EXPLORING THE RELATIONSHIP BETWEEN MUSIC AND CHILDREN'S COGNITIVE ABILITY

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Abstract
The relationship between music and brain has long been the concern of many research studies. Initially, Rauscher, Shaw and Ky (1993) reported preliminary results for what they termed 'the Mozart effect', based on the belief that music with a complex structure, and especially the music of Mozart, could briefly improve the spatial-temporal reasoning ability of adults. This initial, pioneering study paved the way for a significant number of additional studies expanding on the range of musical features, the breadth of cognitive abilities, and the number of individuals included in the research population. However, the debate on the reliability and stability of the Mozart effect has never ceased.
The aim of this current study was to explore the extent to which a) the Mozart effect could be repeated through a series of brief musical conditions working with young children, rather than with the more usual older populations, and b) the spatial reasoning ability of young children could be improved as a result of listening to the music of Mozart, to the more culturally familiar music of Li Huan Zhi and in one further condition of silence.
Keywords: *the Mozart effect, children, cognitive abilities, music, relationship*

Introduction

The development of technology has created a world in which music can be enjoyed at any point in time, and in almost anywhere on the globe. Indeed, today, music has spread to all aspects of our lives (Rentfrow, 2012) and fulfils a vast range of functions including, background entertainment, mood regulation, social cohesion, self-reflection and social connection (Schäfer, Sedlmeier, Städtler & Huron, 2013). Other research studies have further argued that music can be used as a treatment for a wide range of illnesses (Brackney & Brooks, 2018), or to influence both our online and in shop purchases (Areni & Kim, 1993; Hwang, Oh & Scheinbaum, 2020; Lai & Chiang, 2012; Rodgers, Yeung, Odindo & Degbey, 2021). However, the idea that music can improve cognitive development (Beauvais, 2015) is derived, in part, from studies revolving around the 'Mozart effect' (Rauscher & Shaw, 1998).

The '*Mozart Effect'* originally referred to the temporary improvement in people's spatial-temporal reasoning ability following exposure to music by Mozart, or music written in the classical style of Mozart. In a pioneering study by Rauscher, Shaw & Ky (1993), 36 college students experienced each of three conditions namely: (1) listening to Mozart's Sonata for Two Pianos in D Major (K448) for 10 minutes, (2) listening to a 10-minute relaxation instruction, and, finally, (3) sitting in silence for 10 minutes. Following each condition, participants' spatial reasoning ability was measured using a pattern analysis test, a multiple-choice matrices test and a multiple-choice paper folding and cutting test (PF&C), derived from the Stanford-Binet intelligence scale. Findings suggested that participants' performance on each task increased more in the listening to Mozart's sonata condition, than after either the relaxation and silence conditions. However, the increase was also found to be short-lived.

The possible significance of this initial work generated a sizeable volume of further research (Moscucci, Verrusio, Gueli & Cacciafesta, 2015), most of which has been dedicated to extending the definition of the Mozart effect. For example, Rideout, Dougherty & Wernert (1998) found that Yanni's music has the same effect as the music of Mozart and similarly, Ivanov & Geake (2003) found the same effect for Bach's music. Smith, Waters & Jones (2010) adopted a within-subjects design in which young adults participated in three different listening conditions, namely a Mozart piano sonata, listening to a series of motivating statements and sitting in silence. Following each condition, all participants completed the '*Revised Minnesota Paper Form Board Test'* (RMPFB) which assessed the participants' spatial and mental visualization ability. Participants' overall mood was also evaluated before and after each condition. Overall, results supported the Mozart effect with the test scores of participants after listening to Mozart music being higher than scores achieved in the other two conditions. In contrast, Padulo, Mammarella, Brancucci, Altamura & Fairfield (2019) failed to find any support for the Mozart effect amongst their sample of 179 undergraduates and 183 older adults. In this study, participants were randomly divided into one of four conditions, namely a) listening to Mozart KV 448, b) an amplitude modulation tone, c) a frequency modulation tone, and finally, d) white noise. Although the results found no significant effect on the performance of young people's spatial-temporal reasoning tasks, but demonstrated significant impact on the spatial-temporal reasoning ability of the older adults.

Cacciafesta et al. (2010) carried out two studies with two groups of elderly participants. The two groups were of similar age; however, one group was diagnosed with a mild cognitive impairment. This study was notable in that for the first time all the participants completed a series of tests with each one corresponding to different cognitive abilities, namely, a) spatial-temporal reasoning, b) episodic learning, c) ideational-praxis abilities, d) Rey's 15-word test of immediate recall, e) the trail making test of attention, and f) the digit span for number memory. Following this battery of tests, participants listened to Mozart and completed similar post listening tests. 15 days later, they participated in the second identical experiment in which the musical stimulus used was by Beethoven. Results from the extensive series of measures found that the music of Mozart made a more significant impact on elderly participants with mild cognitive impairment than those without.

Several experiments extended the age range of previous studies to include younger participants. For example, McKelvie & Low (2002) found similar results amongst on younger participants 55 grades 7 and 8 students, who were randomly divided into four groups: two groups experienced Mozart's music, and two experienced dance music from 'Aqua'. The test was to complete nine paper folding and cutting. Results suggested that the children's pretest and protest performances were similar in both Mozart and Aqua conditions. A second experiment involving 48 grades 7 to 8 students in eight procedural groups and a control using relaxation music found no overall effect. Further work with 135 grade five students found no effect or significant difference on spatial reasoning test between popular music and Mozart music (Crncec, Wilson & Prior, 2006). However, in a sample of 8120 children (aged 10 – 11 years) Schellenberg & Hallam (2005) found that pop music appeared to impact on their spatial reasoning ability more than music by Mozart.

Hence, since the first reported work by Rauscher, Shaw & Ky (1993), the effect of music on individual development has induced a significant number of further studies, and whilst some have offered support for the Mozart effect (Smith, Waters & Jones, 2010; Cacciafesta et al., 2010), others have not (McKelvie & Low, 2002; Crncec, Wilson & Prior, 2006). However, to date, there has been little agreement as to what precise mechanism sits behind the effect experienced through engaging with the music of Mozart. Essentially, there are two basic groups of theories for explaining any such effects, namely the priming effect, which argues that music causes similar firing patterns in the brain that are involved in the process of spatial-temporal reasoning (Rauscher & Shaw, 1998; Jausovec, Jausovec & Gerlic, 2006). Whilst a second argument suggests that the enjoyment of the musical stimulus causes changes in mood and arousal, thereby improving task performance (Nantais & Schellenberg, 1999; Thompson, Schellenberg & Husain, 2001).

Further confirmation of the priming effect was obtained in the works of authors such as Kozelka & Pedley, (1990), Husain, Thompson & Schellenberg (2002), Jausovec, Jausovec & Gerlic (2006), Verrusio, Ettorre, Vicenzini, Vanacore, Cacciafesta & Mecarelli (2015), Giannouli, Kolev & Yordanova (2019). Though support for the theory of mood and arousal came from Thompson, Schellenberg & Husain (2001), Husain, Thompson & Schellenberg (2002); Schellenberg, Nakata, Hunter & Tamoto (2007), Pekrun et al. (2017).

Further studies have attempted to explore and isolate the individual factors, which may affect the participants' performance in spatial reasoning tests and hence, posit a number of reasons for the lack of homogeneity amongst the previous studies investigating the Mozart effect. For example, Gaser & Schlaug (2003) compared the physical make up of brains from 20 male professional musicians, 20 male amateur musicians and 40 male non-musicians, and found significant differences in the region of the brain associated visual-spatial pattern recognition with, and therefore they argued that musicians should develop higher levels of spatial reasoning ability. Similarly, Brochard, Dufour & Després (2004) found that compared with non-musicians, musicians were faster in associating visual stimuli with specific motor responses resulting from years of daily instrumental practice and from their music reading experience. Therefore, they argued that increased levels of ability in visual-spatial reasoning tasks could well be the result of musical training.

In addition, the results of a longitudinal study by Schlaug (2005) on children aged 5 to 7 showed that 9 to 11-year-old children with an average of four years of music training had significantly higher levels of spatial reasoning about it. The authors explain the variety of skills in reading music and playing musical instruments. Similarly, Rauscher & Hinton (2006) through a longitudinal study of preschool children showed that compared with the control group, children who received music instruction before the age of seven, showed better performance in spatial-temporal and numerical reasoning tasks. Furthermore, they found that the impact lasted for two years. Essentially, music training may enhance spatial reasoning because the musical notation itself is spatial.

Schellenberg (2005) also argued that music improves abstract reasoning because a tune is determined by information about relationship. The llisteners recognize a specific tune whether it is played fast or slow, on a piano or guitar, at a high or a low pitch. In other words, the tune is abstract and the listener is required to generalize patterns that have similar but not the same related information (for example, variations of the theme). Thus, Schellenberg (2005) argued that through this training, learning abstract thinking and understanding the similarities of music under different backgrounds promoted intellectual development more widely. Similarly, Miendlarzewska & Trost (2014) argued that musical training develops children's attention and memory. Therefore, the transfer skills of executive function, self-control and sustained concentration may translate into better results in other subjects and may even translate into higher overall IQ. However, in contrast Giovanni & Fernand (2017) argued that musical training cannot reliably enhance the cognitive or academic skills of children and adolescents, and the previous positive findings may be due to confounding variables.

Having given due consideration to the literature, there is still a lack of clarity as to the extent to which the Mozart effect actually impact on a range of cognitive abilities and factors which might influence the effectiveness of that impact. One thing is clear, namely, that any experience, which positively affect the cognitive development of children must be an important area for future research. Hence, **the current study set two research questions:**

- *To what extent does the Mozart effect impact child?*
- *If we can replicate the Mozart effect, which mechanism can produce the Mozart effect?*

Method and Sample

Our research procedure employed 87 children (students) aged between 9 and 10 years old in the autumn of 2020. All participants had received approximately six years of general, school music education including three years in kindergarten and three years in primary school. Seven participants had also received extracurricular music training on musical instruments. The stimuli for the experiment lasted for 10 minutes. All children experienced three distinct stimuli conditions namely: listening to excerpts of

Mozart's Sonata for Two Pianos in D Major, K 448 for 10 minutes; sitting in silence for 10 minutes; listening to Li Huan Zhi's Spring Festival Overture for 10 minutes.

The silence and Mozart Sonata condition replicated the original stimuli used by Rauscher, Shaw & Ky (1993). However, as other studies had also utilized a further comparative condition (Thompson, Schellenberg & Husain, 2001; Crncec, Wilson & Prior, 2006), we also adopted one further comparative condition. Li Huan Zhi's Spring Festival Overture was chosen for the other stimulus in this experiment because it represented a number of factors (which previous work had suggested) could create a similar effect to that obtained by the music of Mozart, namely, a) complex structure, b) major mode, c) a fast tempo, and d) cultural familiarity and preferences. Li Huan Zhi's music fulfilled all criteria: a fast-tempo piece, in a major mode and based on the theme of the traditional Chinese Spring Festival, which represents joy, unity, friendship, and mutual congratulations for Chinese people and was therefore deemed to be cultural familiar and preferred.

Procedure and Measurement

The main measurement tool used in the original experiments was the Fitzgerald Paper-folding Test, which required participants to imagine what would be the shape of a folded and cut piece of paper, if it were to be unfolded. Responses required participants to select one of five possible figures. Other tests used in the experiments were not suitable for such young children. Two versions of the Fitzgerald Paper-folding Test, which each have 10 questions. In this study, the images for the first set of 10 questions were rotated by 180 degrees to form a third set. Whether there would be a practical effect for such an operation will be explain below.

In addition, supplementary questionnaires were employed in order to assess mood, arousal, and comprehensive information questionnaires. The mood and arousal questionnaire included the evaluation of two indexes (1) mood status, e.g. very unhappy; unhappy; neutral; happy; very happy, and (2) emotional level, which was divided into five levels with numbers from 1 to 5. This questionnaire was used to analysethe extent to which the music could cause changes in participants' mood and arousal, which could have affected their task performance.

Before the formal experiment, nine students participated in a pilot study in order 1) to check whether the Paper-folding Test was suitable for students in primary school, and 2) to help determine which grade students were most appropriate for this experiment. The pilot test was carried out during the summer vacation; so, of these nine students some were going to enter grade 6 (two children), grade 5 (four children), grade 4 (1 child), and grade 3 (two children) when school recommenced in the autumn. The nine participants completed all experiments at home through the Internet due to the need to isolate, because of the Covid-19 virus. They completed three sets of Paper-folding Tests, each of which had 10 questions. Each test lasted for 10 minutes. A brief interview was conducted with all nine participants in order to check the appropriate level of language used in the instructions. As a result of the feedback, some statements have been rephrased and shortened. In terms of the paper-folding tests, except for one student in grade 5 and one in grade 6, who found them relatively easy, the other participants found the test to have a moderate level of difficulty.

Following the pilot study, we adjusted the sequence of three conditions. The Mozart condition was presented first, followed by the silent condition and finally, the Li Huan Zhi condition. The participants were devided in two groups, and although the experiments were not carried out at the same time, the tests in both groups were both carried out during the last period of the morning and all three conditions were completed within one hour. The experiment was carried out in the following sequence:

Sequence One: a) oral explanation, b) mood and arousal questionnaire pre-music, c) listening to Mozart's music (10 minutes), d) mood and arousal questionnaire post music, e) test 1 (7 minutes), f) questionnaire 1.

Sequence Two: a) mood and arousal questionnaire A, b) silence (10 minutes), c) mood and arousal questionnaire B, d) test 2 (7 minutes), e) questionnaire 2.

Sequence Three: a) mood and arousal questionnaire A, b) listening to Li Huan Zhi's Spring Festival Overture (10 minutes), c) mood and arousal questionnaire B, d) test 3 (7 minutes), e) questionnaire 3.

All original content involved in the experiment was originally written in English but, as the participants in this study are all Chinese, questionnaires, information sheet and consent form were all translated into Mandarin Chinese. To ensure the accuracy of translation, a cross-translation process was used with another fluent Chinese/English speaker.

Results

All data was analysed using SPSS 21 software and presented according to each research question.

Research Question 1: To what extent does the Mozart effect impact children?

A normal distribution of data was seen for Test 1 ($p > 0.05$) and Test 2 ($p > 0.05$), while a non-normal distribution was found for the results of Test 3 ($p < 0.05$). Therefore, Wilcoxon signed rank tests were used to compare the differences in scores between Test 1 and Test 3, and between Test 2 and Test 3. A paired-samples T-test was used to compare the differences between Test 1 and Test 2.

Participants' performance in test 1 was higher in the Mozart condition (mean score=4.6) compared to the Li Huan Zhi condition (mean score=3.87), but lower than those obtained in the silent condition (mean score=4.77). Although mean scores were higher in the silent condition than in the Mozart condition, the Wilcoxon Ranks test found no significant differences between them ($p > 0.538$). However, a significance was found to exist between the Mozart and Li Huan Zhi conditions ($p > 0.046$) and a high level of significance between the Silent and Li Huan Zhi conditions ($p > 0.00$). The results suggest that children performed better on the spatial reasoning test in the Silent condition, closely followed by the Mozart condition and significantly better than in the Li Huan Zhi condition. Therefore, the Mozart effect was not supported.

On the other hand, the average time, which participants took to complete the tests, proved to be interesting. The mean time required to complete the test in the silent condition (mean = 2.69 minutes) was significantly shorter than that the completion time required for the Mozart condition (mean = 4.03 minutes). The Li Huan Zhi condition required a completion time of 2.77 minutes. The Wilcoxon signed ranks test revealed no significant difference in the completion times for the silent and the Li Huan Zhi conditions ($p>0.940$), yet a significant difference was found to exist between the completion time required for the Mozart – silent condition ($p>0.000$) and the Mozart – Li Huan Zhi condition ($p>0.000$). Therefore, in this respect, the Mozart condition did not support any level of improvement on the tasks, but also appeared to hinder performance in terms of the time required to complete the task.

Research Question 2: Which mechanism is more likely to produce the Mozart effect?

As stated, we found no support for the Mozart effect amongst our research population, however, turning next to the mood index of participants, we found a significant difference in mood between the pre & post listening test in the Mozart condition indicating a positive increase from 3.66 to 4.08, ($p< 0.05$). In addition, the Mozart condition revealed higher levels of positive mood index than those obtained after sitting in silence (3.63) and in the Li Huan Zhi condition (3.82), and the increase in mood between the Mozart and silent conditions reached a level of significance ($p >0.05$). Therefore, this suggests that Mozart's music did lead to a significant improvement in mood among participants. In addition, post listening measures in the Mozart condition found higher levels of arousal (3.38) than those obtained in silence condition (2.94), although this did not reach a level of significance ($p> 0.05$). However, combined with the previous results, the performance of tasks after the Mozart condition was not found to improve compared with performance after the silence condition. In other words, even if Mozart's music caused positive changes in participants' mood and arousal, it did not help the improvement of subsequent task performance.

Moreover, by comparing the level of liking/disliking, the level of familiarity and the level of concentration when listening to two pieces of music, we found no significant difference in participants' concentration when listening to the two different pieces of music ($p> 0.670$). That is, the participants' concentration in the two conditions was almost identical (2.21 & 2.18 respectively). However, the difference in the level of liking/disliking ($p< 0.08$) and level of familiarity ($p< 0.00$) between the Mozart and Li Huan Zhi conditions were significantly different. Clearly, participants liked and were more familiar with the Li Huan Zhi's Spring Festival Overture (4.18) compared to the Mozart (3.84). However, combined with the previous results, preference and higher familiarity did not appear to create an improvement in mood or the level of arousal amongst participants. We therefore concluded that preference and familiarity might not significantly affect on, or improve task performance. Overall, we argue that our results do not support the preference, mood and arousal hypothesis as an explanatory mechanism for the Mozart effect.

Discussion

Results of the study indicate that listening to Mozart's music for a short period does not immediately improve children's ability in completing spatial-temporal reasoning tasks, whether in terms of accuracy or speed. This finding is consistent with the findings of

McKelvie & Low (2002) and Crncec, Wilson & Prior (2006). We also found that the results did not support the preference, mood and arousal hypothesis. However, there are several possible reasons for this particular result amongst our population of Chinese primary school children. Firstly, we have to consider the simple fact that music may not be able to prime spatial-temporal reasoning ability. Indeed, as music and visual images are two different stimuli and they are processed through their own mechanism in their respective regions of the brain (Baddeley & Hitch, 1974; Giannouli, Kolev & Yodanova, 2019), it is unlikely that they are actually to prime each other, or, perhaps, some form of link develops later in life. As noted in the literature, individuals may learn and establish a relationship between the two forms of stimuli as they mature (Brunel, Carvalho & Goldstone, 2015), and therefore this kind of priming may occur. Admittedly, there are some similarities between music and space. For example, musical notes themselves are spatial (Schlaug, 2005) as notes in different positions on the stave represent different pitches. Through this vertical spatial reading, people translate notes into specific pitches. In addition, our participants were children, whereas evidence of a priming effect has previously only been found in studies with adults (Jausovec, Jjausovec & Gerlic, 2006; Cacciafesta et al., 2010) and therefore we suggest that different factors affect performance ability at different ages/stages of development.

Our results, however, did suggest that listening to 10 minutes of Mozart's music could affect positively on mood. Pekrun et al. (2017) argued that positive emotions could preserve cognitive resources and assist people in focusing on tasks. However, it is possible that children's emotional regulation system is not sufficiently mature and so once music is finished, any emotional state it created may quickly fade and therefore having little or no impact on the task (Crncec, Wilson & Prior, 2006). In terms of the arousal hypothesis, Schellenberg, Nakata, Hunter & Tamoto (2007) suggested that performance on tasks might have a greater relationship with arousal than with mood. Our experimental data found that whilst Mozart condition significantly improved the children's level of arousal after listening to music, the data also showed that sitting in silence also slightly improved children's level of arousal, although this was not statistically significant.

He, Wong & Hui (2017) argued that both a level of arousal that was too high or too low would hinder any subsequent task performance, while a moderate level of arousal tended to result in the best overall performance. Hence, from this perspective, we acknowledge that our stimuli and instrument were possibly insufficiently sensitive to either promote, or measure the optimum performance on the tasks. In addition, we cannot completely exclude the possibility that other variables may have affected the reliability of our data. Certainly, the status of the participants may not have been consistent. With approximately 45 children sitting in one classroom setting, it was inevitable that there would be some interference or inattention amongst the students as the self-control ability of students in fourth grade is weak compared with adults. In addition, individual differences may also have affected the level of performance. Children need to reach an optimal level of arousal according to their own situation, to help them to perform to the best of their ability. Moreover, the effectiveness of measurement methods could also have exerted a level of impact on the experimental results. Due to the limitation of the experimental conditions, only participant self-assessment measure was available for gauging the degree of mood and arousal. Everyone relies on their own subjective consciousness to make such a judgment, which could easily have led to a deviation of the data standard and affected the experimental results in this study. Finally, the design of the experiment was not detailed.

Our experimental results show that Mozart's K 448 and the Li Huan Zhi's Spring Festival Overture had the same degree of influence on mood and arousal, but task performance in the Mozart condition surpassed the performance in the Li Huan Zhi condition. One reason for this may be that music that is more familiar is more likely to be distracting, and the participants in this study were more familiar with either the Spring Festival Overture or the cultural style of this music than Mozart K 448, and this could have evoked memories and/or associations and distractions (Ferreri, Laura et al., 2015).

When music causes activation unrelated with the task currently being undertaken, the residual activation remains in the brain for a period of time (Giannouli, Kolev & Yodanova, 2019), and the resources of working memory are limited (Funahashi, 2017). Hence, it is always possible that a degree of residual activation remained which led to students' inability to focus fully on the subsequent test, thus affecting their level of execution. This could have been resolved by extending the period in between the three conditions, however, given the concentration span of young children (Marshall & Hargreaves, 2007), any extension to the time taken to complete the experiment in full would have created further problems. Ethically, this could also have meant removing children for their usual school timetable, something, which was not desirable and technically not allowed.

Conclusion

This study explored the extent to which listening to different musical conditions could improve the participants subsequent spatial-temporal reasoning ability. To date, the debate on the Mozart effect has mainly focused on its reliability and the occurrence mechanism. The original research populations of studies on the Mozart effect were adults and most related studies have followed on this tradition. Thus, relatively few studies have focused on the Mozart effect on children, and even fewer have found evidence of the effect on children. Therefore, this study attempted to further explore the impact of the Mozart effect on children and try to deeper understand the mechanisms underlying this impact. However, as the media continues to report on the cognitive benefits which the Mozart effect is claimed to bring, and therefore it has become as much a tool for marketing products, as an area of empirical study.

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