The Effect of Music Rhythm Intervention on Spatial Reasoning

Yaxi Cheng[1, a, †], Jingyi Liu[2, b, †], Siqi Ouyang[3, c, †]

[1]School of Arts and Social Sciences, University of Sydney, Sydney, New South Wales 2006, Australia

[2]Sterinhardt School of Culture, Education, and Human Development, New York University, New York, New York 10003, United States

[3]School of Humanity, Soochow University, Suzhou, Jiangsu 215123, China

[a]yche7553@uni.sydney.edu.au, [b]jl8490@nyu.edu, [c]ouyangsq6977@outlook.com

[†]These authors contributed equally.

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Abstract: Some scientific research has established that some forms of music training can enhance children's cognitive activities, especially learning skills used in mathematics. In our study, the relationship between musical rhythm and spatial-reasoning is explored. The participants include 180 Chinese first-grade students (6 years old) from an ordinary elementary school in Beijing. The sample is divided into three gender-balanced groups: the experimental group undergoes one semester of integrated instructive music training (e.g., music theory, singing, composition), while the participation group only receives basic knowledge without creation activity. And the last, as a control group, will be given Chinese courses unrelated to music. The improvements in their spatial-reasoning ability performance are evaluated using the Block Design and Object Assembly subtests from Wechsler Intelligence Scale for Children (WISC) and the Raven Progressive Matrices (RPM). The results in the two WISC subtests show that students receiving systematical music training outperform those without any treatment in WISC. Still, no significant group difference can be seen in RPM. Factors, such as individual inhibitory control working memory that might contribute to outcomes for good reasons, are discussed. We hope that our findings provide helpful insight in teaching practice, but the mechanism of music rhythm intervention on spatial reasoning is still worth further study.

1. Introduction

Since the Mozart effect was reported in Nature in 1993 [1], the effect of music on individual development has been of great concern to scientists and the general public [2, 3]. Compared to normal music listening, musical training engages a wider range of brain areas and a series of higher-level cognitive processes [4], and various findings have found that musical training contributes to the improvement of music-related cognitive functions [5], such as speech segmentation [6] and phonetic consciousness [7][8]. The facilitation is also proved to be transferred to other cognitive activities unrelated to music [9]. According to research, musicians generally perform better in the previous experiments of attention [10], literacy [11], reading ability [12], and even creativity [13] than non-musicians. It means that music training can have an indirect effect on people's academic achievement [14], involving not only art courses like language [15] but also science, especially mathematics [16]-[18].

The researchers found that music training can make positive changes in a child's brain structure, effectively suppressing control, increasing attention, and improving creativity [19-21]. Music training involves multiple senses, including cognitively related auditory, visual, physical, attention, memory, and executive functions [22]. Executive Function (EF), which is also called executive control or cognitive control, refers to a family of top-down mental processes needed when people have to concentrate when going on automatic or relying on instinct or intuition would be ill-advised, insufficient, or impossible [23-25]. Currently, the EF researches follow the definition of Diamond (2013) that there are three components of EF: inhibitory control [26], which involves being able to control one's attention, behavior, thoughts, and/or emotions to override a strong internal predisposition or external lure, including self-control (behavioral inhibition) and interference control (selective attention and cognitive inhibition), working memory (WM), and cognitive flexibility [27, 28].

Two kinds of theories have been proposed regarding the reason for music instruction's enhancement of spatial tasks: "neural connections" theories and "near transfer" theories. The "neural connections" theory, proposed by Shaw and his colleagues, Scheibel, Roney, Patera, Silverman, and Pearson [29], termed the "trion" theory, suggests that musical and spatial abilities share the same processing regions in the brain. Shaw and his fellow researcher, Leng, speculate that any higher-level brain function must use many of the same cortical areas and that musical and spatial abilities are linked due to neurological connections in the cortex [30]. Specifically, these researchers contend that musical abilities are related to "spatial-temporal" abilities, distinguished as processes that require mental manipulation of two- or three- dimensional objects in the absence of physical models [31] and that early music experiences serve as an exercise for higher brain functions such as spatial-temporal reasoning [30]. Leng and Shaw proposed that music may be a 'pre-language' that can excite inherent firing patterns and, at an early age, allow accessibility to brain pattern development and enhancement of additional higher brain functions [30]. Graziano, Peterson, and Shaw maintained that the brief period of music instruction required to improve spatial skills suggests an innate ability of the brain to recognize symmetries [32]. Shaw proposed that the brain recognizes and uses these symmetries to see how patterns develop in space and time [29].

This research aims to find the active music training could be more effective in spatial reasoning. But, currently, there are limited essays compared active music training and participation music training. According to existing research, compared with the third group of students who will teach Chinese, music training in the rhythm group and the participation group is likely to improve spatial reasoning. Besides, the active rhythm training effect may be more significant than the participation group. Because of Raven Progressive Matrices' result, it can be inferred that music training differs only in spatial reasoning.

2. Method

2.1 Participant

First, A total of 180 Chinese first-grade students from an ordinary elementary school in Beijing participated in this experiment. They included 98 boys and 72 girls with an average age of 6 years old. The school is a public elementary school supervised by the Ministry of Education, and the enrollment is citywide. All participants were randomly assigned to three conditions of about 60 people each.

To maintain the homogeneity of variables, the scores of all children were above 90 points on the 6 subtests Short from of Wechsler Intelligence Scale for Children Fourth Edition in Chinese version (WISC-IV [33]; the 50th percentile correspond to an average Full-Scale Intelligence Quotient, and the children's mean was 70, which corresponds to medium). All students do not receive any additional formal music training before, and their parents also had no related background of music occupations.

Besides, based on background investigation, the children we chose were monolingual (Chinese). Their family's average annual household income was between 150,000 and 250,000 RMB, which is in the middle levels compared to other families in Beijing. Before the study's commencement, approval was obtained from the participating schools and the local Ministry of Education. All children participants were volunteered to join the experiments, and their parents or legal guardians signed the written informed consent.

2.2 Measures

The Block Design subtest from the Wechsler Intelligence Scale for Children (WISC) provides one of the most common means of assessing visuoconstructional ability. This familiar task requires replicating red and white designs using three-dimensional colored blocks [34]. Block Design requires the child to view a constructed model or a picture in the Stimulus Book and to use one-color or two-color blocks to recreate the design within a specified time limit. It is one of the more difficult subtests for new examiners to master because it requires skillful management of various materials—the Manual, Stimulus Book, Blocks, Record Form, and a timer are all used to administer this subtest. Block Design yields three different types of scores. The standard scoring procedures apply an "all-or-none" method whereby the child receives credit for a correct design and no credit for an incorrect design, with time bonus points awarded for performance on Items 10–13 (up to 3 additional points). The standard Block Design scoring procedure is always used when calculating the VSI and FSIQ.

To provide an index of visual perceptual abilities, the children also receive the Object Assembly subtest of the WISC-III [33]. In this task, participants must assemble a set of two-dimensional puzzles within a limited time, which shows cartoon images of the object they are familiar with (e.g., bird, car, and block). There are four sections in total. Various materials, such as a Manual, Stimulus Book, Record Form, and a timer, are also needed. According to the number of correct pieces nodes, testers will score students' points: one point for each node, plus points for a shorter time, and up to 44 points. The object Assembly subtest mainly measures students' hand-eye coordination, imagination, generalization, organization, and discrimination ability. It can also be used to reveal the subject's perceptual type, their reliance on trial-and-error methods, and reactions to false responses. Compared to other subtests in WISC-III, the test-retest reliability of Object Assembly is relatively low. The correlation between this test and others in WISC-III is also low [35].

The Raven Progressive Matrices (RPM) will also be used in this research which tests measure "general cognitive ability" or, better, educative, or "meaning-making" ability [36]. The basic version of the test, known as the Standard Progressive Matrices (or SPM), consists of five sets of items. The spatial reasoning and logical reasoning abilities of the students were tested with different levels of the SPM. This research will use Raven's Colored Progressive Matrices [37], an intelligence test that can assess intellectual development and visuospatial reasoning in 5 to 11-year-old children. After that test, the research can avoid other interference variables in the process.

2.3 Intervention

The intervention's focus is rhythm while searching the influence and difference of rhythm on the spatial reasoning of music participants and music creators. These weekly sessions will be arranged during the school day, lasted 40 minutes, based in the music room. The research will recruit primary students who are in grade one. After that, divide them into three different groups to experiment. The students in the rhythm group will use drums to imitate and create rhythms, the students in the participation group will just participate in the music, and the rest will be assigned to the Chinese classes as a control group. Students in the rhythm group will learn some musical terms, basic rhythm, and knowledge of the science of rhythm. The beats and rhythms of songs will be reproduced by drum then. Students will be taught to create their rhythm after the rhythm following a practice.

The third group is the control group, in which children spend the same time on Chinese courses. A professional teacher will impart knowledge from four dimensions: vocabulary, grammar, reading strategy, and writing ability. All chosen language contexts are not related to music. Students receive no music training in or out of school during the experiment period.

2.4 Data analysis

The data will be analyzed using SPSS 22.0 software (Chicago, IL). The means, standard deviations (SD), and ranges for all variables are normally distributed and presented. For parametric data, the Shapiro-Wilk test and Levene's test will be performed, indicating normality and homogeneity of the data. Three-way repeated-measures analysis of variance (ANOVA) followed by Bonferroni's post hoc test will be performed to access the effects. Values of $p<0.5$ will be considered statistically significant. According to ANOVA, there is no significant difference between the experiment group, participation group, and control group in Object Assembly subtest scores. There is also no significant difference in Raven's Colored Progressive Matrices. According to pairwise contrast, students in the experiment achieve the highest scores, followed by those in the participation group and control group the worst. It indicates that the effects of music training are significant for students' spatial reasoning ability.

3. Results and Discuss

3.1 Anticipated Results

We anticipate that result will show no significant difference between the experiment group, participant group, and control group in WISC-Block subtests. For the pair-wise contrasts, students who receive active music training (experiment group) will the highest scores, followed by those in the participation group and the control group the worst. However, the significance will be found between the rhythm group and control group.

According to ANOVA, there will be no significant difference between the experiment group, participation group, and control group in Object Assembly subtest scores. According to pairwise contrast, students in the experiment will achieve the highest scores, followed by those in the participation group and control group the worst. It will indicate that the effects of music training are significant for students' spatial reasoning ability.

According to ANOVA data analysis and past research, Raven Progressive Matrices will assume that there is no significant difference between groups.

3.2 Discussion

Some support was found for the idea that musical training has beneficial effects on human's working memory, the processes that allow us to hold on to and manipulate information [38]. In the study conducted on Brazilian children, statistically significant differences between the experiment and control groups were only observed at the end of the semester for the backward digit recall test [39]. This was an activity that required more phonological working memory. It indicated an essential far transfer effect occurred in the process of musical training, in which students' working memory can be remarkably developed [40]. In our experiment, students in both the music rhythm and music participation groups are exposed to certain periods of music training. They are required to categorize sounds using note sets during the tests. What's more, for music rhythm group children, when they create their composition, they even need to store dynamic music notes information in advance and monitor the performance effect in real-time. These additional activities lead to more practice of the ability to manipulate various auditory information, thus enhancing students' working memory. As a result, since many of the items in spatial reasoning tests are also be solved by using working memory (e.g., visual recognition and pattern matching strategy are indispensable when participants put puzzles together), it is understandable why students in experiment group who develop information processing capability can perform the best among three groups.

Musical training has positive effects on humans, which also can be confirmed on individual inhibitory control. Inhibitory control is one of the components of EF [26]. Besides, throughout the experiment, students need to use inhibitory control in various situations [22]. For instance, students in different groups have to arrive and take turns outside the classroom in advance to wait for the teacher's arrangements. In the process of that, they will need to control their want to enter the classroom or other ideas during that time. That has undeniably contributed to the children's inhibitory control. Also, students in the participation group and drum group need to listen and learn the different rhythms. Therefore, they have to control their attention to the rhythms, which also practice students' inhibitory control.

The group that received active music training is better than students who participated, and it can be explained with the near connection and near transfer theories that we mentioned. Specifically, researchers contend that musical abilities are related to "spatial-temporal" abilities, distinguished as processes that require mental manipulation of two- or three- dimensional objects in the absence of physical models [31] and that early music experiences serve as an exercise for higher brain functions such as spatial-temporal reasoning [30]. Leng and Shaw proposed that music may be a 'pre-language' that can excite inherent firing patterns and, at an early age, allow accessibility to brain pattern development and enhancement of additional higher brain functions [30]. Graziano, Peterson, and Shaw maintained that the brief period of music instruction required to improve spatial skills suggests an innate ability of the brain to recognize symmetries [32]. Shaw proposed that the brain recognizes and uses these symmetries to see how patterns develop in space and time [29].

4. Conclusion

This study indicated no significant difference between the experiment group, participant group, and control group in WISC-Block subtests and Object Assembly. However, the experiment groups in both WISC-Block and Object Assembly subtests had the highest scores and not in the Raven test, which indicated that active music training enhances spatial-temporal and spatial recognition reasoning skills. The improvement in this study should be viewed positively.

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