Exposure to music in the perinatal period enhances learning performance and alters BDNF/TrkB signaling in mice as adults

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Abstract

Music has been suggested to have a beneficial effect on various types of performance in humans. However, the physiological and molecular mechanism of this effect remains unclear. We examined the effect of music exposure during the perinatal period on learning behavior in adult mice, and measured the levels of brain-derived neurotrophic factor (BDNF) and its receptor, tyrosine kinase receptor B (TrkB), which play critical roles in synaptic plasticity. In addition, we measured the levels of 3-phosphoinositide-dependent protein kinase-1 (PDK1) and mitogen-activated protein kinase (MAPK), downstream targets of two main pathways in BDNF/TrkB signaling. Music-exposed mice completed a maze learning task with fewer errors than the white noise-exposed mice and had lower levels of BDNF and higher levels of TrkB and PDK1 in the cortex. MAPK levels were unchanged. Furthermore, TrkB and PDK1 protein levels in the cortex showed a significant negative correlation with the number of errors on the maze. These results suggest that perinatal exposure of mice to music has an influence on BDNF/TrkB signaling and its intracellular signaling pathway targets, including PDK1, and thus may induce improved learning and memory functions.

Keywords: Learning; Music; BDNF; TrkB; MAPK; PDK1; Mice

1. Introduction

Music is well known to affect biological systems [1,61]. Listening to music enhances cognition and learning [41,42], reduces blood pressure [2,52], and ameliorates various symptoms in epilepsy [22], Alzheimer’s disease [21], Parkinson’s disease [35], and senile dementia [11]. In addition, some studies suggest a beneficial effect of listening to music for a short-term period on spatial tasks in human. Particularly, listening to Mozart’s music for several minutes leads to enhanced spatial reasoning scores, the so called “Mozart effect” [17,42]. However, the “Mozart effect” is a matter of great controversy because some laboratories have been unable to produce a “Mozart effect” [27], or positive results have been interpreted as being explained by arousal or preference differences [4,32,53].

There are also several studies on the effect of music training on cognition and memory which have been carried out in developing children, although these studies are not limited to the listening effect of music. Better performance on spatial-temporal or verbal tasks was found in children who had received music lessons prior to testing in comparison with children who had received non-musical courses. For example, children aged 3–4 years, who were given keyboard music lessons, showed a dramatic increase in scores on spatial-temporal reasoning tests following the lessons, while the lessons showed no effect on a different spatial recognition test [43]. In another study, children with music training demonstrated better verbal memory than their counterparts without such training [13]. Furthermore, music training has long-term influences on non-musical abilities [45]. Indeed, adults who received music training before the age of 12 had a better memory for spoken words than those who did not, but there was no beneficial effect on a visual-spatial memory task [5]. These findings indicate the possibility that music has some effect on neuronal plasticity that is more efficient at early developmental stages. The controversy of the “Mozart Effect” and the lack of biological evidence on the effect of music on cognition or memory encouraged us to investigate the effect of music in an animal model during early developmental stages.

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