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Znanstveni teoretsko-pregledni prispevek

Mozart effect – reality or science fiction?

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Abstract: This article provides an overview of the theoretical underpinnings and some empirical findings regarding the Mozart effect. The »Mozart effect« refers to an enhancement of performance or change in neurophysiological activity associated with listening to Mozart's music. It was first reported in 1993 by researchers at the University of California, Irvine. They decided to choose Mozart since he started composing at the age of four. Thus they suggested that he was exploiting the inherent repertoire of spatial-temporal firing patterns in the cortex. Causal basis for relations between music ability and spatial reasoning ability is provided by the trion model of cortex. In this research context music is used as a window into higher brain functions. The Mozart effect can be referred to two different phenomena. The first is short-term increase in spatial abilities, the other is the possibility of formal training in music to bring benefits to other areas of human's knowledge. The effect can be found in the subsequently improved performance on spatial test results, increased EEG coherence, increased correlations of neurophysiological activity on the temporal and left frontal areas, increased spatial-temporal reasoning after piano lessons in preschool children, an enhanced learning of a maze by rats, changes in amplitude of alpha rhythm and increased interhemispheric coherence, in changes in EEG power and coherence, especially on the right temporal area, significant decreases in epileptiform activity, and enhanced short-term spatial-temporal reasoning in Alzheimer patients.

Key words: neurophysiology, trion model of cortex, Mozart effect, spatial-temporal reasoning

Mozartov učinek – resničnost ali znanstvena fantastika?

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Povzetek: V članku je predstavljen pregled teoretičnih osnov in nekaterih empiričnih študij o Mozartovem učinku. Mozartov učinek je nevrofizološki fenomen, ki se kaže v pomembnem izboljšanju reševanja prostorsko-časovnih nalog in v spremembi nevrofiziološke aktivnosti ob prisotnosti Mozartove glasbe. Prvič so o njem poročali znanstveniki Kalifornijske Univerze, Irvine, leta 1993. Celoten koncept temelji na preizkušanju trionskega modela organizacije korteksa. Glasba je v tem primeru le posrednik za vpogled v delovanje višjih kognitivnih funkcij. Mozartova glasba je bila v raziskovalne namene izbrana na podlagi predpostavke, da je omenjani skladatelj že pri štirih letih uporabljal inherentni repertoar prostorsko-časovih vzorcev v korteksu, saj je začel skladati že v zgodnjem otroštvu. Mozartov učinek se nanaša na dva različna fenomena, po eni strani gre za kratkotrajno povečanje prostorskih sposobnosti ob poslušanju Mozartove glasbe ter po drugi strani za dolgotrajni učinek formalnega glasbenega izobraževanja na delovanje višjih kognitivnih funkcij. Kaže se v pomembnem izboljšanju rezultatov reševanja prostorskih testov, povečani EEG koherenci, povečanih korelacijah nevrofiziološke aktivnosti

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temporalnih in levo frontalnih področij, v povečanem prostorsko časovnem sklepanju pri predšolskih otrocih po nekajmesečnem učenju klavirja, v izboljšanem učenju orientacije v labirintu pri podganah, v spremembah v amplitudi alfa ritma in povečani interhemisferični koherenci, v spremembah v moči in koherenci EEG-ja, posebno v desnem temporalnem področju ter v pomembnem upadu epileptiformne aktivnosti ter v povečanem kratkoročnem prostorsko časovnem sklepanju pri Alzheimerjevih bolnikih.

Ključne besede: nevrofiziologija, trionski model organizacije korteksa, Mozartov učinek, prostorsko časovno sklepanje

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Trion model of higher brain functions: prediction that music enhances spatial-temporal reasoning

Early studies showing enhancement of spatial-temporal reasoning after exposure to Mozart were motivated by Shaw and his colleagues' "trion" model of the cortex (Leng & Shaw, 1991; McGrann, Shaw, Shenoy, Leng & Mathews, 1994; Shaw, Silverman & Pearson, 1985; Shenoy, Kaufman, McGrann & Shaw, 1993). The trion model is a highly structured mathematical realization of Mountcastle's (1997) organizational principle for the cerebral cortex. Mountcastle proposed that the cortical coloumn, the basic neural network of the cortex, can be exited into complex firing patterns which, in the trion model, are exploited in the performance of tasks requring ability to recognize and classify physical similarities among objects – spatial recognition tasks. These neural firing patterns can be strengthened through small modifications to their connectivity strengths as indicated by Hebbian principles (1949, in Shaw, 2000) , yielding a huge repertoire of inherent firing patterns which probabilistically develop into explicit temporal sequences lasting tens of seconds and occuring over large portions of the cortex (Leng & Shaw, 1991; McGrann et al., 1994; Shaw et al., 1985; Shenoy et al., 1993). The trion model proposes that these neural firing patterns allow for the performance of more complex spatial tasks- spatial-temporal tasks. In addition to requiring the recognition of object relations, spatial-temporal tasks require the ability to transform mental images in the absence of a physical model (Rauscher, Shaw & Ky, 1995; Rauscher, Shaw, Levine, Ky & Wright, 1994; Rauscher, Shaw, Levine, Wright, Dennis & Newcomb, 1997). Spatial-temporal reasoning is required for higher brain functions relevant to mathematics, engineering and chess (Leng & Shaw, 1991; McGrann et al., 1994; Shaw et al., 1985; Shenoy et al., 1993). Music cognition, it was argued, should also require these temporal sequences of neural activity (Leng & Shaw, 1991). Music acts as an »exercise« for exciting and priming the common repertoire and sequential flow of the cortical firing patterns responsible for higher brain functions. The cortical simmetry operations among the inherent patterns are enhanced and facilitated by music (Rauscher et al., 1995). Leng and Shaw (1991) proposed that music is a »prelanguage« (with centers distinct from language centers in the cortex), available at an early age, which can access these inherent firing patterns and enhance the cortex's ability to accomplish pattern development, thus improving other higher brain functions.

Music enhances spatial-temporal reasoning

In a study published in the journal Nature, Rauscher et al. (1993) found, that college students who had spent 10 minutes listening to Mozart's Sonata for two pianos in D Major had Stanford-Binet spatial subtest IQ scores 8-9 points higher than students who had (a) listened to a relaxation tape or (b) listened to nothing. The IQ effects did not persist beyond the 10-15 min testing session. In a follow-up study, Rauscher et al. (1995) attempted to replicate their findings with a new sample of 79 college students. Over the course of 5 testing days, they examined differences between those who had listened for 10 min to Mozart's Sonata K 448 and those who had heard nothing or had listened to variety of nonclassical musical selections. The Mozart group had significantly higher scores on Day 2, but was not significantly different from the other two groups on Days 3, 4, and 5. Interestingly, the effect of listening to Mozart in this study was not immediate as it was in the first study; however, in both experiments, the effect did not persist.

Most interesting are findings with preschool children. In one study, children between the ages of 3 and 5 who had private piano keyboard lessons 10 min/day for 6 month were compared to those who had computer lessons, singing lessons, or no lessons. The piano group had higher posttest scores on the Object Assembly task (requiring spatial-temporal abilities) of the Wechsler Preschool and Primary School Test of Intelligence (WPPSI). There were no differences between the groups on spatial recognition tasks (Rauscher et al., 1997). The researchers described the changes in spatial-temporal ability as »long-term« because they were equally evident for children who were tested less than 1 day after their final lesson and those tested more than 1 day later. The authors concluded that »music training«, unlike listening, produces long-term modifications in neural circuitry… in regions not primarily concerned with music,« and that the improvement for the piano group was equivalent to »an increase from the 50th percentile on the WPPSI-R standardized test to above the 85th percentile« (Rauscher et al., 1997, p.7). The »Mozart effect« has also been established in rats (Rauscher, Robinson & Jens, 1998). Long-term exposure to the Mozart Sonata enhanced learning of a maze by rats and the enhanced performance lasted more than four hours after the last exposure to music.

In their studies of both preschoolers and college students, Rauscher and colleagues conjecture about the mechanism underlying the findings. They suggest that exposure to music (Mozart in particular) primes the portion of the cortex responsible for spatial-temporal reasoning. Presumably, this »priming«, if it occurs over a period of time, serves to strengthen those neural circuits and results in »long-term« change.

The Mozart effect (lasting approximately 10 minutes) further supports the trion model, suggesting that listening to music helps to »organize« temporarily, the cortical firing patterns for spatial-temporal processes.

Replications of the Mozart effect

There have been several studies that replicated the Mozart effect, showing that exposure to Mozart produces an enhanced spatial performance (Rideout, Dougherty & Wernert, 1998; Rideout & Laubach, 1996; Rideout & Taylor, 1997; Shreiber, 1988; Wilson & Brown, 1997). However, just as many studies have failed to replicate the Mozart effect (Carstens, Huskins & Hounshell, 1996; McCutchen, 2000; Newman, Rosenbach, Burns, Latimer, Matocha & Vogt, 1995; Steele, Ball & Runk, 1997; Steele, Bass & Crook, 1999; Steele, Brown & Stoecker, 1999; Stough, Kerkin, Bates & Mangan, 1995).

Reviewing many of these studies, Rauscher and Shaw (1998) indicated that failures in replicating the Mozart effect can be explained in terms of the dependent measures used, the experimental procedure employed, and the class of musical stimuli used. In terms of dependent measures, four of the studies that did not support the Mozart effect used different Tests compared to Rauscher et al. (1993): the Raven's Progressive Matrices Test (Newman et al., 1995; Stough et al. 1995), the Revised Minnesota Paper Form Board Test (Carstens et al., 1996) and Backward Digit Span (Steele at al., 1997). Where the dependent measure was the PF&C task from the Stanford-Binet Intelligence Scale, successful replications of the Mozart effect have been found (Rideout & Laubach, 1996; Rideout & Taylor, 1997, Rideout et al., 1998). Rauscher and Shaw (1998) subsequently restricted the effect, claiming that it was only found on spatial-temporal tasks that involve the ability to transform mental images in the absence of a physical model. Rauscher and Shaw (1998) suggest that two components of spatial-temporal tasks-spatial imagery and the temporal ordering of spatial components- are essential for the Mozart effect and should be used as dependent measures.

In terms of procedure, Rauscher et al. (1993) found the Mozart effect trough a treatment followed by a post-test design. Several studies that did not replicate the Mozart effect used a pretest-post-test design (McCutcheon, 2000; Newman et al., 1995; Steele et al., 1999b), which was not included in the original study. Rauscher and Shaw (1998) explained that they avoided a pretest in their original study (Rauscher et al., 1993) in order to prevent carryover learning effects that may otherwise mask the Mozart effect.

Finally, Rauscher and Shaw (1998) point out that it is also important for researchers to consider the class of music that may produce the hypothesized enhancing effect. They argued that complexly structured music similar to the Mozart sonata in tempo, melody, organization, and predictability may also enhance spatial-temporal task performance. That was confirmed with Rideout et al.'s (1998) findings where a musical piece by Yanni that was perceived to be similar to Mozart's sonata in tempo and structure also enhanced spatial-temporal task performance. Rideout et al. (1998) exposed subjects to the music of Mozart, a contemporary Yanni composition (which authors propose is similar to the Mozart sonata in tempo, structure, melodic and harmonic consonance, and predictability), or instructions for progressive relaxation. Performance on a paper-folding task was significantly improved following exposure to both the Mozart and Yanni works. Enhanced spatial-temporal task performance, after hearing Schubert's Fantasia for Piano, 4 Hands in F Minor (D940) or Mozart's Piano Concerto No.23 in A major (K488) (Wilson & Brown, 1997) was observed. However, paper-folding scores of subjects exposed to either minimalist or contemporary »trance« music showed no improvement (Rauscher et al., 1995). These varied findings suggest that complexly structured music, regardless of style or period, may enhance spatial-temporal task performance more readily than repetitious music.

Mozart effect as an artefact of preference

On the contrary of the trion hypothesis, a second hypothesis explains the Mozart effect as an artifact of mood and arousal (Nantanis & Schellenberger, 1999). The authors claim that the effect could be generalized to a wide variety of enjoyable pieces of music composed in the Classical (late 1700s; Mozart, Haydn) or Romantic (early 1800s; Schubert, Liszt). A similar effect might be evident when any positive stimulus (music or otherwise) is paired with a less engaging stimulus. Nantanis & Schellenberger's study confirmed (1999) that performance on spatial-temporal tasks may be enhanced after passive listening to a pleasant or interesting auditory stimulus and that decrements on such tasks may be consequence of exposure to 10 min of a stimulus deemed to be relatively boring or unpleasant. Based on a meta-analysis of 16 studies, Chabris (1999) came to the conclusion that there may be a small intermittent effect which probably arise from »enjoyment arousal« induced by music. It is possible that the Mozart effect has little to do with Mozart in particular or with music in general. Rather, it may represent an example of enhanced performance caused by manipulation of arousal and mood. Husain, Thompson and Schellenberg (2002) examined effects of tempo and mode on spatial ability, arousal, and mood. The study showed that performance on spatial task was superior after listening to Mozart's Sonata K.448 at a fast rather than a slow tempo, and when the music was presented in major rather than minor mode. Tempo manipulations affected arousal but not mood, whereas mode manipulations affected mood but not arousal. Changes in arousal and mood paralleled variations on the spatial task. This was not confirmed in our pilot study (Habe & Jaušovec, 2003) in which the event-related responses of 16 individuals were recorded while they were listening to 3 music clips of 6 s duration which were repeated 30 times each. The music clips differed in the level of their complex structure (assessed by music experts), induced mood (assessed by naive listeners), and musical tempo. They were taken from Mozart's sonata (K. 448), and Brahms' Hungarian dance (no. 5). The third clip was a simplified version of the theme taken from Haydn's symphony (no. 94) played by a computer synthesizer. Significant differences in induced event-related desynchronization between the 3 music clips were only observed in the lower-1 alpha band, which is related to attentional processes. Respondents showed greater desynchronization in the lower-1 alpha band while they were listening to the clip taken from Mozart's sonata (MS). It seems that the MS music clip – with no regard to the level of induced mood, musical tempo and complexity – had the highest impact on the respondents' attention, their level of alertness or arousal. This suggests that other distinctive aspects of the Mozart sonata may have a key influence on the reported neurophysiological activity.

Neurophysiological basis of the Mozart effect

Although brain functions are typically associated with specific, localized regions of the cortex, most higher cognitive abilities draw upon a wide range of cortical areas (Petsche, Richter, Stein, Etlinger & Filz, 1993; Sarnthein, Von Stein, Rappelsberger, Petsche, Rauscer & Shaw, 1997). Leng and Shaw (1991) proposed that exposure to music might excite the cortical firing patterns used in spatial-temporal reasoning, thereby affecting cognitive ability in tasks that share the same neural code-spatial-temporal tasks. The improvement of spatial reasoning capabilities by listening to music has been studied by EEG power analyses (Rideout & Laubach, 1996). Sarnthein et al. (1997) reported the presence of right frontal and left temporo-parietal coherent activity induced by listening to Mozart which carried over into spatial-temporal tasks in three of seven subjects. This carry-over effect was compared to EEG coherence analysis of spatial-temporal-tasks after listening to text. The authors suggest that these EEG coherence results provide the beginnings of understanding of the neurophysiological basis of the causal enhancement of spatial-temporal reasoning by listening to specific music. The observed long-lasting coherent EEG pattern might be evidence for structured sequences in cortical dynamics that extend over minutes.

Bodner, Mutfuler, Nalcioglu, and Shaw (2001) used fMRI to examine the specific structural activations that occur in subjects during exposure to the Mozart Sonata (K.448) as compared to control (piano) music. They found that particularly, listening to the Mozart Sonata (K.448) resulted in activation of prefrontal and auditory cortex for all three subjects. The fact that no prefrontal activation was observed for either the popular or the Beethoven piano music (which was familiar to the subjects) shows that this activation was not due to expectations from either knowing the piece, some general expectations because the piece was classical, or some type of general build-up or afterdischarge of activity.

Clinical implications of the Mozart effect

There are two major clinical areas where the Mozart Effect was confirmed. An amazing study was done by Hughes, Daaboul, Fino & Shaw (1998) by monitoring the EEG of epileptic patients. In 23 of 29 subjects he found a dramatic and statistically significant reduction of abnormal firing in the cortex while listening to the first movement of the Mozart Sonata (K.448). Some of these subjects were in coma. Brain maps during the music showed theta and alpha activity decreased on the central areas, while delta waves increased on the frontal midline area. Hughes, Fino & Melyn (1999) demonstrated that a chronic change could also be seen from hourly exposures of this music over a 24-hour period of time.

Johnson, Cotman, Tasaki & Shaw's study (1998) showed that Alzheimer patients after listening to the Mozart sonata had enhanced short-term spatial-temporal reasoning. The subjects who did not improve from pretest to posttest after a listening condition of silence or 1930s »popular piano music« had substantial increases after listening to the Mozart sonata (K.448). Some studies of the Mozart effect were also conducted with patients with Williams Syndrome, stroke and Down syndrome (Shaw, 2000). But the outcomes are not evident enough to lead us to any firm conclusion.

Educational implications of the Mozart effect

Spatial-temporal (ST) reasoning – »thinking in pictures« - has long been recognized as essential to how we think in math and science and has been crucial in the intellectual history of technological development (Ferguson, 1977). The educational system relies almost entirely on language-based reasoning, while neglecting the complementary and innate ST reasoning. ST reasoning involves maintaining, transforming, and comparing mental images in space and time using symmetry operations, and is fundamental in learning and using math and science concepts.

The causal connection between music training and enhanced learning of difficult math concepts by young children has been firmly established. Rauscher et al. (1997) had seventy-eight preschool children participated in their study. Thirty-four children received private piano keyboard lessons, 20 children received private computer lessons, and 24 children provided other controls. Significant improvement on the spatial-temporal reasoning was found for the keyboard only and the effect lasted at least one day, a duration traditionally classified as long term. Graziano, Peterson and Shaw (1999) conducted a study in which they demonstrated that preschool children who were taught fractions and proportional math using Spatial-Temporal Math Video Game software in combination with piano keyboard training scored significantly higher on proportional math and fractions than children given a control training along with the Math Video Game. Shaw (2000) suggests that the most effective solution for teaching math concepts would be integration of piano keyboard training and S.T.A.R (spatial temporal animation reasoning) training into standard language-analytic math curriculum.

Conclusion

As can be observed from the presented article the Mozart effect comprises a wide variety of different researches. The term »Mozart effect« could be missleading for a reader while researches about the Mozart effect sometimes do not use Mozart music, but they just derive from the basic concept that Mozart music enhances spatial-temporal reasoning. So Mozart music is just a milestone. Studies about Mozart effect could be organized in three main categories; Mozart-effect listening experiments, direct tests of the trion model of higher brain function and music training that enhances children's spatial-temporal (ST) reasoning and math learning. In general we can say that Mozart effect contains a range of studies that involve using music as a window into higher brain functions. The starting point of all the researches is that music and mathematics are causally linked through the build-in, innate ability of the brain to recognize symmetries and use them to see how patterns develop in space and time. The trion model of cortex provides a causal basis for relations between music ability and spatial reasoning ability. The main purpose of the researches of Mozart effect is to gain better understanding of the functioning of higher brain functions and music is just being used as a mediator, as a key to understanding how we think, reason and create, and how it can enhance these higher brain functions through our innate ST abilities.

So, is Mozart effect reality or science fiction? In our opinion it's a science fiction becoming reality. Some findings are highly promissing, but a major breaktrough would be finding an answer why this specific Mozart's sonata and compositions that have the same musical complexity resonate with the brain causing an enhancement of spatial-temporal ability. If music was really a sort of prelanguage for scientific thinking, this would mean, that we could use it in teaching difficult abstract concepts. Music can access inherent firing patterns and enhance the cortex's ability to accomplish pattern development, thus improving other higher brain functions. New findings would also provide more solid proof of the importance of music in educational system.

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