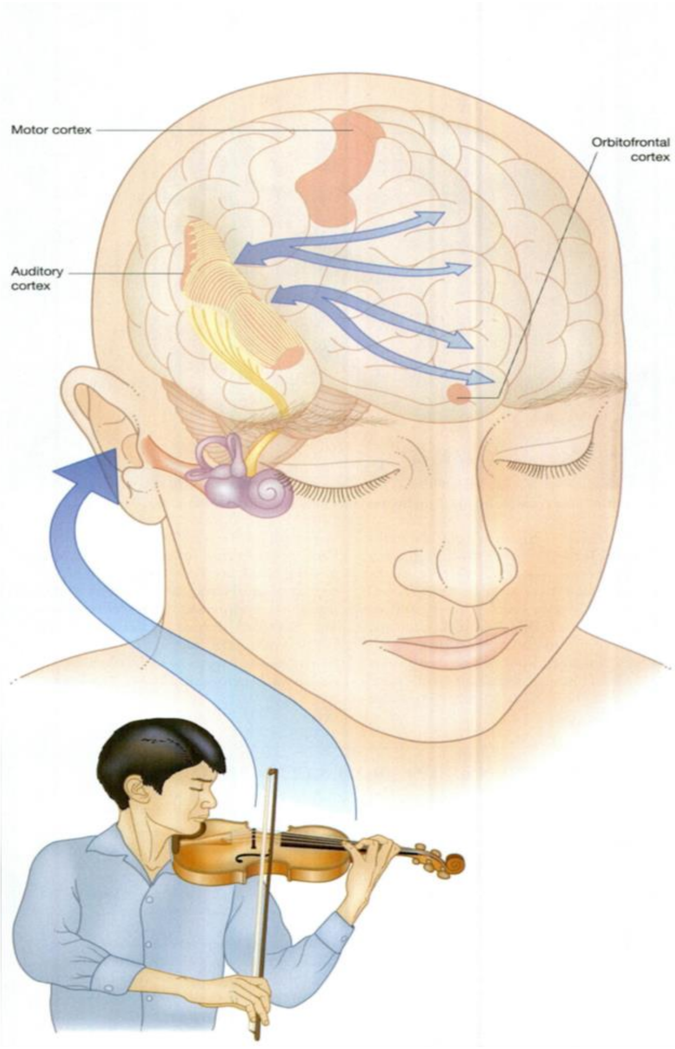

Figure 1. The processing of sound waves from a musical instrument (Zatorre, 2005).

As seen in figure 1 information coming from the auditory cortex also affects areas that control other functions of the brain; it steps in especially for the frontal lobe memory formation. The orbifrontal area is one of the areas where emotional evaluation is realized. And the motor cortex is of course the area that controls the movements necessary to play an instrument (Zatorre, 2005).

Thus, the total conscious experiance of music is the result of activity widely distributed brain areas, wich form neural networks dedicated to particular aspects of musical processing (Warren, 1999). Many areas of the brain are involved in processing the various elements of music. Rhythm, wich is the analysis of relative lengths and spacing of notes occurs mainly in the left hemisphere, while timbre (coulor) and melody are processed mainly in the right.

Timbre is the difference in sound color that enables the differentiation of sounds. It can also be called the quality of sound. Pitch is the perceptual correlate of periodicity in sounds. Periodic sounds by definition have waveforms that repeat in time (Mc Dermott, Oxenham 2008). It is more difficult to decide on the timbre than to describe the pitch or the fullness. It is easy to express whether the pitch is higher or lower, or whether the fullness is less or more whereas it is quite difficult to decide about when it comes to timber.

Timber perception is in third position in the auditory system while it occupies the first position in music or in recognition of the source of the sound and the instrument. In other words, the first thought upon hearing a sound is not the pitch or the fullness but what sound it is. The situation is clear also for harmony. Imaging studies of the cerebral cortex find greater activation in the auditory regions of the right temporal lobe when subjects are focusing on aspects of harmony. Identification of familiar compositions, is predominantly a left hemisphere function. (Figure 2)

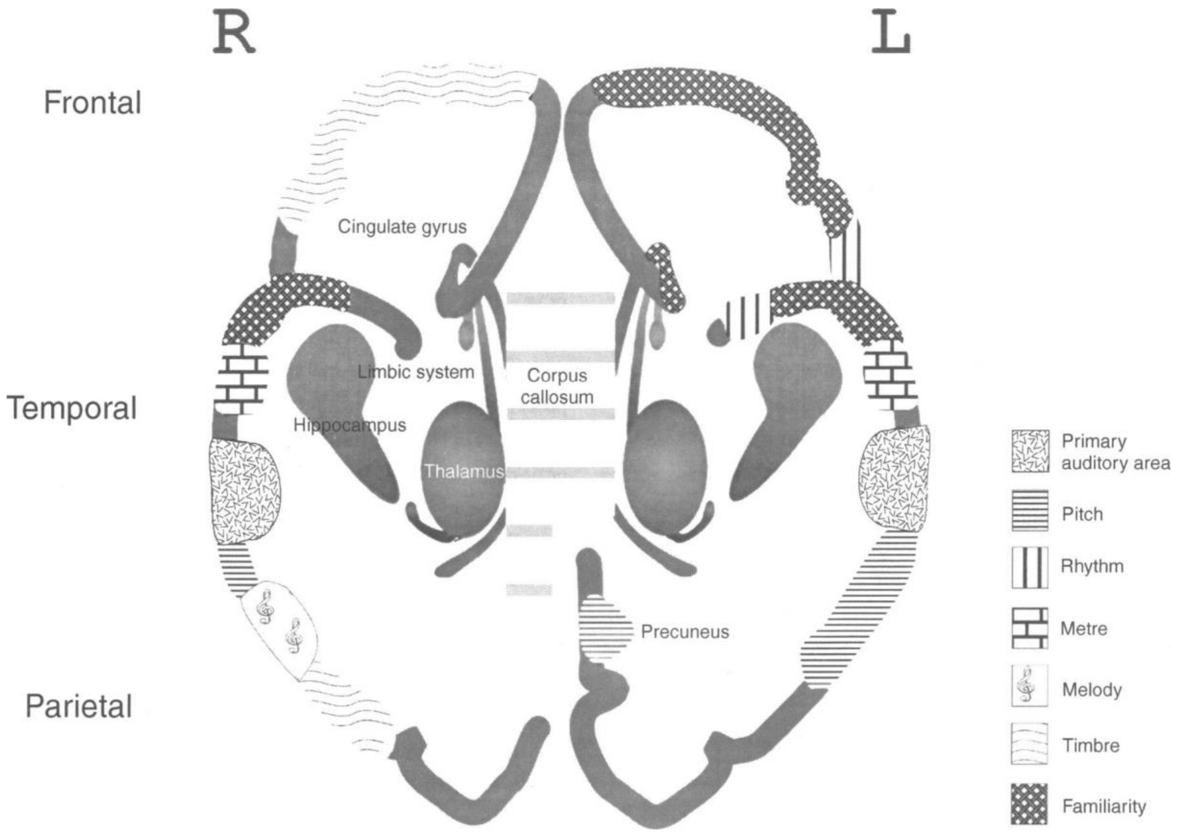

Figure 2. Human cerebral hemispheres, shwoving structures involved in music perception (Warren, 1999).

The role of the two hemispheres in music perception has been investigated with dichotic auditory testing of healty subjects (Kimura, 1961). These studies indicate involvement of the left hemisphere in temporal, sequential and rhythmical discrimination and the right hemisphere in tone pitch, melody and harmony. However, a study with monaural stimulation established that the cerebral dominance for the recognition of melodies was in fact on the left in musicians, while in non-musicians right dominance was reconfirmed. In musicians left hemisphere perceives the progress of the melody which requires musical memory. In agreement with the general theory of hemispheric differentiation, musical perception in musicians, therefore, takes place analytically in the left hemisphere and in nonmusicians holistically in the right hemisphere (Bever and Chiarello, 1974). Holisticaly means dealing with or treating the whole of something and not just a part. Musicians interpret music more deeply than non – musicians. A point to note is that for musicians, just passive listening is more difficult because of their spontaneous analytical processing, and this possibly contributes to the left lateralization.

A distinct opinion on this subject is that hemispheric dominance is affected by culture. For example, Weisser's research in 1987 has determined that while the Japanese perceive Japanese folk music in their left hemisphere, the Westerners perceive the same music in the right hemisphere (Warren, 1999).

It is unfortunate that researchers have not been able to identify to this date which hemisphere of the brain specializes in one of the most important components of music, namely the rhythmic procedure. Determining the area of the brain where rhythmic and metric processes take place must certainly be a difficult task for researchers since they seem to provide constantly conflicting results.

Following a general presentation of how and where musical elements are perceived in the brain, looking at what happens to the brain when it comes to "memory", a crucial subject for musical performance and performers as well, is necessary. There are several memories such as auditory memory, visual memory and motor memory. For example, auditory memory is connected with both shortterm and long-term memory. The short-term memory necessary in perceiving pitch is connected especially with the inferior frontal gyrus, the premotor cortex, the parietal areas of the brain and the cerebellum.

In order to attain a complete musical perception, the connection and the integration between the two brain hemispheres through corpus callosum is necessary. This interaction through the corpus callosum can be enhanced by music.

3. THE BRAIN OF MUSICIANS

Scientists, have been particularly interested in the brain structure of musicians, whether it differs from that of non-musicians and whether training could account for these differences.

A musician does not consider music to be monolithic, but recognizes within it multiple features including melodies, chords, themes, rhythms and tempos. This psychological and musical complexity makes music a challenging topic for scientific researchers. Another reason music has caught the attention of scientists trying to understand the brain is that the ability to perceive music seems to be present from very early in development (Zatorre, 2005).

Performing music at a professional level is arguably among the most complex of human accomplishments. The musician's brain constitutes once again an ideal example for the analysis of the neuroplasticity of, not only the auditory fields but motor fields as well. A pianist, for example, has to bimanually coordinate the production of up to 1,800 notes per minute (Figure 3). Motor learning takes place during continuous practice in order to increase performance level step by step. (Münte et al., 2002).

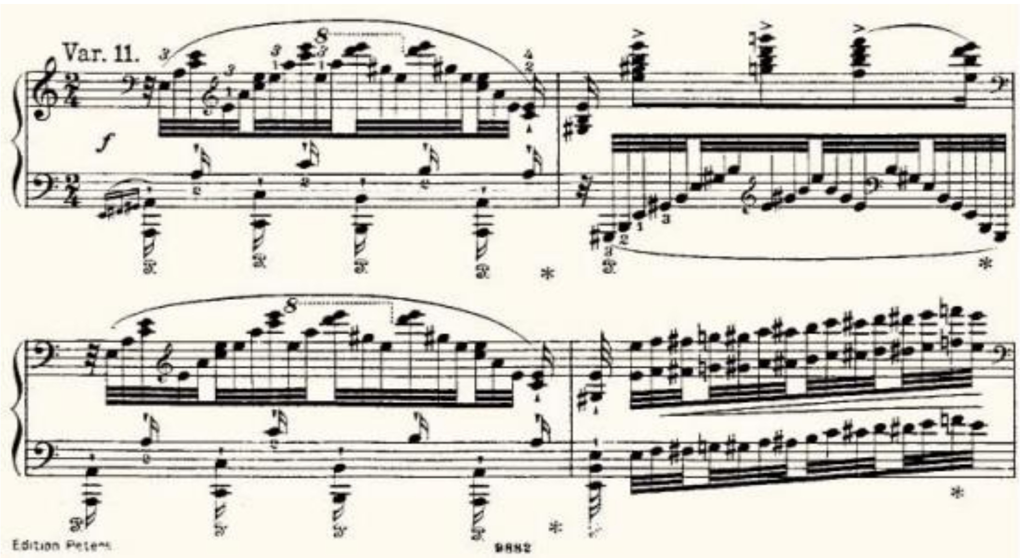

Figure 3: Example of a hypercomplex musical score. Two three-second segments of the 11th variation from the 6th Paganini-Etude by Franz Liszt. (Peters Edition).

A number of studies show that training in music enhances the activity of certain neural systems. For exemple in figure 4 areas corresponding specifically to the fingers of the left hand show a clear difference among violin players (Pantev, Engelin, 2003).

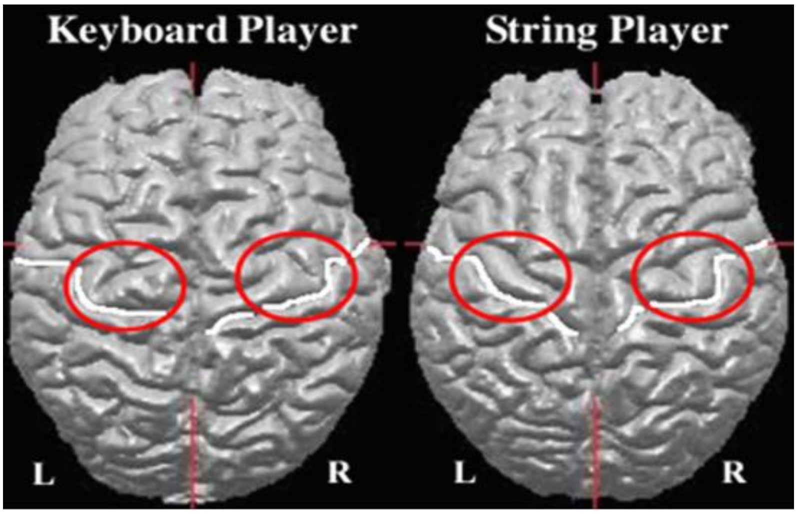

Figure 4: Areas of motor cortex corresponding specifically to the fingers of the left and right hands (Pantev, Engelin, 2003).

In a study in 1995 analysis revealed that the cortical representation of the the left hand (the fingering hand) in string players was larger than in controls (non musicians). In the case of the right hand, there were no differences between musicians and controls. The cortical reorganization of the representation of the fingers was more pronounced in musicians who had begun their musical training at an early age (Elbert et al., 1995). These changes are directly related to the age at wich training is begun: those who began studying music in early childhood show the most extensive modification to brain response, whereas those who waited until after puberty show much less (Pantev, Engelin, 2003).

3.1. Developmental Aspects Of Music On The Brain

Numerous researches demonstrate that some mental functions of children who are musicians develop faster than those of other children of the same age. There are conflicting results on whether these differences have any reflections upon the later stages of their lives. There are studies showing that the advantage gained during the first years of music training fade away with time and that the differences, including mathematical skills disappear. On the other hand, it is observed that these studies have always been conducted on children between the ages of 5-11 who are attending elementary school; namely before or at the very beginning of their non-musical academic education. The musical training they receive during that period can lead to important differences in their perceptions and brains and they might have surpassed other children of the same age. However, this difference might be disappearing over time with age, increase in education level and areas. Since a child's mind is unoccupied and clear it is evident that an education, which includes mathematical elements and is based on rhythmicality and symbols, will set those children apart from the others. However, an intensive mathematics, physics or literature education later on might result in the same brain areas of the other children to develop in the same way. In other words, while musicians develop the area of the brain related to mathematics with music training, the non-musicians develop the same area with an intensive mathematics education. It can be stated that even though it might differ from one person to the other, the development is in general similar however the ways used to achieve it are different.

4. CONCLUSION

In many studies complex and widespread activation in many brain areas is seen while performing, listening or mentally imaging music, activity that varies with training, previous exposure, emotional involvement and many other factors.

Science has not found a specific "music center" in the brain because the ways in which the brain processes music is complex. It is known that music affects human neurological, psychological and physical functioning in such areas as learning, language processing, emotional expression, memory, and motor responses.

To play an instrument needs practice. Musical training involves complex motor and auditory and other cognitive skills. It requires also memorizing long, complex bimanual finger sequences and translating musical symbols into motor sequences. Practice of complicated bimanual motor activity produce changes in the brain structure.

Today, modern music education plays a crucial role in the bringing up of the modern man. Music education is, with its educating, training, improving, emotion and skill enhancing, challenging, patience and discipline teaching and motivating qualities, a considerably important type of education.

However since music is a personal experience affected by the union of environmental and genetic factors such as education, personal preference and sentimental involvement, the capacity of neuroscience to understand and explain this personal musical experience is quite limited.

Whether factors involved in musical training such as bimanual motor coordination, learning to read musical notation, concentration, attention, auditory and memory training, timing can transfer to non-musical domains such as lunguage, mathematics, or spatial reasonning is polemical. There is some evidence that it might be the case, but many of the studies are based on few individuals under specific test situations and further studies are needed.

Although all the research done is shedding light on many points, it cannot totally answer all of these questions, for certainty is not possible in science. Since the universe is ever changing, science has always to be open to innovations. The aim of the researches is to obtain some results in the light of the information available today. But in the future, with new inventions and new technologies the information at hand might completely change and totally new results may be obtained. Nonetheless, results obtained from researches conducted with today's technologies and means are not to be underestimated. Possibilities such as seeing what happens in the brain during a music performance, which were until recently unimaginable, are nowadays considered common.

It is thought that some interdisciplinary studies used today and that will continue to be used in the future, will bring different points of view to humanity in all fields including the arts; they will open new horizons, provide the opportunity to determine new strategies for education and practice.

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