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Instruments of Knowledge: Music and the Brain

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Abstract

There is little doubt that music plays an important role in cultures all over the world and is an interconnected piece of every society. More specifically, actively engaging in the music by playing a musical instrument, particularly at a young age, has been a hot topic in neuroscience in recent decades. Playing a musical instrument has been shown to increase cognitive ability through enhanced neuronal communication between the left and right hemispheres of the brain, resulting in positive effects on learning, memory, fine motor skills, verbal and non-verbal reasoning, resulting in an overall more capable brain to apply in a multitude of settings. The current research and results are discussed, ultimately showing the importance of engaging children in instrument lessons of any kind to enhance the network of neuronal connections developing in the brain.

Keywords

playing music, music, brain, instruments, musicians and brain functioning

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There is little doubt that music plays an important role in cultures all over the world and is an interconnected piece of every society. Creating music has been one of the most basic actions of humans since prehistoric times. Although we have no official record because early music wasn't handed down between generations, flutes carved from bones have been found suggesting a musical presence in early civilization (O'Donnell 1999). We know that simply listening to music can produce changes in mood, behavior, and physiological functions of the body that are easily detected such as, breathing rate, heart rate, and blood pressure (O'Donnell 1999). Music is also perceived in different ways depending on one's level of expertise and familiarity with the rhythm and the genre. We cannot deny that music has a significant power in our world; even top universities place great emphasis on music education and participation in music (O'Donnell 1999). More specifically, actively engaging in the music by playing a musical instrument, particularly at a young age, has been a hot topic in neuroscience in recent decades. Playing a musical instrument has been shown to increase cognitive ability through enhanced neuronal communication between the left and right hemispheres of the brain, resulting in positive effects on learning, memory, fine motor skills, verbal reasoning, and non-verbal reasoning, resulting in an overall more capable brain to apply in a variety of diverse settings.

The connection between academic achievement and music can be seen throughout history. Thomas Jefferson used music and his violin to help him write the *Declaration of Independence* when he couldn't come up with the right words. Music helped Jefferson get his thoughts from his brain onto paper. Albert Einstein, one of the smartest men in history, was also a violin player. His mother bought him a violin in grade school and he attributes his intellect to his ability to play Mozart and Bach on the violin. His friend, G.J. Withrow, said Einstein figured out problems and equations by improvising music on the violin (O'Donnell 1999). Flashing forward into the present day, neuroscience technology such as fMRI, PET scanners, and MRI imaging have greatly increased our ability to understand the effect of music on the brain.

Recent studies show that neurophysiological distinction is trained when a child actively learns to play an instrument. Their brains learn to hear and interpret sounds unique to the experience of playing music that is not trained by just listening to it (Locker 2014). This is great for developing brains because as the brain is still maturing, it rewires the normal course of neuronal communication to be more elaborate in connecting the left and right hemispheres. The result is a brain more capable of processing complex information. Playing an instrument involves the interconnectedness between the motor, sensory, auditory, visual, and emotional components of the central and peripheral nervous systems (PCO, accessed 2016). This full brain mental workout involves artistic and aesthetic aspects of learning that is a unique characteristic of playing an instrument that an individual cannot stimulate by any other activity, even athletics. The combination of linguistic and mathematical precision in the left hemisphere is trained to work in coordination with the creative and novel functions in the right hemisphere. This will increase activity in the corpus callosum, allowing messages to get across the brain faster and through more diverse routes (Collins 2014). The improved communication between hemispheres is then translated to a musician's enriched ability to solve problems more effectively and creatively in academic and social settings (Collins 2014).

There have been numerous studies supporting the increased brain functioning of musicians compared to their non-musician counterparts. In 2005, Bengtsson and his colleagues found that instrumental practice increases myelination by using MRI technology to measure the amount of white matter found in the brain of children, adolescents, and adults that play the piano on a regular basis (Bengtsson *et al.* 2005). They concluded that playing the piano is an effective way to enhance the structure of white matter especially when the fiber tracts are still under maturation. In children, the correlation was extensive. Long-term training beginning in childhood induces regionally specific plasticity in myelinating tracts (Bengtsson *et al.* 2005). Another study completed by Gaser and Schlaug showed that gray matter volume in the motor, auditory, and visual-spatial brain regions is greater in musicians than non-musicians. This is mostly likely due to structural adaptations in response to long-term skill acquisition and repetitive rehearsal of that skill (Gaser and Schlaug 2003). The superior parietal region also plays an important role in integration of sensory information. It provides guidance for motor operations while appearing very active in the sight-reading skill that many musicians study for mastery (Gaser and Schlaug 2003).

Learning and memory improvement was also reported by multiple sources. The Portland Chamber Orchestra reports that practicing a musical instrument can lead to numerous structural changes in the brain just after 15 months of training in early childhood. These changes are correlated with improvement in certain motor and auditory skills. For example, the hippocampus, involved in learning and memory, increases neuronal connection and neurogenesis during development when the child is involved in musical training. This leads to improved learning and memory activity (PCO, accessed 2016). This is also supported by studies of those with amusia (tone deafness preventing basic musical skills and perception) possessing less white matter in regions of the brain compared to normal subject, especially those highly involved with music (PCO, accessed 2016). The creating, storing, and retrieving aspects of memory are faster and more efficient in the brains of musicians according to a *TedEd* report. This memory enhancement is attributed to the musicians highly connected brains giving a memory multiple tags. This process is subconsciously trained when learning to play an instrument because of the interconnectedness between the visual, auditory, and motor functioning and activity going on in the brain when we play a musical instrument (Collins 2014).

TIME magazine and nprEd (WXXI public broadcasting) both reported on a study published in the *Journal of Neuroscience* facilitated by Northwestern University that focused on The Harmony Project, a community music program in LA for low-income kids. The study showed direct evidence that music training has a biological effect on a child's developing nervous system (Locker 2014). The results of the study indicate students that were actively engaged (twice per week) in the interactive music class scored higher on reading tests and showed larger improvements in their brain's ability to process speech than their less involved or non-attending peers (Locker 2014). In addition, 93% of the seniors from this program go to college unlike the 50% dropout rate of peers in the neighborhoods where the children were raised (Turner 2014). Interestingly, this study opposes the myth of the "Mozart Effect" that claims just listening to certain genres of music will improve one's intelligence (Locker 2014). Through the use of scalp electrodes and heat mapping to capture the depth and richness of the brains ability to interpret sounds (increased by playing an instrument), this research supports that processing music has a very close resemblance to processing speech because of three common denominators: pitch, timing, and timbre (Turner 2014).

The sensory-motor integration and auditory-motor interactions are greater in those that play musical instruments than those that do not. Playing a musical instrument such as the piano requires precise mapping between a musical note (sound) and the finger used to execute that specific note on a keyboard (movement) (Zatorre *et al.* 2007). Functional neuroimaging studies and studies involving brain-damaged patients reveal the link between motor control systems (i.e. timing, sequencing, spatial organization, movement) and several cortical and sub-cortical regions. Included in the most prominent areas of activity are the cerebellum, basal ganglia, and supplementary motor area (Zatorre *et al.* 2007). The cerebellar cortex plays a critical role in planning, preparation, execution, and control of sequential finger movement (Gaser and Schlaug 2003). Patients with cerebellar lesions have an impaired ability to complete perceptual and motor timing tasks and damage to the basal ganglia also impairs movement timing (Zatorre *et al.* 2007). The auditory processing streams of pitch and rhythm in the auditory regions of the temporal lobe are stimulated consistently when playing music, providing more reason for increased brain matter in these areas (Zatorre *et al*. 2007).

The connection between practicing a musical instrument in childhood and enhanced verbal ability as a result of lasting function brain changes is a corresponding topic of research to the musical instrument studies. Children with at least 3 years of instrumental music training outperformed their control counterparts on auditory discrimination ability and fine motors skills as well as vocabulary and nonverbal reasoning skills (Forgeard *et al.* 2008). Additionally, in 2015, Moreno *et al.* published a study that explored the similarities between learning French and practicing an instrument. In both situations, there was improved processing of relevant trained sounds and increased ability to suppress irrelevant untrained sounds. Even after one year, the training-induced brain changes persisted, which is evidence supporting lasting benefits of early intervention in children. The similarities between the two processes in our brain include the same acoustic cues—timing, pitch, and timbre—to convey meanings (Moreno *et al*. 2015).

Playing a musical instrument, one of the most complex and demanding cognitive challenges the brain can undertake, is a very rewarding experience for many people on both the emotional and the biological level. The remarkable sensory-motor interplay that is trained during the process can be applied to so many other tasks one may face in their life. It is not a surprise that playing a musical instrument requires such integration of our brain's auditory, visual, and motor regions. This orchestra of the brain enhances a child's neuronal development between the right and left hemispheres, leading to a brighter academic future. There is still a great deal to discover about the effects of playing music on the brain, so with continuously improving neural technology, neuroscientists will be able to dive deeper into the question, revealing even more about the truth behind music and our brains.

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