Title
A Review of the Relation Between Music and Plasticity

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ABSTRACT

Although music has been called the universal language, its unifying effects aside, music seems to be universal in a particular biological phenomenon: plasticity. Music experience (defined as either playing, listening to, or creating music) has garnered responsibility for a broad range of processes that can ultimately be unified under the broad umbrella of 'plasticity' (Strait, 2012). Plasticity can take many forms and can be developed through numerous avenues. Music is able to play a part in many of those avenues. From the molecular to the individual level, and from the clinical to the basic-science realms, the effects of music on plasticity are intriguing, and its implication in numerous medical settings or neurological functions cannot be understated.

INTRODUCTION

The influence of music on the ability of the brain to perceive various information and perform various tasks has been studied in controlled experimental settings since the introduction of neuroimaging as means to investigate neuroscience. Specifically, music has been studied and used as the means to improve several functions of the brain through neuroplasticity or brain plasticity in both clinical and non-clinical environments. According to Zhang et al. (2020), brain plasticity is defined as that the brain can be modified by the environment and experience, and has the ability to shape the structure and function of the brain under the influence of the external environment and experience (Zhang, 2020). In a clinical setting, brain plasticity is also referred to as the structural changes in the brain due to illness or activity (Konopka, 2014). This will subsequently be described through molecular mechanisms such as NMDA receptor upregulation, by more global brain changes such as increases in cortex size post-musical experience, or by cognitive scales, where musicians and music 'experiencers' differentially perform on cognition tests compared to controls. Musical experience works to contribute to these brain changes via particular aspects of music such as "...the long duration, high emotional intensity and focused attention of a musical experience" (Reybrouck and Brattico, 2015). Further, individuals with certain neurodevelopmental and neurocognitive disorders such as ADHD, or cerebrovascular disorders such as stroke, are differentially subject to music and other art-related brain plasticity phenomena (Konopka, 2014; Zhang, 2020). Additionally, according to Sihvonen (2021), cerebrovascular injuries such as stroke often lead to damage along the language network that can be mediated by post-stroke vocal music listening due to its effects on neuroplasticity along this language pathway. Moreover, brain plasticity in the auditory cortex is also affected by music experience, as found by Strait et al. (2012), who purport that their method of musical-training may be instrumental in "...language-based learning deficits, which are often characterized by poor speech perception in noise" (Strait, 2012).

BODY

Zhang et al. (2020) describe the molecular basis that connects brain plasticity to music experience, which they claim is a result of secretion of neurotransmitters and peptide hormones. For example, vasopressin (antidiuretic hormone) activates the MAPK signaling pathway as a result of the feelings associated with a musical experience. This leads to expression of c-fos, which is known colloquially as the "immediate early gene" due to its influence on learning and memory. Additionally, Zengxian et al. (2004) found that expression of NMDA receptors is upregulated in neurons due to musical experience (Zengxian, 2004). NMDA receptors play an important role in the foundation of long-term potentiation between neurons, especially in hippocampal neural pathways. Further, NMDA receptors in the auditory cortex in particular are important along the pathways vital to learning and memory. As such, Korsos et al. (2018) reported an increase in both NMDA receptor subunit NR2B and spatial memory in mice as a result of musical experience (listening to Mozart, to be specific).

Preliminary studies regarding the impact music has on the brain compare the brains of musicians with non-musicians. Schlaug et al. (2006) used functional magnetic resonance imaging (fMRI) in right-handed musicians and non-musicians and found size differences in the corpus callosum, motor cortex, cerebellum and planum temporale between the brains of musicians and that of the non-musicians (Schlaug, 2006). This implies plasticity mechanisms are at play in regards to individuals with music training, as noted by the differential size of the investigated brain structures. More specifically, the planum temporale is essential for both speech processing in right-handed people, and auditory processing in general. Schlaug et al. conclude that music training induces changes in neuroplasticity that lead to enhancement of pitch perception. Nevertheless, the structural changes in the planum temporale, for example, could also be indicative of improvements regarding language and speech processing. In fact, Strait and Kraus (2011) compared auditory attention performance and speech-in-noise perception between musicians and non-musicians (Strait and Kraus, 2011). They found that there was a decrease in cortical response variability due to auditory stimuli in the central, temporal and parietal lobes in both musicians and non-musicians, but that only musicians exhibited this same decrease in the prefrontal cortex. This finding provides support for the hypothesis that musical training in particular is able to mediate auditory attention via neural networks in the prefrontal cortex - the area of the brain largely responsible for complex cognitive functioning, such as speech. This finding adds weight to the concept that the authors previously (2010) described as the mechanism behind a musician's advantage in auditory tasks (Strait, 2010). Strait et al. (2012) then went on to find that musicians possess stronger cognitive abilities due to musical training, as exhibited by correlations between auditory working memory and attention and auditory brainstem response properties (Strait, 2012). This gave musicians in the pivotal developmental years an advantage over non-musicians to better process speech in noise; an example of competing stimuli that may lead to difficulty in auditory processing. They conclude that, since language-based learning deficits revolve around poor ability to perceive speech in noise, it may prove useful to use musical training as a means to mediate such disorders.

On a separate note, music experience is implicated in improvements along a wide variety of neuro-related disorders, such as stroke. Zhang et al. (2020) note that stroke results in death at a rate of between 30% to 50% as a result of the particular neurological deficits caused by acute cerebrovascular circulatory dysfunction. Cha et al. (2014) applied a form of music called rhythmic auditory stimulation to patients with chronic hemiparetic stroke, which is stroke that leads to weakness of just one side of the body (Cha, 2014). Using the Berg balance scale, they noted that intensive gait training along with rhythmic auditory stimulation led to improvements in gait velocity, cadence, stride length, double support period, and even in stroke-specific quality of life. On the other hand, Särkämö et al. (2008) describes that early post-stroke patients benefit from cognitive recovery and mood enhancement as a result of music experience (Särkämö, 2008). Measurements such as focused attention, verbal memory and mood all showed improvements in patients in the music-listening condition

CONCLUSION

Music experience has been implicated in numerous forms of brain plasticity. From the molecular mechanisms of long-term potentiation, to the cognitive and auditory advantages of musicians, and even to the ability of music to meditate post-stroke symptoms, music shows versatility in its potential as a treatment in clinical or otherwise brain-related functioning. Clinical applications of the findings stated above include the shaping of neural mechanisms that underlie selective attention to speech, as noted by Strait and Kraus (2011). Further exploration of these ‘underlying mechanisms’ may allow clinicians tasked with remediation of attention-based learning and language impairments, such as ADHD. Strait et al. (2012) further bolster this claim, since their findings indicate that musically-trained individuals show an advantage in perception of speech in noise;

a widely recognized deficit that characterizes language-based learning deficits. Additionally, music has a powerful potential in the therapy of post-stroke patients, in the gait training of unilaterally-afflicted stroke patients, and in the mediation of cognitive and mood symptoms of stroke patients. Looking to the future, clinical trials should implement music therapy in a wider range of neurocognitive or neurodevelopmental disorders.

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