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The effects of music on brain development

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Abstract
The influence of music on brain development is a complex and widely studied area in science. Studies show that being exposed to music, especially in early stages of life, can improve different cognitive abilities like language, reasoning, and spatial-temporal skills. Engaging with music also helps in regulating emotions and developing social skills. Furthermore, music education supports creativity and self-expression, which are crucial for overall brain development. With a deeper understanding of how music affects the brain at a neurological level, educators, therapists, and parents can leverage its advantages to enhance well-being and cognitive functions for people of all ages.

Keywords: music; brain development; brain research; cognitive skills; neurological level

1. Introduction

Music has been a part of human culture for centuries, serving various purposes such as entertainment, communication, and emotional expression. Music, as a universal human experience that transcends cultural boundaries and evokes a wide range of emotions, plays a significant role in shaping our brains, particularly during development. From the catchy tunes of childhood to the complex compositions we appreciate as adults, music permeates our lives and leaves a lasting imprint on our cognitive abilities. "The Effects of Music on Brain Development" have been a topic of interest for scientists and researchers. In recent years, there has been a growing body of research investigating the impact of music on brain development, particularly in children. Music education has been found to have several benefits for brain development, including language and reasoning skills. One of the main areas of brain development that music has been found to impact is language and reasoning skills. Multiple studies have shown that early musical training can enhance the development of the areas of the brain associated with language and reasoning. Musical training that involves the integration of auditory, motor, and cognitive processes, which can lead to enhanced language abilities. Additionally, an instrument instruction accelerates brain development and leads to more-developed auditory pathways in school children. Research has shown that songs can help imprint information on young minds, contributing to better language acquisition and reasoning skills in children. Furthermore, a longitudinal studies investigating the effects of music training on children's brain and cognitive development demonstrated that children in the music group had better performance in musical and verbal memory tasks compared to those in the non-music group.

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Research has also shown that music can have a significant impact on various cognitive functions. Apart from language and reasoning skills, music education has been linked to improvements in spatial-temporal skills, which are crucial for mathematics and complex problem-solving. This is because learning to play a musical instrument requires the coordination of various cognitive processes, such as reading music notation, understanding rhythm, and coordinating hand movements. These skills can transfer to other areas of academic and cognitive development, providing a more holistic benefit to brain development beginning from early ages.

Besides, the emotional impact of music should not be overlooked. Exposure to and participation in music has been shown to have a positive effect on emotional regulation and social skills in individuals. Music has the ability to evoke and convey emotions, and this engagement with emotions can have a profound effect on an individual's emotional development, empathy, and social interactions. Studies have indicated that musical experiences can promote emotional expression and communication, which are vital for healthy social and emotional development for individuals.

In addition to the cognitive and emotional benefits, music education also fosters creativity and self-expression in social communities. Engaging with music allows individuals to explore their creativity, develop their own musical ideas, and express themselves in a unique and personal manner. This aspect of music education contributes to the overall cognitive, emotional, and social development of individuals, providing a well-rounded influence on their brain development.

In this regard, this article aims to provide an overview for understanding the neurologic effect of music on brain development is crucial in unlocking the potential benefits it may have on cognitive abilities and overall well-being, while exploring the neurological underpinnings of music processing and how musical engagement influences brain development across various cognitive domains. Recent research has shown that engaging with music can have a profound impact on brain development. As individuals listen to or create music, various areas of the brain are activated, leading to improved cognitive function and emotional well-being. For example, playing a musical instrument requires coordination between the visual, auditory, and motor areas of the brain, which could contribute to enhanced overall brain development. Additionally, the emotional response to music stimulates the release of neurotransmitters such as dopamine and oxytocin, which play a crucial role in regulating mood and social bonding. Furthermore, studies have indicated that children who receive music education demonstrate improved language and mathematical skills, as well as better memory and attention span. This suggests that exposure to music at a young age can have long-lasting effects on brain development.

Exploring the impact of music on cognitive abilities and emotional well-being provides valuable insights for educators, therapists, and parents on how to incorporate music into daily activities to promote holistic brain development. Understanding the multifaceted neurologic effects of music can pave the way for innovative interventions and practices that harness its potential benefits for individuals of all ages.

2. Conceptual Structure of Human Brain

The brain, which constitutes the most important part and center of the nervous system in the human organism, is the organ responsible for thinking, learning, and remembering, as well as the regular functioning of the organs and control of the body movements.[2] The total number of cells in the human brain is around 100 billion. Out of this number, 10-15 billion are nerve cells called

[2] Deffenbaugh, L.A.F. "Brain Research and its Implications for Educational Practice." Doctoral Dissertation, Brigham Young University, 1996; Wortock, J.M.M. "Brain Based Learning Principles Applied to the Teaching of Basic Cardiac Code to Associate Degree Nursing Students Using the Human Patient Simulator." Doctoral Dissertation, University of South Florida, 2002; Yiğit, E.A. & Uluorta, N. "Beyin Eğitimi ve Fen Bilgisi Laboratuvar Öğretimindeki Yeri." Sakarya Üniversitesi Eğitim Fakültesi Dergisi, Sayı: 8, 2003. https://www.researchgate.net/publication/292551514_Beyin_Egitimi_ve_Fen_Bilgisi_Laboratuvar_Ogretimindeki_Yeri

Yazar, İ. U. (2024). The effects of music on brain development. *Journal of Human Sciences*, *21*(3), 234-246. doi:10.14687/jhs.v21i3.6483

neurons, which provide thinking and learning functions, and the remaining part are auxiliary cells called glia, which perform functions such as cleaning and nutrition. The branches called dendrites, which provide connections between neurons, consist of intercellular connection elements called synapses, and are not sufficiently developed in the period immediately after birth. Experiences over time enable the formation of synapses, and right after birth, the brain, which is one-fifth the size of a normal adult individual, grows with the increasing number of neurons, dendrites and synapses in later ages, similar to telephone cables that are connected to each other and gradually expand.[3]

The human brain is a complex organ that plays a crucial role in the functioning of the human body. Understanding the general structure of the human brain is essential for comprehending its functions and processes. In this regard, researchers have made significant progress in unraveling the intricate organization of the human brain. Given that the brain is responsible for both mental processes and physical actions of the human body, brain health including its key regions and their functions is important across the life span. One of the remarkable features of the human brain is its complexity. It contains billions of neurons and glial cells, which form an elaborate and determined pattern of circuitry in the adult individual. These complex neural circuits are responsible for various cognitive functions such as perception, memory, language, and decision-making. The human brain can be divided into several major regions, each with its own unique functions and characteristics. The cerebrum is the largest and most prominent region of the human brain, accounting for about 80% of its total volume. Within the cerebrum, there are two hemispheres, the left and right hemispheres, which are connected by a thick bundle of nerves.[4] The more frequently used synaptic connections in the brain, which resemble a network of nerve cells, become stronger, and when not used, they die and disappear. Therefore, continuous stimulation of the brain with enriched and new experiences is considered effectively important for brain development.[5]

3. Neurological Correspondents of Music in Human Brain

Listening to music activates a vast network of brain regions, forming a temporary orchestra conducted by the auditory cortex. The auditory cortex, located in the temporal lobes, is responsible for processing the raw sound information reaching our ears. However, music is more than just sound; it's a complex tapestry of pitch, rhythm, melody, and harmony. Each of these elements engages distinct brain regions to be fully appreciated. In this context, music perception involves dissecting complex auditory information which are composed of pitch, rhythm, melody, and harmony. Different brain regions specialize in processing these elements. For instance, the planum temporale is crucial for pitch perception, breaking down the sound wave into its constituent frequencies and enabling us to discriminate between notes. The auditory cortex then takes over, analyzing the temporal envelope of the sound to extract the melody, the sequence of pitches that gives a tune its character. Meanwhile, the motor cortex and cerebellum work in tandem to synchronize our movements with the beat, allowing us to tap our feet or sway to the rhythm. Finally, the superior temporal gyrus and prefrontal cortex come into play when we perceive the overall harmonic structure of the music, appreciating the interplay of different pitches and the resulting chords. To make this clearer; pitch perception relies heavily on the planum temporale, a region located where the two temporal lobes meet. This area is crucial for discriminating subtle differences in sound frequencies, allowing us to differentiate between notes and appreciate the melodic contours of music. Rhythm,

[3] Gopnik, A., Meltzoff, A.N. & Kuhl, P.K. "The Scientist in the Crib: Minds, Brains and How Children Learn.", Journal of Nervous & Mental Disease, Vol. 189, No: 3, 2001; Chudler, E.H. "Brain Plasticity: What Is It? Learning and Memory." http://faculty.washington.edu/chudler/plast.html.

[4] Sousa A.M.M. et al. "Evolution of the Human Nervous System Function, Structure, and Development." Cell, Vol. 170, No: 2, 2017. https://doi.org/10.1016/j.cell.2017.06.036

[5] Weiss, R.P. "Brain-based Learning: The Wave of the Brain." Training & Development, Vol. 54, No: 7, 2000; Thomas, P.B. "The Implication of Brain Research in Preparing Young Children to Enter School Ready to Learn." Doctoral Dissertation, The Florida Agricultural and Mechanical University College of Education, 2001.

Yazar, İ. U. (2024). The effects of music on brain development. *Journal of Human Sciences*, *21*(3), 234-246. doi:10.14687/jhs.v21i3.6483

the pulse or beat of the music, activates the motor cortex and cerebellum. The motor cortex, responsible for planning and executing movements, helps us tap our feet or nod our heads along to the beat. The cerebellum, known for its role in motor coordination and timing, is essential for synchronizing our movements with the musical rhythm. Melody, the recognizable sequence of notes that forms the tune of a piece, involves interplay between the auditory cortex and the hippocampus, a key player in memory and emotional processing. The auditory cortex analyzes the sequence of notes, while the hippocampus helps us store and retrieve this information, allowing us to recognize familiar melodies and anticipate upcoming notes. Harmony, the pleasing combination of different pitches played simultaneously, is processed in a distributed network of brain regions, including the auditory cortex, superior temporal gyrus, and prefrontal cortex. The auditory cortex breaks down the individual notes, while the superior temporal gyrus integrates this information to perceive the overall harmonic structure. The prefrontal cortex, involved in higher-order thinking, contributes to our aesthetic appreciation of musical harmony.[6]

Studies on the neurological correspondents of music in human brain have shown that the region of the brain called Herchl's Gyrus is effective on musical aptitude and musical ability, that the Planum Temporale area is associated with the "absolute pitch" phenomenon, and that Broca's area provides the tonal perception of pitches.[7] Magnetic Resonance Imaging (MRI) scans in research on music taste have shown that disliked music triggers areas known to be activated in situations perceived negatively by the individual, such as the amygdala, temporal poles, hippocampus and parahippocompal gyrus. On the other hand, it has been observed that liked music causes activation in the anterior superior insula, frontal gyrus, ventral striatum, Rolandic Operculum and Helsch Gyrus, and in this context, it has been suggested that music perception and music appreciation create activations in different parts of the brain.[8]

When we consider the process in terms of the perception created by sound on humans, it is stated that the brain transforms sensory information into objects, for example, a siren-like sound is heard as an approaching ambulance. In object perception, which is essentially based on learning (naming these objects and knowing their functions), it is suggested that there is a basic training stage that is considered as the binding of stimuli to objects.[9] The perception function that occurs in the brain based on auditory sensations is defined as a physiological formation and turns into an individual's musical perception process within the network of musical stimuli.[10] It is an important finding that should be kept in mind that during the human development process, three- to five-month-old babies can easily distinguish music from other sounds (such as the sound of speaking, washing machine, vacuum cleaner) and notice whether the pitches, that is, the music, are presented in regular patterns.[11] In research on the effect of learning and remembering, it has been observed that special pieces of music at the right tempo activate the right and left parts of the brain, while the music listened to activates the right side of the brain, the words a child reads or speaks aloud activates the left side of the brain. And, it has been observed that this activation increases the learning potential

[6] Hargreaves, D.J., & Lamont, A. "The psychology of musical development." Oxford University Press, 2017. https://assets.cambridge.org/97811070/52963/frontmatter/9781107052963_frontmatter.pdf ; Skoe, E & Kraus, N. "Auditory Brain Stem Response to Complex Sounds: A Tutorial." Ear and Hearing, Vol. 31, No: 3, 2010. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2868335/

[7] Limb, C.J. "Structural and Functional Neural Correlates of Music Perception." The Anatomical Record, 2006. https://anatomypubs.onlinelibrary.wiley.com/doi/full/10.1002/ar.a.20316

[8] Koelsch S. et al. "Investigating Emotion With Music: An fMRI Study." Human Brain Mapping, Vol. 27, No: 3, 2006. https://www.ncbi.nlm.nih.gov/pubmed/16078183 ; Blood, A.J. "Emotional Responses to Pleasent and Unpleasent Music Correlate with Activity in Paralimbic Brain Regions." Nature Neuroscience, Vol. 2, No: 4, 1999.

[9] Morgan, C.T. "Psikolojiye Giriş Ders Kitabı." 10. Bs., Hacettepe Üniversitesi Psikoloji Bölümü Yayınları, Yayın No:1, 1999.

[10] Uçan, A. "Müzik Eğitimi." Müzik Ansiklopedisi Yayınları, 1994.

[11] Chang, H.W. & Trehub, S.E. "Auditory Processing of Relational Information by Young Infants." Journal of Experimental Child Psychology, Vol. 24, No: 2, 1977.

Yazar, İ. U. (2024). The effects of music on brain development. *Journal of Human Sciences*, *21*(3), 234-246. doi:10.14687/jhs.v21i3.6483

by at least fivefold. Based on the results obtained from these data, it is stated that the brain has regions such as the right posterior superior temporal cortex that perform music-specific tasks in the form of frequency analysis, and combines different processes and areas to create new cognitive patterns such as sound and time organization.[12]

The activity of making music together, which is not exactly described as music therapy, is described as a somatosensory[13] multimodal activity in which simultaneous auditory, visual and motor information is used to manage motor activity, in terms of the functioning of the brain.[14] It has been determined that collective music-making activities that include synchronization and imitation can be beneficial in cognitive development by associating the regions of the brain that contain the mirror neuron system.[15] In addition, functional neuroimaging studies on music have revealed that music can modulate regions of the brain thought to be associated with emotion, such as the nucleus accumbens, amygdala, hippocampus and hypothalamus.[16] It is suggested that music performed for therapy and treatment and containing various mirroring techniques and other techniques can support cerebral development in many ways by affecting many parts of the brain.[17]

The part of the human brain where the emotional effects of music are collected and evaluated is called the limbic system. Excitements and emotions undergo appropriate adaptation in the limbic system together with other nerve centers. The sound that creates music affects this system through the sense of hearing, and from there it affects behavioral changes. In this regard, there is a strong connection between the sense of hearing and feeling and excitement. Scientifically conducted brain mapping technique studies have shown that sound, melody, rhythm, emphasis and harmony are recorded in the right hemisphere of the brain, while sound intensity and frequency changes, as well as music-related thought patterns, are recorded in the left hemisphere of the brain. On the other hand, feelings and effects such as pleasure, fear, and anger are also processed in the limbic system, which is emotional memory and regulator. Other findings show that the "corpus carlesun" area, which is located in the middle part of the brain of people who are constantly interested in music and acts as a bridge, is relatively more developed. In recent years, as a result of scientific studies on nervous system physiology, following the discovery of the close relationship between the limbic system and hypothalamus in the brain and the emergence and expression of excitement reactions in humans, excitement phenomena have begun to be considered as a psycho-biological science subject, and the disciplines of physiology and psychology have mutually agreed on these studies., and they have become two complementary branches of science. In addition, the ability to appreciate music in the human brain has been confirmed by studies conducted on babies, and it has been determined that

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[12] Yazıcı, D. "Müziğin İnsan Beyni Üzerindeki Etkisi." "**International Journal of Cultural and Social Studies**." Vol. 3, No: 1, 2017. https://dergipark.org.tr/tr/download/article-file/339657 ; Münte, T.F. et al. "The dissociation of speech from music and sound effects in the human auditory cortex." NeuroImage, Vol. 15, No: 6, 2002.

[13] The system that detects stimuli from our environment such as touch, heat, light, pain, vibration and transmits them to the relevant centers in the brain via the spinal cord is called the "somatosensory system". This system works in conjunction with other systems, such as the movement system, to help us respond appropriately to our environment. For detailed information, see https://www.neuropark.com/duysal-uyandirilmis-potansiyeller-sep/

[14] Schlaug, G. et al. "Evidence for Plasticity in White Matter Tracts of Chronic Aphasic Patients Undergoing Intense Intonation-based Speech Therapy." The Neurosciences and Music III-Disorders and Plasticity: Annual New York Academic Science, No: 1169, 2009. https://www.musicianbrain.com/papers/Schlaug_WhiteMatter-Plasticity_MelodicIntonationTherapy_nyas_04587.pdf

[15] Overy, K. & SzakacsIstvan, I.M. "Being Together In Time: Musical Experience and the Mirror Neuron System." Music Perception, Vol. 26, No: 5, 2009. https://www.research.ed.ac.uk/portal/files/11822810/Being_Together_in_Time_Musical_Experience_and_the_Mirror_Neuron_System.pdf

[16] Koelsch, S. "Brain Correlates of Music-evoked Emotions." Nature Reviews Neuroscience, Vol. 15, No: 3, 2014.

[17] Yurteri, N. & Akdemir, M. "Otizm Spektrum Bozukluğu Olan Çocuklarda Müzik Terapinin Otizm Belirtileri ve Yaşam Kalitesine Etkisi." Anadolu Psikiyatri Dergisi, Cilt: 20, No: 4, 2019. https://www.bibliomed.org/mnsfulltext/91/apd.12505.pdf?1584872736

Yazar, İ. U. (2024). The effects of music on brain development. *Journal of Human Sciences*, *21*(3), 234-246. doi:10.14687/jhs.v21i3.6483

music is processed into neural networks in more than one area of the brain. In this context, music is also defined as an energy band that triggers areas such as happiness, pain, anger, joy and hatred in the human brain.[18]

The effectiveness of music on human brain has become clearly visible as a result of EEG analyzes carried out with advancing medical technology. These studies show that EEG creates different fluctuations during emotions such as anxiety, sadness, grief, happiness, and fear. Similarly, it has been known that different fluctuations occur in the EEG of people who listen to different types of music. Singing songs that give happiness, excitement and pleasure causes the secretion of oxytocin and endorphin hormones in the body, which reduce sadness and anxiety, and the oxytocin hormone, which increases feelings of connection and trust, removes feelings of loneliness and depression.[19] In an experiment conducted with jazz musicians at the Johns Hopkins Medical Institute on January 4, 2016, it was observed that the neural pathways in the brain reflected different stimulations in different emotional effects of music. The test results are shown in the image below.[20]

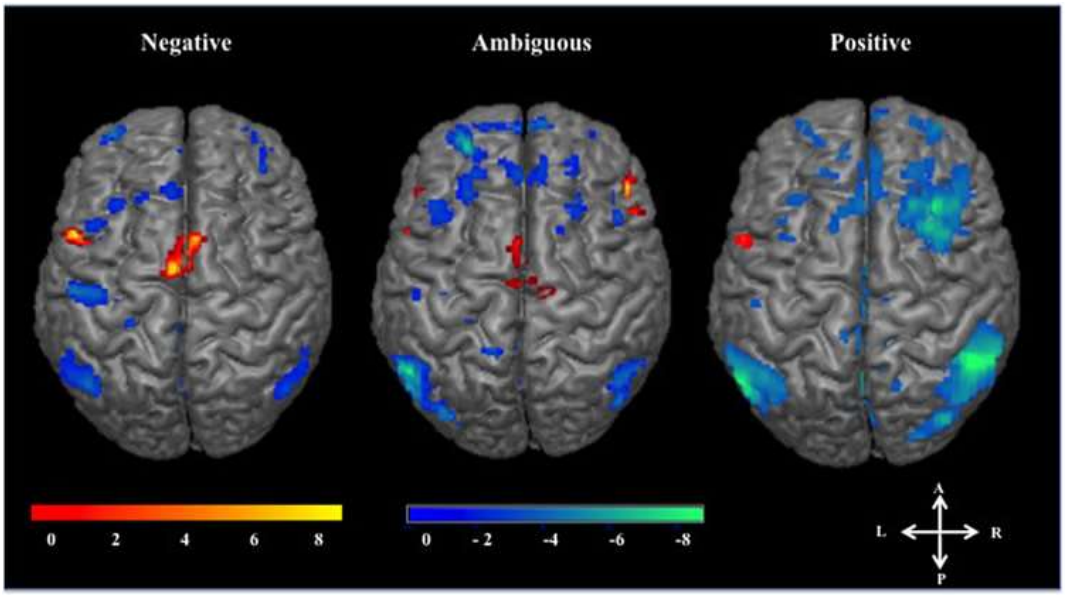

Image 1: Different Neural Stimulations of Happy and Sad Music in the Brain

4. Music and Cognitive Development

Cognitive development refers to the growth and maturation of cognitive processes such as perception, memory, attention, and problem-solving abilities. It is widely recognized that music can play a significant role in cognitive development. Research suggests that music engages various cognitive processes, including auditory perception, working memory, attentional control, and executive functions. Musical interventions can enhance cognitive skills such as executive function, attention, and memory in children. Moreover, a study published in the Journal of Neuroscience found that musical training increases connectivity between brain regions involved in executive functions, such as attention and impulse control. Studies supporting this idea, state that music training can lead to improvements in cognitive abilities such as working memory and processing speed.[21]

[18] Ersanlı, C. "İndüksiyon Uygulanan Primipar Gebelere Travayda Verilen Eğitim ile Dinletilen Müziğin Doğum Sürecine Etkisi." Yüksek Lisans Tezi, Marmara Üniversitesi Sağlık Bilimleri Enstitüsü Doğum ve Kadın Hastalıkları Hemşireliği Anabilim Dalı, 2007.

[19] Horn, S. "Singing Changes Your Brain." TIME, 16 August 2013. http://ideas.time.com/2013/08/16/singing-changes-your-brain/

[20] Neuroscience News. "Happy and Sad Music Evoke Different Neural Patterns." 2016. https://neurosciencenews.com/music-emotion-neural-network-creativity-3335/

[21] Patel, A.D. "The Music of Speech: Music Training Facilitates Vocal Learning." Science, Vol. 310, no: 5755: 5749, 2009;

Yazar, İ. U. (2024). The effects of music on brain development. *Journal of Human Sciences*, *21*(3), 234-246. doi:10.14687/jhs.v21i3.6483

Engaging with music offers a multifaceted workout for the developing brain. Some distinguished effects in question are referred as follows:

-Auditory Processing: Musical training refines auditory processing skills. Musicians demonstrate heightened sensitivity to subtle changes in pitch and rhythm, which translates to improved language development and reading abilities. Research suggests this enhanced auditory processing may even benefit children with language learning difficulties like dyslexia.[22]

-Memory and Attention: Studies suggest that musical training enhances working memory, the ability to hold and manipulate information in the short term. It can also improve sustained attention, allowing children to focus better in learning environments. One study even linked musical training to improvements in processing speed, suggesting a broader cognitive benefit.[23]

-Motor Skills: Learning a musical instrument strengthens the connection between the brain and motor system, leading to improved dexterity and fine motor skills. This can benefit tasks like handwriting and coordination. The precise movements required to play an instrument may also enhance visuospatial skills, which are crucial for tasks like navigating through the environment.[24]

-Social and Emotional Development: Playing music together fosters social skills like collaboration, communication, and empathy. Music can also be a powerful tool for emotional regulation, helping children express and manage their feelings. Group music activities can be particularly beneficial for social development, as they require turn-taking, listening to others, and working towards a common goal.[25]

5. Empirical Research Indicating the Correlation Between Music and the Brain

In 2016, at the Hospital Infantil de México Federico Gómez Hospital in Mexico, research was conducted to determine the neurological changes caused by music training in the brain on 23 healthy children aged 5 and 6, who had not received any music training before and did not have any sensory, nervous or neurological disorders. In the study, the white matter of the brain was scanned with DTI-Diffusion Tensor Imaging[26] technology, an advanced MRI technique, on each child, before and at the end of the nine-month music education. White tissue consists of millions of axons that provide signal transmission between nerve cells, and these provide integrity between parts of the brain. Axons have a highly myelin sheath. Myelin, on the other hand, is almost white in color because it contains a high amount of fat and prevents the diffusion of water molecules. During the development and maturation of the brain, the connections between brain regions also develop and the rate of passage of water molecules between axons increases. With the DTI technique, the movement of water molecules between axons is measured, and brain development can be monitored in this way. In neurological research on children's brain development, it has been evaluated that there

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Patel, A.D. "Music, Language, and the Brain.", 2010; Schellenberg, E.G. "Music Training and Emotional Intelligence in Children." Emotion, Vol. 9, No: 4, 2020; Swaminathan, S. & Schellenberg, E.G. "Music Training.". In T. Strobach & J. Karbach (Eds.), "Cognitive training: An overview of features and applications" Springer 2021. https://doi.org/10.1007/978-3-030-39292-5_21 ; Gold, C., Voracek, M. & Wigram, T. "Effects of Music Therapy for Children and Adolescents with Psychopathology: A Meta-Analysis." Journal of Child Psychology and Psychiatry, Vol. 50, No: 8, 2004. https://pubmed.ncbi.nlm.nih.gov/15257662/

[22] Bhide, A. et al. "Music lessons enhance cognitive function in children with learning disabilities." Annals of the New York Academy of Sciences, Vol. 1090, No: 1, 2008.

[23] Forgeard, F. et al. "Music training and the development of attention control networks." Cerebral Cortex, Vol. 18, No: 8, 2008.

[24] Schlaug, G. et al. "Increasing corpus callosum size: a side-effect of musical training?" Neurology, Vol. 45, No: 3, 1995.

[25] Kirschner, S. & Tomasello, M. "Joint music making promotes prosocial behavior in 4-year-old children." Proceedings of the National Academy of Sciences, Vol. 107, No: 1, 2010.

[26] Diffusion Tensor Imaging (DTI) is an advanced MRI imaging technique that shows which direction water diffusion is more restricted within the brain tissue and expresses this quantitatively. Demir, A. "Beyaz Beyin Cevher Yolaklarının Difüzyon Tensör Görüntüleme ile Gösterilmesi." Bitirme Projesi, Yeditepe Üniversitesi Bilgisayar Mühendisliği-Biyomedikal Mühendisliği Bölümleri, 2008.

Yazar, İ. U. (2024). The effects of music on brain development. *Journal of Human Sciences*, *21*(3), 234-246. doi:10.14687/jhs.v21i3.6483

is a connection between nerve connections in the brain and the decrease in the passage of water molecules. At the end of the nine-month music lessons given to the children participating in the research, a new DTI scan was performed on their brains, and in this scan, in addition to the increase in the length of the axons, it was noted that there was an increase and development in the passage of water molecules between the axons. Besides, it has been found that the connections between different parts of the brain also developed stronger. Imaging results published by the Radiological Society of North America are shown in the image below. Accordingly, the development of nerve fiber connections in the region of the brain called the major forceps was observed in participants who received music training for 9 months. As a result of the research, it was observed that learning music at an early age optimizes the formation and development of neural networks while having a stimulating effect on the existing structure of the brain. Accordingly, when a child receives music education, his brain is forced to perform certain tasks related to the use of hearing, motor, cognitive, emotional and social abilities, and activating the parts of the brain related to these areas creates a stimulating effect on the connections between the right and left hemispheres. On the other hand, researchers have observed a significant development in the part of the brain called the minor forceps. Therefore, it has been concluded that if music education is continued regularly and with correct methods, it has an important effect, as well as support on the brain development of children.[27]

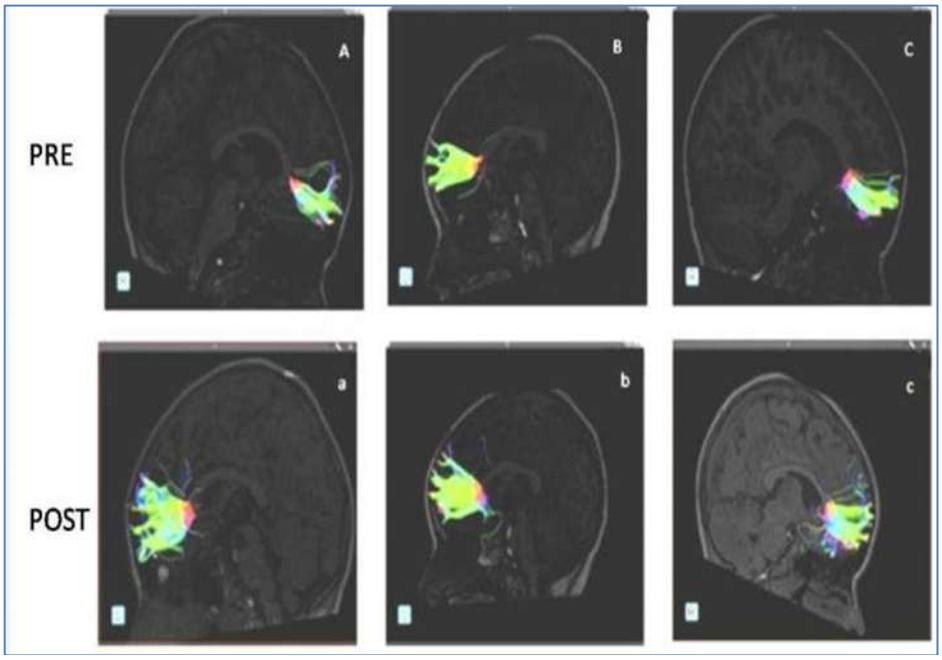

Image 2: Development Difference in Nerve Fiber Connections in the Major Forceps Region of the Brain in Participants Before (A, B, C) and After (a, b, c) Nine Months Music Training

The empirical research that was published in 2021 and conducted by Queensland University of Technology focused on investigating the cognitive basis of earworms, which are involuntary musical imagery experiences where a song gets 'stuck' in one's head. The study utilized a dual-task paradigm involving a serial recall task and a lexical decision task to examine the impact of catchy songs on cognitive performance. Key aspects of the research in question and results include the following:

-Participants were tested individually in two sessions, with each session comprising blocks of tests where they completed trials of the serial recall task while listening to music or in silence.

[27] Elite Music Academy. "Music Lessons Can Help Children with ADHD and Autism." 2016. https://elitemusic.ca/music-lessons-can-help-children-with-adhd-and-autism/ ; ScienceDaily. "Musical Training Creates New Brain Connections in Children." 2016, https://www.sciencedaily.com/releases/2016/11/161121180403.htm

Yazar, İ. U. (2024). The effects of music on brain development. *Journal of Human Sciences*, *21*(3), 234-246. doi:10.14687/jhs.v21i3.6483

-The method of inducing earworms through recent exposure to songs was effective, with a majority of participants reporting experiencing at least one song stuck in their head during or between sessions.

-Significant relationships were found between factors such as the desire to sing along, familiarity with the song, enjoyment of the song, and the experience of an earworm.

-Performance on the serial recall task was measured in terms of the proportion of digits produced in the correct order in each trial, with differences observed depending on whether catchy or non-catchy music was presented.

-The study highlighted the importance of using experimental methods to objectively examine the earworm phenomenon and avoid demand characteristics that could influence results.

Overall, this research provided insights into how catchy songs can impact cognitive tasks and trigger involuntary musical imagery experiences, shedding light on the cognitive mechanisms underlying earworms.[28]

According to a recent study conducted in the University of Tokyo in 2024, listening to music can cause certain physical sensations, especially in the heart and belly, and these sensations can be connected to emotional reactions and the love of art. Researchers found that while unexpected chords elicit higher heart sensations associated with pleasure, predictable music generates relaxation and satisfaction in 527 individuals when they analyzed their responses to chord sequences generated from Billboard chart singles. This study highlighted the significant effects of music on human interoceptive sense and the therapeutic uses it may have to improve mental and general wellbeing. Through the charting of physiological reactions to musical chords, this research revealed the profound and visceral relationship between music and emotional encounters. The attention-grabbing details regarding this research are listed as follows:

-Unexpected chord progressions predominantly influence the heart, causing enjoyment and aesthetic appreciation, whereas recognizable patterns relax and satisfy the abdomen.

-Eight four-chord sequences based on well-known Billboard songs were produced by the study, which also revealed common patterns of bodily reactions linked to musical surprise and anticipation.

-In order to gain a better understanding of music's therapeutic potential for stress alleviation and mental health improvement, researchers are examining the physiological reactions that may be measured to music, such as heartbeat alterations.[29]

6. The Effect of Musical Singing Activity on Brain Development

Today, children's songs with simple melodies and a few simple written words, considering the developmental and age characteristics of children, are used as an effective tool in supporting children's educational processes and speech development. These children's songs, performed with various instruments, improve children's communication, speaking and language skills, and their positive effects are observed in choir and school activities.[30] Based on this observation, educational music and songs have begun to be used in the field of therapy. In children diagnosed with mental disorders, these music and song activities in question help develop both gross and fine motor skills, develop self-concept and body awareness, extend attention span, improve verbal and non-verbal communication and social skills, and change anger behaviors and repetitive behaviors to reduce them. These activities focus on helping perceive the senses of sight, hearing and touch and connect them to the body's movement system.[31]

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[28] Killingly, C, Lacherez, P. & Meuter, R. "Singing in the Brain: Investigating the Cognitive Basis of Earworms." Music Perception, Vol. 38, No: 5, 2021.

[29] Karaoğlan, A. "Music Evokes Distinct Bodily Sensations.", 2024. https://www.linkedin.com/feed/update/urn:li:activity:7181982721588555776/

[30] Türkmen, E.F. "Müzik Araştırmaları." Kocatepe Akademik Yayınevi, 2012.

[31] Çoban, A. "Müzik Terapi: Ruh Sağlığı için Müzikle Tedavi." Timaş Yayınları, 2005.

Yazar, İ. U. (2024). The effects of music on brain development. *Journal of Human Sciences*, *21*(3), 234-246. doi:10.14687/jhs.v21i3.6483

It is stated that the use of rhyme in the singing activity applied during the music therapy process reduces monotonous (*single-tone*) speech by supporting word pronunciation and the flow of speech accompanying music, and also helps individuals with mental disorders to form sentences with grammatically correct structure.[32]

In order to qualitatively evaluate the educational and therapeutic effect of children's songs on speech disorders of children, two songs were selected for an experiment in 2018 at the Fethi Güzen Special Education Application Center (the songs "Ali Baba's Farm" and "Minik Kuş"). As a result of this research conducted within the framework of the applications made by seven expert teachers and the opinions received from the teachers about the results of these practices;

- Children's songs sung by taking advantage of the effect of rhythm on auditory memory supported the speech problems of children, and were also useful in helping children acquire some daily skills,
- Thanks to music, children's self-confidence increased, and they could socialize,
- Music was also a beneficial element in terms of eliminating children's distractions,
- It made a significant contribution to children's speech disorders in terms of increasing their vocabulary, improving their speech, and learning new concepts and new words,
- It has been observed that it supported children in gaining spiritual serenity.[33]

7. Conclusion

In conclusion, the effects of music on human brain development are multifaceted and encompass not only cognitive enhancement but also emotional intelligence and social skills development. In this context, music has been shown to play a crucial role especially in the emotional development of an individual. It has the capacity to evoke various emotions and help a person develop emotional intelligence. Engaging in musical activities such as singing, dancing, and playing instruments can facilitate social bonding and cooperation especially among children. According to the research on the impact of music on emotional intelligence and social cognition has revealed significant findings. Music has the power to evoke and regulate emotions, allowing children to develop greater emotional awareness and understanding. Engaging in musical activities encourages children to express themselves emotionally and communicate with others, fostering empathy, compassion, and effective social interaction.

Furthermore, music has been shown to enhance social cognition by promoting the development of skills such as perspective-taking, theory of mind, and understanding others' emotions. This suggests that music not only aids in emotional expression but also contributes to the overall social development of children. Exploring the specific mechanisms through which music influences emotional intelligence and social cognition would provide valuable insights into how to optimize the use of music in educational and therapeutic settings.

Beyond cognitive deveopment, the emotional impact of music should not be overlooked, as exposure to and participation in music has been shown to have a positive effect on emotional regulation and social skills. Empirical studies have indicated that musical experiences promote emotional expression and communication, which are vital for healthy social and emotional development. Furthermore, research have shown that music therapy can be beneficial in improving emotional regulation and social skills in children with developmental disorders. Research on the impact of music on emotional intelligence and social cognition has revealed significant findings. Music has the power to evoke and regulate emotions, allowing people to develop greater emotional

[32] Warber, A. "Music Therapy for Autism." n.d. https://autism.lovetoknow.com/Music_Therapy_for_Autism

[33] Özorak, Ö.O. "Otizmli Çocuklardaki Konuşma Problemlerine Çocuk Şarkılarının Etkilerinin Öğretmenlerin Görüşlerine Göre Değerlendirilmesi." Afyon Kocatepe Üniversitesi Akademik Müzik Araştırmaları Dergisi, Cilt: V, Sayı: 9, 2019. https://dergipark.org.tr/tr/download/article-file/640832

Yazar, İ. U. (2024). The effects of music on brain development. *Journal of Human Sciences*, *21*(3), 234-246. doi:10.14687/jhs.v21i3.6483

awareness and understanding. Engaging in musical activities encourages individuals to express themselves emotionally and communicate with others, fostering empathy, compassion, and effective social interaction. This suggests that music has a multifaceted impact on individual development, influencing cognitive, emotional, and social domains, and plays a valuable role in promoting holistic development.

While various activities promote brain development, music offers a unique combination of benefits that set it apart as stated below:

-Multisensory Integration: Music integrates auditory, motor, and emotional processing, providing a rich workout for various brain regions simultaneously. This cross-modal engagement may be particularly beneficial for promoting neuroplasticity, the brain's ability to adapt and form new connections.

-Motivation and Engagement: Music is inherently enjoyable, motivating children to practice and persist through challenges. This fosters a love of learning that can extend beyond music education and into other academic domains. The intrinsically rewarding nature of music can promote a growth mindset, encouraging children to view challenges as opportunities to learn and improve.

-Emotional Connection: Music taps into our emotions, creating a powerful memory association. This emotional salience can enhance learning and retention. Music can help encode information into memory by creating a multisensory experience that is more likely to be remembered than simple rote memorization.

The positive impact of music on brain development is undeniable. By incorporating music education into lives, a range of cognitive, social, and emotional skills can be nurtured. Further research is needed to fully understand the long-term effects of music on the brain and optimize music-based interventions for diverse populations. However, one thing is clear: music is not just entertainment; it's a powerful tool for shaping minds and promoting lifelong learning.

Moving forward, it would be valuable to delve deeper into the empirical studies on music and neuroplasticity to understand how musical interventions can enhance neuroplasticity in brain research. Additionally, exploring the role of music in language and learning skills enhancement would provide insights into how music can further contribute to the overall development of an individual. Researching the relationship between music and language acquisition, as well as the potential for music to enhance learning skills such as memory, attention, and problem-solving, can shed light on a comprehensive understanding of the benefits of music education in promoting cognitive development especially in children.

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Image 1: Different Neural Stimulations of Happy and Sad Music in the Brain
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Image 2: Development Difference in Nerve Fiber Connections in the Major Forceps Region of the Brain in Participants Before (A, B, C) and After (a, b, c) Nine Months Music Training
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