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MUSICAL TRAINING SHAPES BRAIN ANATOMY AND AFFECTS FUNCTION

Training before age seven has bigger impact on brain anatomy; improvisation can rewire brain

SAN DIEGO — New findings show that extensive musical training affects the structure and function of different brain regions, how those regions communicate during the creation of music, and how the brain interprets and integrates sensory information. The findings were presented at Neuroscience 2013, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

These insights suggest potential new roles for musical training including fostering plasticity in the brain, an alternative tool in education, and treating a range of learning disabilities.

Today's new findings show that:

- Long-term high level musical training has a broader impact than previously thought. Researchers found that musicians have an enhanced ability to integrate sensory information from hearing, touch, and sight (Julie Roy, abstract 550.13, see attached summary).
- The age at which musical training begins affects brain anatomy as an adult; beginning training before the age of seven has the greatest impact (Yunxin Wang, abstract 765.07 see attached summary).
- Brain circuits involved in musical improvisation are shaped by systematic training, leading to less reliance on working memory and more extensive connectivity within the brain (Ana Pinho, MS, abstract 122.13, see attached summary).

Some of the brain changes that occur with musical training reflect the automation of task (much as one would recite a multiplication table) and the acquisition of highly specific sensorimotor and cognitive skills required for various aspects of musical expertise.

"Playing a musical instrument is a multisensory and motor experience that creates emotions and motions — from finger tapping to dancing — and engages pleasure and reward systems in the brain. It has the potential to change brain function and structure when done over a long period of time," said press conference moderator Gottfried Schlaug, MD, PhD, of Harvard Medical School/Beth Israel Deaconess Medical Center, an expert on music, neuroimaging and brain plasticity. "As today's findings show, intense musical training generates new processes within the brain, at different stages of life, and with a range of impacts on creativity, cognition, and learning."

This research was supported by national funding agencies such as the National Institutes of Health, as well as private and philanthropic organizations. Find more information about music, learning, and brain development at *BrainFacts.org*.

Related Neuroscience 2013 Presentation:

Fred Kavli Public Symposium on Creativity
Saturday, Nov. 09, 1:30–4 p.m., Room 6A

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Abstract 550.13 Summary

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Musical Training Influences Sense of Touch

Musical training improves the nervous system's ability to integrate information from multiple senses

Long-term, high level musical training strongly influences not only how people integrate their sense of sight and of sound, but also how they integrate their sense of touch and sound. The findings were presented at Neuroscience 2013, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

Prior research on the sensory impact of musical training has focused on audiovisual processing. The new research, presented by Julie Roy, of the University of Montreal, suggests a broader role for musical training in improving the ability of the nervous system to integrate information from all senses into an understandable whole.

"By looking beyond the audiovisual system and examining the nexus of touch and sound, our work demonstrates the impact of high-level, long-term musical training on sensory integration more generally," Roy said. "This opens the door to developing novel rehabilitation techniques that can address sensory integration disorders."

The ability of the nervous system to integrate information from all senses — sight, sound, touch, smell, self-motion, and taste — is critical to day-to-day life, but even more important for some specific pursuits. High-level musical ability requires a variety of sensory and cognitive abilities developed over the course of years of training. Recent research has revealed that long-term musical training improves the brain's ability to adapt, and shapes brain regions involved with audiovisual processing.

To examine how musical training may affect multisensory processing more generally, researchers administered two tasks that simultaneously engaged the sense of touch and hearing to two groups of people: a group of highly trained musicians and a group of non-musicians. In people with normal sensory capabilities, the specific combination of touch and hearing used in the tests could trick the senses and create perceptual illusions. For example, when distracted by sounds of a certain pitch, people could be fooled into thinking a normal piece of paper is rough like sandpaper.

Test results showed that, while musicians and non-musicians had identical capabilities to detect and discriminate information based on a single sense, people with long-term intensive musical training were better able to separate auditory and tactile information, and not fall prey to illusions when presented with multisensory stimulation. The results imply that long-term musical training has an influence on multisensory processing.

This research was supported with funds from the Québec Health Research Fund and the Natural Sciences and Engineering Research Council of Canada.

Scientific Presentation: Tuesday, Nov. 12, 8–9 a.m., Halls B-H

550.13, Enhanced multisensory processing in musicians
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TECHNICAL ABSTRACT: Recent investigations have revealed that long-term musical training promotes brain plasticity and generates reorganization in regions affecting multisensory processing. In addition to these anatomical and activation changes, recent studies have also shown behavioral alterations in multisensory processing induced by long-term musical training. While past investigations of multisensory integration have suggested an enhanced ability, only audiovisual modalities have been studied as of yet.
The aim of this study was to examine whether musical training enhanced multisensory integration and segregation abilities for other modalities, namely audiotactile. Two non-speech audiotactile illusory tasks were administered to a group of highly trained musicians and a group of non-musicians. Control conditions revealed that unisensory (detection and discrimination) capabilities were identical across groups. For the first task, musicians were able to segregate auditory and tactile information effectively in the context of an audiotactile illusion, whereas non-musicians were not. For the second task, unlike non-musicians,

musicians did not experience any illusory change of tactile perception in presence of modified auditory stimulations. Results from these investigations reveal that musicians have reduced susceptibility to auditotactile illusions, suggesting that auditory and tactile information can be processed more independently in musicians than in non-musicians. These results imply that long-term musical training has an influence on multisensory processing.
This research was supported by the FRQS and NSERC.

Abstract 765.07 Summary

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Starting Age of Musical Training Affects Brain Anatomy

Finding shows greatest impact on brains of adults who started musical studies by age seven

Musical training at a young age may strengthen the brain, especially regions that influence language skills and executive function (needed for activities such as planning, organization, and managing time and space). The new findings were presented at Neuroscience 2013, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

Specifically, the volume of brain regions related to hearing and self-awareness appeared to larger in those who began taking music lessons before age seven. The findings suggest that early musical training could potentially be used as a therapeutic tool, reported study author Yunxin Wang, of the State Key Laboratory of Cognitive Neuroscience and Learning at Beijing Normal University.

"Early musical training does more good for kids than just making it easier for them to enjoy music, it changes their brain and these brain changes could lead to cognitive advances as well," Wang said. "Our study provides evidence that early music training could change the structure of the brain's cortex."

The researchers investigated the impacts of music training on brain structure in 48 Han Chinese adults between the ages of 19 and 21, each of whom had engaged in formal musical training for at least a year, beginning sometime between the ages of 3 and 15. After controlling for the influence of gender and total practice time, researchers examined the volume of the brain's grey matter, surface area, and folding index across the entire brain. Findings suggested that music training started at a younger age might strengthen brain regions serving executive function and language skills. A comparison of participants that began music training before or after age seven revealed that members of the under age seven group also tended to have a thicker cortex (the outer layer of the brain) in areas linked to auditory processing and self-awareness.

Since the brain matures and develops in different ways at different ages, the study highlights the potential impact of the age at which musical training begins on brain development.

This research was supported with funds from the Ministry of Education of China and National Natural Science Foundation of China.

Scientific Presentation: Wednesday, Nov. 13, 10–11 a.m., Halls B-H

765.07, It matters when you start: The age of onset of music training predicts brain anatomy
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TECHNICAL ABSTRACT: Musical training, especially when it occurs in childhood, is assumed to benefit cognitive development. Recent studies have also pointed out that musical training could reduce the age-related decline of brain function. As theories on cognitive neurodevelopment have indicated that the human cortex undergoes a rapid maturation and development around the age seven, musical trainings at diverse ages might contribute differently to the shaping of the brain. Thus, the age of onset of music training is one of the critical contributors to the effects of training on cortical anatomy.
We investigated the impacts of musical training on brain anatomy in 48 (40F, all right handed) young Han Chinese adults. All participants were aged 19-21 years and each had an experience of formal musical training that lasted for at least a year (range: 1-16 yr, mean = 5.34±3.87 yr). The onset age of training varied from 3 to 15 years old (mean=7.58±2.67 yr). Surface based measures of cortical thickness and gray matter volume across the whole brain were generated from T1-weighted MR images by FreeSurfer v.5.0.
A regression analysis was carried out with onset age as the predictor for global brain anatomy, with gender and years of music training as covariates (intracranial volume was controlled in volume analysis).Then we divided the participants into the 7- group (who started musical training before age seven, 20F) and 7+ group

(who started music training later than age seven, 20F) and a whole brain analysis was done to explore the group difference. Gender, years of training and intracranial volume (volume analysis only) were also controlled as covariates.
Regression analysis shows that younger age of music training commencement was related to thicker right caudal ACC and larger volume of right lingual gyrus, as well as thinner cortex and smaller volume in the right lateral occipital region (Fig.1 a). Results of group analysis revealed that 7- group tend to have thicker cortex in right STG and precuneus compared with 7+ group (Fig.1 b).
Our study suggests a potential role of the onset age of music training in neural maturation and shaping of cortical cortex.

Abstract 122.13 Summary

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To Change Your Brain: Improvise, Improvise, and Improvise Some More

With practice, specific brain circuits are strengthen and music flows

Brain circuits involved in musical improvisation are shaped by systematic training, suggest a new study presented at Neuroscience 2013, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

Researchers also found that more experienced improvisers show higher connectivity between three major regions of the brain's frontal lobe while improvising. This suggests that the generation of meaningful music during improvisation can become highly automated — performed with little conscious attention, reported lead author Ana Pinho, MS, of the Karolinska Institutet.

"Our research explored whether the brain can be trained to achieve greater proficiency in improvisation," Pinho said. "The lower activity in frontal brain regions that we saw in trained improvisers is interesting, and one could speculate that it is related to the feeling of 'flow.' This is the feeling that many musicians report feeling during improvisation – when music comes without conscious thought or effort."

Improvisational training entails the acquisition of long-term stores of musical patterns and cognitive strategies to aid in their expressive, skillful combination. To test brain activity during improvisation, researchers worked with 39 pianists with a wide range of both classical piano training and training in jazz improvisation. They used functional magnetic resonance imaging (fMRI), which images blood flow in different parts of the brain. While the pianists improvised for brief periods on a 12-key MRI compatible piano keyboard, researchers tracked activity in the frontal lobe. More experienced improvisers showed a combination of higher connectivity and lower overall regional activity during improvisation. Higher connectivity also reflected extensive reorganization of functional connections within the regions of the frontal lobe that control motion.

According to the researchers , the extensive connectivity within the frontal lobe of experienced improvisers may allow the musicians to seamlessly generate meaningful re-combinations of music.

"This study raises interesting questions for future research, including how and to what extent creative behaviors can be learned and automated," said Pinho.

This research was supported with funds from Swedish Research Council, Sven and Dagmar Salén Foundation, and Fundação para a Ciência e a Tecnologia.

Scientific Presentation: Sunday, Nov. 10, 8–11:30 a.m., Room 7B

122, Neural basis of expertise in musical creativity - a functional magnetic resonance imaging study
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TECHNICAL ABSTRACT: One approach when studying the neural basis of creativity is to analyze the neurocognitive processes underlying performance in ecologically valid model behaviors. We studied neural correlates of musical improvisation in a sample of professional pianists (n = 39) with varying degrees of improvisational training. The participants performed different types of improvisations on a MRI-compatible 12-key MIDI keyboard, while brain activity was being measured with fMRI.
Two specific hypotheses were tested. Firstly, we tested whether regional brain activity during improvisation is specifically associated with hours of improvisational training. The results confirmed the hypothesis. A negative correlation was found between hours of improvisational training and the level of activity in the right superior parietal lobule and the dorsolateral prefrontal cortex. There was neither a correlation between expertise and behavioral complexity of the improvisations, nor between general piano practicing and brain activity.

Secondly, we investigated whether improvisational training also influences the patterns of functional connectivity between the brain regions that are active during improvisation. Analyses of psychophysiological interactions (PPI) were performed using seed regions in premotor and prefrontal cortex that have earlier been identified as key regions involved in free response generation and improvisation. For all these regions, it was found that improvisational training was related to increased functional connectivity with other motor, premotor, and prefrontal regions, when controlling for age and general piano playing.
The findings support that improvisation training has specific effects on neural networks involved in musical creativity. Extensive experience with improvisation is associated with lower levels of activity in frontal and parietal association areas, regions which are central for cognitive control, working memory, and explicit response selection, suggesting that generation of meaningful musical materials can be more automated or performed with less attentional effort. The PPI analysis indicates that improvisational training results in extensive functional reorganizations within motor regions of the frontal lobe.