Bulletin of the *Transilvania* University of Braşov
Series VIII: Performing Arts • Vol. 9 (58) No. 2 - 2016

Improving children's executive functions by learning to play a musical instrument

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Abstract: *Executive functions are the mental processes that support individuals to organize, focus attention, remember guidelines, and manipulate multiple tasks successfully. The brain needs these abilities in order to filter diversions, prioritize tasks, remember the information needed for completing them, to complete a task set and achieve goals, control and resist impulses and sustain attention during a particular activity. They provide essential support for children in order to develop properly and learn. Although children don't natively possess these skills, they are born with the potential to cultivate and improve them through interactions and practice.*

Key-words: *executive functions, working memory, mental flexibility, self-control, musical instrument*

1. An overview of the executive functions of the brain

Executive functions of the brain are the mental processes that help planning, remembering, paying attention, managing tasks and control the behaviour and correlate with academic skills. These functions coordinate other cognitive processes of the brain, connecting past experiences with present operations. They help predicting consequences, suppressing inappropriate actions and differentiating between positive and negative outcomes.

According to the *Center on the Developing Child* from Harvard University, executive function and self-regulation skills depend on three types of brain function that are highly interrelated, and the successful application of executive function skills requires them to operate in coordination with each other. These are *working memory*, *mental flexibility*, and *inhibitory control*.

Growth-promoting environments provide children with the support that helps them practice necessary skills before they must perform them alone. It is essential for children to exercise them through activities that nurture creativity, learn how to cope with stress, involve exercise, and provide opportunities for directing their own actions with decreasing adult supervision.

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The development of executive function takes place rapidly throughout early childhood (Diamond 2002, 466–503), though specific cognitive flexibility, working memory, and planning have a long-term developmental course that extends into adulthood. Some executive function constructs, like working memory, develop in a linear tendency until early adolescence (Gathercole, 1998), while others is thought to follow a more particular developmental curve into adolescence, with increasing accomplishment in rule representation starting only at approximately six years of age and difficulty switching between task sets until above age nine (Schellenberg, 2011). Prefrontal brain regions shown to be essential for executive functioning are acknowledged to structurally develop throughout childhood and adolescence (Kanemura et al., 2003).

1.1. Working memory

Working memory is the capacity to hold and manipulate information over short periods of time, offering a mental background for placing important information in order for it to be used in the course of everyday life. It enables children to remember and connect information from one paragraph to the next, to keep track of the moves and make a logical next step in a given task, and to follow multiple-step instructions without reminders.

Working memory has a limited capacity of storage, meaning that only a small amount of information can be held, so the most part is easily lost unless is mentally rehearsed. According to Neha Khetrapal from Macquire University (Khetrapal, 2014), "working memory is subdivided into short-term modality-specific stores like a phonological loop of dealing with auditory information, a visuospatial sketchpad for visually based information, and a modality free attention controlling system associated with the regulation of modality-specific and other information for the purpose of achieving goal-directed behaviour".

1.2. Mental flexibility

Mental flexibility is the capacity to adjust to changed demands, priorities, or perspectives, enabling one to apply diverse rules in different settings, to identify mistakes and fix them, to look over ways of doing things in light of new information, to consider something from a new perspective. Children can use this skill to learn exceptions to rules, to approach tasks in different strategies until they succeed.

1.3. Inhibitory-control

Inhibitory control is the skill used to master judgments and impulses in spite of temptations, distractions and habits and to stop and think before making actions. It represents the most important aspect regarding the process of developing selective, focused, and sustained attention, prioritization, and action, to be able to prioritize important tasks.

2. Musical training

An interest in associations between music training and cognitive and executive functioning has generated a series of studies over the past years. In the last decade, research has been developed regarding musical training as a tool for enhancing specific perceptual, motor, cognitive, and emotional skills The study of how far associations between learning to play an instrument and cognitive abilities range, and whether these relations are expected for some domains of cognition than for others, has theoretical relevance for issues of transfer, modularity, and plasticity (Schellenberg, and Winner, 2011). There is a similar interest of parents and educators who want to know if nonmusical intellectual and academic benefits are a result of music lessons. Some educators and arts advocates justify music training in schools because of the presumed and desired nonmusical cognitive functions. Meanwhile, several studies show that learning to play a musical instrument can bring substantial neurologic changes in motor, auditory and speech processing networks of the brain.

A series of music activities constrain the use of attention, inhibition, updating and mental flexibility, and provide recurrent feedback to students and teachers. Musical tasks differed in levels of executive functioning affordances and constraints. The music activities observed in many studies were associated with high levels of student engagement, particularly active engagement, and fewer off-task behaviour. Further analyses revealed some relationships between executive functioning affordances and constraints and students' levels of engagement and off-task behaviour. When students are actively engaged in music class, they are more likely to be practicing the important skills of attending, inhibiting, updating and shifting. Good music instruction can teach us about ways to engage students with any kind of instructional material.

Being an important component of executive functioning of the brain, the working memory's role in music processing has been a research subject in the last years. Studying a musical instrument involves high demands on working memory, as it requires processing visual, auditory and tactile cues all together. The effort that musicians have to make in order to process these cues is said to have extended effects on other daily tasks. These extensions of the brain capacity may be the

positive influences of musical training on cerebral functioning. Working memory is required for any type of complex activity, like language understanding or problem-solving skills, hence musical training may have extensive effects.

3. Studies regarding the effect of musical training on executive functions

A series of studies suggest that musical training may be complementary to helping children develop executive functioning skills important to success in school and life, supporting the inclusion of music programs in schools.

In 2011, Glenn Schellenberg compared musically trained and untrained 9- to 12-year olds on a measure of IQ and five measures of executive function (IQ and executive function were correlated). The musically trained group had higher IQs than their untrained counterparts and the advantage extended across the IQ subtests.

Degé, Kubicek and Schwarzer (Degé et al., 2011) also compared 9- to 12-year-old children, regarding intelligence and five different executive functions (mental flexibility, selective attention, planning, inhibition, and fluency) were assessed in with varying amounts of music lessons. Significant associations emerged between music lessons and all of the measures of executive function. Executive functions mediated the association between music lessons and intelligence, with the measures of selective attention and inhibition being the strongest contributors to the mediation effect. Their results suggest that at least part of the association between music lessons and intelligence is explained by the positive influence music lessons have on executive functions, which in turn improve performance on intelligence tests.

Sportsman (Sportsman, 2011) investigated the development of musical skills and behaviours associated with executive functioning among students in one urban elementary school, across one academic year of participation in an intensive after-school music program.

In 2014, Zuk, Benjamin, Kenyon and Gaab compared 15 musically trained children, 9 to 12, with a control group of 12 untrained children of the same age. Musically trained children had to have played an instrument for at least two years in regular music lessons. The neural correlates of executive function skills in musically trained and untrained children were investigated using fMRI. Musically trained children showed enhanced performance on measures of verbal fluency and processing speed, and significantly greater activation in supplementary motor area and pre-supplementary area and right ventrolateral prefrontal cortex during rule representation and task-switching compared to musically untrained children. Also, musically trained children further show heightened brain activation in traditional executive function regions during task-switching. These results support the working hypothesis that musical training may promote the development and maintenance of certain executive function skills, which could mediate the previously reported

studies between musical training and enhanced cognitive skills and academic achievement.

Overall, data trended toward supporting the hypothesis that music and executive functioning skills develop together. More research is needed to better understand the extent to which the relationship between expert musicians and high executive functioning skills is due to a reciprocal developmental process or selection.

4. Conclusions

While listening to the genre of music that makes listeners feel good can influence the feelings and the performance on a series of tasks, learning to play a musical instrument has been correlated with cognitive abilities and executive functioning of the brain. The effects of music arise for different reasons after short-term and long-term exposure or training. The evidence in neuropsychology field shows that, at the beginning, music is processed in the right hemisphere and, as the experience develops, music processing shifts to the left hemisphere of the brain. The long-term benefits of musical training have been explained as a result of a transfer of problem solving skills from one domain to the other, an ability that helps when cognitive mechanisms such as syntactic processing overlap for both language and music. Learning a musical instrument enhances performance in mathematics, sensitivity to emotional prosody, temporal-order processing and spatial-temporal skills. The positive association between executive functions and performance on different cognitive tasks might not only lie beneath the general relationship, but also the observed correlations between music lessons and specific cognitive abilities. The link between music and language abilities might be intermediated by executive functions (Moreno 2011, 329-345), considering that executive functions are heightened in musicians as well as in bilinguals (Bialystok and DePape 2009, 565-574). The possible mediating role of executive functions in reported associations between music lessons and specific cognitive abilities could be examined in future research.

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