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Editorial Journal of Neurology, Psychiatry and Brain Research JNPBR-127
ISSN: 2641-7049

The Effects of Musical Training on Brain Plasticity and Cognitive Processes

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Received Date: 15 April, 2019**; Accepted Date:** 18 April, 2019**; Published Date:** 29 April, 2019

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The link between musical training and its effects on brain plasticity have been studied since the early 20th century neuroanatomy research of Ramon y Cajal. In recent decades, studies have observed the contributions of musical training in enhancing auditory, motor, and language processing areas of the brain. The ability of musical training to impact behavior and critical thinking skills may also open the door for new methods of combating age- and illness-related cognitive decline **[1, 2]**. Therefore, understanding the ways in which musical training gives rise to neuroplastic change and its benefits for cognitive function will provide insight into its role in brain development.

One effective method of studying brain differences is through deformation-based morphometry (DBM), which detects changes in brain size through units of voxel expansions or contractions with reference to an MRI. Using DBM, one longitudinal research study by Hyde et al. **[3]** of 31 children determined that structural brain changes could be seen in as little as 15 months of instrumental musical training. Compared to a control group enrolled in group singing and playing drums/bells, the children enrolled in weekly half-hour private piano lessons showed marked increases in the voxel size of brain areas including motor and auditory cortexes, which significantly correlated to improvements in finger-motor and melody/rhythmic tasks, respectively. Hyde et al. further demonstrated that similar size differences are found in adult musicians compared to non-musicians, which suggests better planning, execution, and control of motor skills and refined auditory processing across a musician's life-span. As a result, Hyde et al. suggests a potential to use musical training as a form of intervention for children and adults with developmental disorders and neurological diseases.

Other studies direct their focus solely towards the impact of musical training on the auditory aspects of brain processing, specifically on musicians' abilities to differentiate sounds. In one 2012 study by Strait et al. **[4]** of 31 normal-hearing youths, musically trained participants displayed faster auditory brainstem response timing indicated by their heightened ability to discern words from "speech-shaped noise," meaningless sounds that have similar auditory properties of words. When placed in a soundproof booth and asked to identify words mixed with speech-shaped noises, the musicians outperformed the non-musicians in both the speed of their response and attention to the words. These results suggest a developmental role of instrumental musical training in the shaping of neurosensory function. Such contributions leave consideration for the use of musical training as a means of therapy for auditory-based learning impairments, such as language impairment, developmental dyslexia, and auditory processing disorders.

Similar speech encoding studies further support the idea that musical training leads to enhanced listening and language skills, as well as better integration of cortical processes, such as the cooperation of motor and multi-sensory networks **[5, 6]**. In addition, areas such as the cerebellum responsible for balance, coordination, and proprioception are structurally different in musicians compared to non-musicians. This is due to a wide range of skills necessary to play an instrument, including the translation and interpretation of foreign symbols into a target sound and using a combination of upper body, arm, and finger movements to produce the sound. As a

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result, musicians often engage in a "multisensory motor experience" that contributes to large brain differences between musicians and non-musicians in adulthood **[7]**.

Many of the enhanced brain processes identified in these studies last into adulthood **[4]**, which supports the idea that there is high plasticity in the nervous system at an early age. Some research suggests that this "window of opportunity" occurs before the age of seven **[7]**, but musical training could be capable of extending this period of heightened plasticity into teenage years **[6]**. Some studies suggest that training-induced plasticity is possible even in the mature brain. While there is little research on this subject, studies on brain plasticity in adults have shown that adults who continuously practice a skill, such as taxi-driving or juggling, observe increases in gray matter in certain areas of the brain. There is evidence that musical training has been successfully used in post-stroke rehabilitation of motor skills in the upper extremities **[8]**. Furthermore, one 2002 study found greater gray matter densities in Broca's area of male symphony orchestra musicians, whereas non-musicians displayed decreased total brain volumes compared to musicians. These results suggest an ability to delay age-related cognitive decline with continued musical training **[9]**.

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Citation: *Ker J, Nelson S (2019) The Effects of Musical Training on Brain Plasticity and Cognitive Processes. Jr Neuro Psych and Brain Res: JNPBR-127.*