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Music and the Brain

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Abstract

Music is an important part of cultures worldwide. It has been used throughout the ages as a method of conveying emotions to the listener. However, there is some confusion about exactly which areas of the brain are affected by music. This study shows the general areas of the brain stimulated by music, explaining how these sections influence emotion and learning capability. In addition, this paper demonstrates that music therapy may be helpful in relieving stress or some neurological disorders, based on the areas activated by music. Training in music has cognitive and motor coordination benefits, as well, because this training causes structural changes in brains of musicians.

Introduction

According to the Merriam-Webster dictionary, music is the "vocal, instrumental, or mechanical sounds having rhythm, melody, or harmony (Merriam-Webster, 2018)." However, the word "music" suggests a much deeper meaning than the formal dictionary definition implies. Music is known as the "language of the soul." It speaks to its listener, conveying a message of emotions, such as a calming sensation of relaxation or intense feeling of elation or sadness. The language is universal; even people who have lost their ability to verbally communicate can understand the empathy inherent in music (Ridder, et al., 2009). When a musician plays his instrument, he is forming an emotional connection with his listeners. But music has effects beyond emotions. Learning to play music facilitates cognitive reasoning, motor coordination, and sensory perception. Because music has this unique combination of emotional connection and cognitive benefits, music therapy has been developed to alleviate emotional and physical hardship in a number of neurological illnesses. This analysis will discuss the varying effects of music on the brain, including the physical changes that manifest and the mechanisms through which music leads to enhanced learning and emotion. Additionally, through this study, the possible benefits of music therapy are revealed.

Methods

Research for this paper was gathered from Touro's online library from databases including ProQuest and EBSCO. Articles found discuss the different areas of the brain affected by music, the usefulness of music therapy, differences in anatomy and processing of stimuli in the brains of musicians and non-musicians, whether music induces emotion, and the potential learning benefits to be gained through musical training. Review articles, case studies and experimental studies were used in forming the analysis.

Parts of the Brain Affected by Listening to Music

It is unclear, as of the research to date, exactly which parts of the brain are stimulated by music. The general mechanism for music that was heard travelling to the brain is as follows; music enters the ear and is received by the cochlea. It is then transferred to the thalamus, and then to the auditory cortex for processing (Boso, et al., 2006). If the person listening to the music is deciding whether to buy that music, there is a further association between the auditory cortex and the ventral striatum, which processes enjoyment (Koelsch, 2014).

Although most reward stimuli do not activate the hippocampal region, music does. The hippocampus's main roles are the conversion of short-term memory into long term memory and spatial relations. It is also responsible for encoding information from the amygdala, which controls emotion, with the long-term memories. In other words, emotional memory becomes combined and remembered with long-term memory through the hippocampus. This supports a growing theory that the hippocampus plays a role in emotional recollection that occurs when listening to music. Because music affects emotions in a way unlike money, food or other reward stimuli, it couples emotion and the memory of a specific piece of music. This activates the hippocampus, leading to feelings of peacefulness, tenderness, joy, or even sadness when the piece is later recalled (Koelsch, 2014).

People can have varying parts of their brain stimulated, depending on how they think of the song. For example, remembering a song in one's head can stimulate the visual cortex, while hearing the song stimulates the auditory cortex. Also, different parts of music affect different areas of the brain; pitch, melody, harmony and beat are usually processed in the right hemisphere of the temporal lobe, while lyrics, pacing, frequency, and intensity are analyzed in the left temporal lobe. The connection between music and thoughts, which will stimulate emotions or previous memories, is formed by the frontal lobe. The stimulation of the frontal lobe is activated by the limbic system which provides the emotions felt (Bennet, Bennet, 2008).

Although both speech and music utilize pitch, pitch seems to be used differently in the different circumstances. While speech cannot be "off-tune," music can. It is possible, therefore, that coarse contour in speech and music are processed in one area, while a more finely-tuned pitch perception is analyzed in a different area. This argument is strengthened by the fact that there were cases of people who lost the ability to understand language prosody but retained musical pitch acuity. However, people who lost basic musical contour perception also lost their speech prosody awareness (Zatorre, Baum, 2012).

Music is also processed in different areas depending on whether the music is perceived as pleasant. Music that has dissonance and disharmony is more likely to be processed in the temporal lobe, while music that is pleasant and has harmony will be processed in the frontal lobe (Boso, et al., 2006).

Pleasant music is processed in the same way that primary and secondary pleasure stimuli are generally handled. Music activates the nucleus accumbens, ventral tegmentum area, hypothalamus, orbitofrontal cortex, and the insula-frontal cortex. The nucleus accumbens is the center which processes pleasant stimuli, and then releases dopamine into the ventral tegmentum area. In the brains of both musicians and non-musicians, listening to music activates the mesolimbic dopaminergic reward system (Herholz, Zatorre, 2012, Schlaug, et al., 2010, Menon, Levitin, 2005). Pleasant music, such as music which gives the listener chills, or goosebumps, causes the release of dopamine both in the ventral tegmentum and in the ventral striatum. The anticipation of chills, itself, releases dopamine, as well. However, the exact area where dopamine is released when expecting such music differs from when the expectation is fulfilled. Expected chills activate dopamine in the ventral striatum. When the music causes the chills to actually happen, the dorsal striatum becomes activated with dopamine (Koelsch, 2014, Boso, et al., 2006). The hypothalamus, too, gets activated, which lowers the heart rate and breathing rate, leading people to feel calmed and relaxed by music (Menon, Levitin, 2005).

Music Therapy as a Useful Tool

Music therapy is unique in that listening to music sends signals to the visual, auditory and motor cortices simultaneously (Schlaug, et al., 2010, Walworth, et al., 2008). The fronto-temporo-parietal connection formed by music is a component of mirror neurons. Because mirror neurons are important for the coupling of perceptional events and their motor response, listening to music, and thereby activating these areas, may help link cognition and perception, heightening concentration, memory and executive control (Schlaug, et al., 2010).

Connected to the general cognitive and perceptive benefits is the effect of music on reducing cognitive stress. This idea was proven through a study conducted on eighty-nine college students. These students were given a cognitive stressor; they were told that they would have to present a complicated speech. Then, the control group worked on preparing their speech without background music, while the experimental group was exposed to music. The groups were given surveys to fill out before and after the stressor was given. Also, salivary IgA levels were measured to check if biologically, music can help boost the immune system. The IgA test and the stress surveys indicated that the group listening to music experienced less stress and had a more effective, boosted, immune system than the control group (Knight, Rickard, 2001). A study of patients who were waiting to undergo surgery showed that music can return heart-rate, cardiac output and blood pressure values to normal, non-stress levels. Additionally, blood glucose levels and skin temperature will be overcompensated in the return to normal status when listening to music. Not only will the brain restore blood glucose levels and skin temperature to the normal levels in response to listening to music, it will establish levels corresponding to a state of relaxation. Music, therefore, can relieve its listener of feelings of stress and induce calmness in its place (Miluk-Kolasa, et al., 2002).

The stress-relieving benefits of music are helpful clinically as well. Music can destress a patient before a difficult surgery. Research done by Walworth et al. demonstrated that music therapy can have psychological effects on patients undergoing brain surgery. In their experiment, twenty-seven subjects who were scheduled for a surgery were divided into two groups. The control group did not receive any music therapy prior to surgery, while the experimental group received twenty to fifty minutes of therapy. Surveys taken by the subjects before and after the surgery analyzed mood level, perception of hospitalization, and to what extent each subject felt anxious, stressed, or pain. The results indicated that subjects who had received the music therapy felt less anxiety and stress and were more relaxed before and during the surgery. They generally had a better perception of their hospitalization. This is important since studies have shown that pessimism and anxiety correlate with worse outcomes in brain surgeries (Walworth, et al., 2008). Another study which focused on spinal epidurals, as opposed to brain surgery, concurs with Walworth et al. that music therapy can decrease stress in patients undergoing surgery. The patients having spinal anesthesia who listened to music throughout the surgery had a shorter induction time and required less medication than the control group. Interestingly, the patients listening to music did not recall hearing the music, suggesting that the effects of music occur subconsciously. A possible explanation for the reduction of necessary anesthesia is that the auditory and pain pathways inhibit each other. This can be an important method for decreasing the amount of anesthesia necessary non-pharmaceutically (Zhang, et al., 2005).

Music therapy can increase the quality of life for a patient with fronto-temporal dementia. Listening to familiar music can allow these patients to express themselves nonverbally, and thus allows for the building of social interactions and communication. After four weeks of music therapy, patients had less agitated behavior and were less distressed. Whether the patient actively participated in the therapy sessions did not diminish the benefit of the therapy, as both active and inactive participants clearly showed less agitation than before the sessions (Ridder, et al., 2015).

In addition to helping patients psychologically by reducing stress, music, and specifically musical training can help patients physically. In one study, stroke patients learned to play an electronic drum and MIDI keyboard. The results showed that the drum training improved gross motor skills, and the piano lessons honed fine motor skills. These patients began to recover some of their motor coordination. Additionally, brain tests demonstrated that these patients had more success with motor planning and neuronal coherence with music therapy than other therapies. Interestingly, these skills were not limited to the musical instruments played. The coordination had improved overall, in every activity attempted (Schneider, et al., 2007).

Different Music Affecting the Brain Differently

Music is a very broad term. It includes many genres, styles and pieces. Just as the varying aspects of music are processed in different areas of the brain, the various genres within music affect the brain in unique ways.

A network analysis was conducted, based on imaging from 21 subjects, on different genres of music. Network imaging shows the connections of the brain, along with the important functioning parts at a given point. The analysis illustrated that different genres of music created "hubs" of activity in varying areas of the brain, depending on the music. Specifically, classical music made the largest hub in the auditory cortex. It is possible that the size of the hub is related to the complexity of the music being heard, and because classical music is often complex, its hub is the largest (Wilkins, et al., 2012).

In addition to the different genres affecting the brain, preferred music, as opposed to disliked music, shows different patterns in the brain. When comparing a subject's favorite song with songs that the subject liked and disliked, all songs stimulated the default mode network, and particularly the precuneus. The precuneus is in the parietal lobe, anterior to the occipital lobe. This area is important in the processes of self-reflection and episodic memory, along with cognitive thinking and creativity. Although the precuneus was activated by every music heard, there was a strong correlation between the favorite song and liked song in activation of the lateral parietal and medial prefrontal cortices. The disliked song, however, had excitement that remained isolated in the precuneus. Another difference between the favorite song and the liked and disliked songs is the involvement of the hippocampi. While all the songs showed some stimulation of the hippocampus, both the liked and disliked songs had auditory cortex "hubs" that included the hippocampi, while the favorite song had two separate hubs: one for the auditory cortex, and a second for the hippocampi. The activation of the hippocampi stimulates the encoding or retrieval of emotional memory. It is possible that the separation of hubs when listening to the favorite song leads to emotional memory retrieval, rather than inscription. The interconnection of the precuneus and the other areas contributes to the default mode network and causes the feelings of self-reflection and creativity, along with memory encoding, specifically of emotional memories (Wilkins, et al., 2014).

Although liked-music stimulates the default mode network and hippocampi leading to feelings of self-reflection and introspection, if the liked music is unfamiliar, it may not necessarily lead to the mesolimbic reward. Fourteen participants in a study listened to music to determine familiarity and preferences of songs. These participants listened to twelve songs in each category previously determined: familiar liked, familiar disliked, unfamiliar liked and unfamiliar disliked. Familiar music activated the anterior cingulate cortex, amygdala, thalamus, putamen, right nucleus accumbens, left hippocampus, temporal pole and orbitofrontal cortex. Unfamiliar music either did not activate these regions altogether or activated them only slightly. There was an increased blood oxygen level dependence, indicative of a lot of activation, in the emotion-related areas, including the putamen, amygdala and nucleus accumbens. The high amount of stimulation in the limbic and reward systems for familiar songs suggests that familiarity with a song will increase the liking of the song. The only difference in activation between the liked and disliked songs was in the right anterior cingulate cortex and the inferior frontal gyrus. This stimulation during liked songs correlates with the known functions of these areas, namely, judging beautiful stimuli (Pereira, et al., 2011).

Musicians vs. Non-Musicians

There are numerous differences between the way that musicians and non-musicians process music, and therefore, differences in their brain structures. Firstly, as mentioned previously, music affects both hemispheres concurrently. However, while the right hemisphere usually processes the long-term patterns, such as pitch and melody, the left, usually dominant hemisphere, evaluates the short-term patterns, including changes in rhythm and frequency. Generally, while a musician is listening to music, he is examining the form. Therefore, his left hemisphere would be stimulated predominantly. On the other hand, a non-musician, who listens to music to enjoy the melody would be mainly stimulating his right hemisphere (Bennet, Bennet, 2008).

Although in each case there is largely one hemisphere that is excited, both hemispheres are stimulated each time music is heard. Besides for hearing the music, the musician often performs complex hand sequences with his instrument, also exciting both hemispheres with his actions. The information is transmitted across both hemispheres through the corpus callosum. Neurons stimulated most often get the most strengthened by myelin sheath to allow for more efficient processing and faster reactions (Iusca, 2011). Because musicians listen to and practice playing music on a consistent basis, their neurons routinely fire across the anterior corpus callosum, leading to a larger anterior corpus callosum with more myelinated axons and a greater number of neuronal fibers than that the non-musician (Iusca, 2011, Herholz, Zatorre, 2012).

Another outcome of the need for musicians to use both hands is that musicians lose dominance in a single hand and become more ambidextrous. This is a necessary adaptation for the musical profession, which has underlying neuronal reasoning. Because the musicians use both hands to play complex musical sequences, the part of the motor cortex which stimulates both hands, rather than just the dominant hand, becomes strengthened with more myelin sheath and a greater number of synapses. This phenomenon is especially true for a keyboard player (Iusca, 2011).

Musicians have an enhanced short-term plasticity in the motor cortex, resulting in higher motor performance and synchronization in intricate manual tasks. For example, pianists were able to learn a nonmusical finger tapping sequence quicker than non-musicians, which correlated to an increased activity in their motor cortex. This, too, correlates with the noticeably larger finger area in a musician's motor cortex (Herholz, Zatorre, 2012).

Besides for music affecting the cerebrum, musical training also affects the cerebellum. The cerebellum is used for fine motor skills. Playing an instrument requires these skills, and, therefore, learning to play them leads to more synapse connections, bigger capillaries to supply blood to these cells, and more glial cells to create a more effective support for the frequently used neurons in the cerebellum. Musicians' cerebellums are larger than those of non-musicians because of the extra stimulation (Iusca, 2011).

Musicians can process simultaneous information more accurately than non-musicians can. When fifteen non-musicians were told to report their touch sensations while simultaneously listening to two sounds, they had a hard time distinguishing between the auditory and sensory information and generally reported feeling two touches rather than one. However, musicians who underwent the same test were more than twice as accurate at differentiating between the two stimuli. One reason for increased accuracy in musicians is that musicians are accustomed to reading sheet music, feeling their instruments and responding to the sounds produced. This balance of a combination of different stimuli enables the musician to better ignore one stimulus in favor of another (Sparks, 2013). In another study, musicians and non-musicians were presented with audio-visually incongruent stimuli. The non-musicians tended to react more to the visual stimulus, while the musicians relied on their auditory perception. The likelihood of musicians relying on audio information is dependent on the length of time the musician has trained in his craft. (Abel, et al., 2016). Although the results of this experiment seem incongruent with first study, in which musicians relied on touch rather than sound to determine how many stimuli were before them, the studies are demonstrating different aspects of musicians' skills. The first experiment aimed at establishing the accuracy of musicians' sensory perception when coupled with incongruent auditory input. The musicians were successful in distinguishing between the two stimuli and, therefore, were able to accurately state the number of stimuli they touched. The second study, on the other hand, was not attempting to determine accuracy. Rather, the goal was to discover which stimulus the musician would rely on when presented with two incongruent stimuli. Because the musician was not attempting to determine a specific stimulus, he was able to respond to whichever stimulus he perceived. This study proved that, given the option of two conflicting stimuli, musicians are more prone to relying on auditory perception than visual perception.

One reason that musicians rely more on auditory than visual stimuli when the two are conflicting is that the musical training process provides auditory feedback, strengthening the sensorimotor associations between the auditory and motor systems. Because of this continual strengthening, when the musician encounters inconsistent visual information, he has an easier time blocking it out and relying solely on his auditory perception. A non-musician, who never had such training, has poorer auditory perception, and therefore compensates with his visual perception (Abel, et al., 2016). Although this argument is compelling, the possibility remains that music does not, in fact, change perception preferences from visual to auditory in musicians. Perhaps people who naturally are inclined towards using auditory information, rather than visual, are inherently more disposed to becoming musicians, and that is the reason for the trend observed (Abel, et al., 2016, Banai, Ahissar, 2013).

Effects of Beginning Musical Training Young

Although musical training can affect the brain at any age, it has an extra impact when started at a young age. String instrument musicians who began training early have a greater representation of their left fingers in their motor cortex (Herholz, Zatorre, 2012). Another neuroanatomical change found in musicians who began training before the age of six or seven is found in the corpus callosum. Because these children are practicing complex sequences daily, their brains need to accommodate a large transfer of information efficiently. This continual stimulation leads to an enlarged anterior corpus callosum (Iusca, 2011).

When studying the brains of forty-eight young adults who had at least one year of musical training in their youth, a researcher found that those who had begun training before the age seven had more developed brain areas connected to language and executive function (Sparks, 2013).

Starting musical training young seems to lead to improved visuomotor and auditory-motor synchrony, (Herholz, Zatorre, 2012). It is possible, however, that the children had exemplary visuomotor or auditory-motor coordination, which led them to begin music training young. If this is the case, the auditory-motor synchrony is the cause for early music training, rather than the reverse.

Music Facilitates Learning

Music can facilitate learning in numerous ways. Firstly, music affects the limbic system and subcortical regions, the areas that control long-term memory. Areas such as the hippocampus and cingulate cortex are stimulated through music. These areas convert short-term memory into long-term memory. When learning while listening to music, the long-term memory areas are already stimulated, and the learning will become part of long-term memory as an association of the music heard (Koelsch, 2014, Wilkins, et al., 2014).

Listening to music seems to improve other cognitive tasks as well. A music director in North Carolina arranged for a woodwind quintet to play music three times a week to first grade, then first and second, and finally, first, second and third. Although the average IQ score for this school's first through fifth graders had been below the national grade level, after the three years of listening to music the third-grade's academic performance increased tremendously. Eighty-five percent of the students were above grade level for reading and 89% for math. The improved math skills received from music is understandable. Music is inherently related to math because music measures beat and rhythm which are mathematical concepts (Bennet, Bennet, 2008).

Although relatively little musical training can improve basic perceptional skills, especially among the originally poor performers, the larger population of musicians do not overall show improved verbal and cognitive skills. When children were given one year of after school music lessons, they did not show improved non-auditory skills. In other words, the students had better pitch discrimination, but the training did not generalize into verbal memory. The learning did not extend past the auditory perception the students gained directly from their music training. Possibly, with more time, other skills, such as verbal and cognitive skills, could emerge. Perhaps had the children had three years of music training, like the students from the previous study, the boost in reading and math skills would be evident as well.

Word decoding and reading comprehension were studied in six to nine-year-old musicians. The evidence showed no association between length of training and word decoding, however, there was a close association between reading comprehension and musical training. Possibly, the reason that there was no significant difference between those with musical training and those without it with respect to word decoding is that the children in the control group were old enough that they cognitively caught up on word decoding. If the children had been studied at a younger age, evidence may have shown a difference in word decoding ability. If musical training does in fact facilitate word decoding in younger children, perhaps the reason that the musical children tested had superior reading comprehension was because they had earlier and more proficient reading comprehension. According to this theory, the children did have a superior word decoding ability when they were younger, which led to an earlier reading comprehension. Because the musical children have been reading and effectively decoding, they show a higher reading comprehension than the non-musical children (Corrigall, Trainor, 2011).

In addition to reading comprehension, musical training facilitates improved reading skills in general, as well as the discrimination of small pitch variations in speech. Because pitch differentiation is an important part of music, learning to play an instrument will improve pitch discrimination for both the instrument being learned and speech in general (Moreno, et al., 2009).

Since music training affects the motor cortex, which enables the musician to play more complex pieces with greater dexterity, learning that involves the motor cortex is easier for musicians. Long-term musical training, specifically, augments short-term plasticity in the motor cortex. This is the reason that musicians have an easier time learning a nonsensical finger tapping sequence. Overall, motor performance and coordination are improved and, therefore, any learning that involves the motor cortex will be facilitated by musical training (Herholz, Zatorre, 2012).

Besides for the anatomical changes music effects, listening to music produces psychological benefits. Listening to music puts one in a good mood. When in a good mood, people are more productive and generate a higher quality of work. A study of employees listening to music in the workplace demonstrated that the weeks that the employees listened to music, higher quality of work was reported. However, it is possible that the higher review was an effect of the employees' improved mood, and the quality of work was unchanged (Lesiuk, 2010).

The Mozart Effect

In the first study that correlated music and learning ability, participants were placed into three groups and told to work out a spatial reasoning problem. The first group listened to Mozart's music, the second practiced various relaxation techniques, and the third, the control group, did no preparation. The results showed that the group listening to Mozart performed the best. The phenomenon was coined the "Mozart Effect." However, the benefit from the music lasted for a very short time, ten to fifteen minutes. Also, similar studies later showed that other music can achieve the same results. Therefore, it is possible that the result was not exclusively related to Mozart's music but that music with an even tempo or rhythm may temporarily improve spatial relations (Bennet, Bennet, 2008).

Length of Training Needed to Effect a Change

Music training affects the brain's structure. Some learning changes are evident almost immediately, while others take longer. Temporarily improved auditory-motor coordination is evident after twenty minutes of instrument practice. However, the effects do not last long. More permanent improvement in this area happens after five weeks of training (Herholz, Zatorre, 2012).

Besides for length of training, the age that the musician begins his lessons determines the extent of his brain's structural changes. For example, string instrument musicians who began training young have a greater representation of their motor cortex dedicated to their fingers (Herholz, Zatorre, 2012). Also, musicians who began training before the age of seven had a larger corpua callosum than musicians who began later in life. For example, the change in the corpus collosum of a six-year-old child would begin after about fifteen months of training (Iusca, 2011, Herholz, Zatorre, 2012). The phenomenon is logical; the brain goes through the most changes during childhood, discovering which areas require more synapses based on frequency of use. The younger the child begins music training, the earlier the brain learns to accommodate the varying complexities needed, and the more prominent the resulting structural changes of the brain will be (Iusca, 2011).

Music Affecting Emotions

Although there is some controversy about whether music can induce emotions, there are some indications that music does play a role in stimulating emotion. There are six mechanisms which can explain the emotions generated by listening to music. The first is a brain stem reflex. The brain stem reacts to sounds that are loud and discordant with an arousal mechanism designed to protect the person from possible danger. Listeners who enjoy arousal will be stimulated by jarring music.

A second mechanism is conditioned response learning. When music is heard for the first time in an emotional environment the emotions become connected to the music heard. Later, when the music is replayed, the emotional feeling is regenerated.

Another mechanism is emotional contagion. The mirror neurons in the brain react by imitating stimuli in the environment. The tone, frequency or pitch of music will be mirrored by the listener by eliciting either calm or excitement.

A fourth mechanism through which music stimulates emotions is visual imagery. Often, while the listener is hearing the music, his brain conjures up images associated with the sounds he hears. It is possible for those images to lead to emotions. The images recalled may or may not be from memory. However, when the images are from the listener's episodic memory, a different mechanism provides the emotions associated with the memory.

Finally, momentary surprise or confusion will occur when the listener anticipates a particular sequence of chords. For example, if a listener hears a C sharp, D sharp, and then E sharp, he naturally expects the next note to be an F sharp. If the music breaks the rhythm, the listener is temporarily put off balance and may be confused. Although this will not lead to emotions such as joy or sadness, it can cause brief surprise or confusion (Juslin, Västfjäll, 2008).

Besides for these mechanisms, specific areas of the brain related to emotion are stimulated by music. One area activated by music is the amygdala. Because the amygdala controls the processing of emotions, stimulation to that area leads to feeling emotion. Joyful music stimulates the superficial amygdala, leading to happiness. Both happy and sad music stimulate the latero-basal amygdala, which is associated with positive and negative reinforcement. This reinforcement can activate the mesolimbic reward system in both musicians and non-musicians (Koelsch, 2014).

Pleasant music activates the nucleus accumbens and ventral tegmental area, which controls motivation through reward. The "reward" feeling is in the form of dopamine being released into the brain. Performing an action that leads to reward is enjoyable. Because listening to music stimulates the nucleus accumbens and ventral tegmentum which send the dopamine reward as a response, the listener appreciates the music (Koelsch, 2014, Schlaug, et al., 2010, Boso, et al., 2006, Menon, Levitin, 2005, Pereira, et al., 2011). Reward feelings are enjoyable, and therefore, improve the listener's mood and affect his emotions. Besides for activating the dopaminergic reward system, listening to music causes the release of endorphins into the blood stream. Endorphins reduce pain and stress and can lead to feelings of happiness (Koelsch, 2014, Herholz, Zatorre, 2012, Boso, et al., 2006).

Conclusion

Music affects a variety of areas in the brain, including areas that control cognitive learning, coordination and emotion. Not all music affects the brain in the same way. Different genres of music cause different size "hubs" of activation in the auditory cortex. Similarly, music that the listener likes is processed in a different way from music that he dislikes. Based on areas of activation in the brain, music therapy can be a useful tool for treating neurological disorders, such as stroke, cerebral palsy, and fronto-temporal dementia, as well as calming stress. Because musicians practice playing their instrument, and in general have more exposure to music, there are distinct differences in the structural anatomy of a musician's brain, as opposed to that of a non-musician. Musicians tend to have a larger anterior corpus callosum, as well as greater representation of their fingers in the motor cortex, especially when musical training had been started at a young age and continued for at least fifteen months. Because playing an instrument requires complex multitasking, musicians develop superior multitasking skills, such as the ability to distinguish between conflicting auditory and visual stimuli. Additionally, since music affects areas of the brain connected to learning, people who listen to music or train in music show higher reading comprehension and math ability compared to non-listeners and non-musicians. Listening to music can be an emotional experience, in addition to the learning benefits, because of specific mechanisms associated with emotion which are stimulated by listening to music, as well as activation in areas which control underlying emotions, such as the amygdala and the mesolimbic reward system. Music is more than just sounds strung together. The effects of music are broad and should continue to be studied to determine the full extent of the benefits.

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