The Effect of Music on Spatial Ability

Hanyu Lin[1] and Hui Yueh Hsieh [2]

[1] Industrial Design Department, National Kaohsiung Normal University
No.62, Shenjhong Rd., Yanchao, Kaohsiung, Taiwan
hanyu@nknu.edu.tw
[2] Department of Visual Communication Design, Ming Chi University of Technology
No.84, Gungjuan Rd., Taishan, Taipei, Taiwan
tsauk@mail.mcut.edu.tw

Abstract. In the first Mozart Effect study, Rauscher, Shaw, and Ky [1] found that exposure to a Mozart sonata enhanced visuo-spatial task performance. In this study, we sought to examine whether there was such an effect on three spatial ability sub-factors, namely spatial visualization factor (the paper folding test), spatial relation factor (card rotation test) and perceptual speed factor (hidden pattern test). In a between-subject design, 90 participants were exposed to 10 minute periods of a Mozart Sonata, Bach, or silence. After listening to a music stimulus or silence period, participants completed three spatial tests. The treatment conditions did not yield significant differences between groups. The results from all three spatial tests did not support the Mozart effect.

Keywords: Mozart effect, music, spatial ability.

1 Introduction

The Mozart Effect is a well known phenomenon in that listening to Mozart's music may improve spatial task performance. Rauscher, Shaw, and Ky [1] found that 36 undergraduates who had spend 10 minutes listening to Mozart’s Sonata for two pianos in D Major (K.448) scored 8-9 points higher on the Stanford-Binet Paper Fording and Cutting (PF&C) test than participants who had listened to “Music With Changing Parts” or silence. However, they also found that the Mozart effect was temporary, having disappeared within 10 to 15 minutes.

Spatial ability plays a key role in many types of reasoning and communication, and is important in domains such as design, mathematics, natural sciences and engineering. Researches have demonstrated that spatial ability is a predictor of success in an engineering graphics design class [2], [3]. For example, tests of spatial abilities are the best predictors of success in engineering courses, particularly engineering drawing [4]. Industrial design is based on technical expertise and creative thinking. Creative thinking involves mental transformation, mental combination and mental synthesis [5]. According to Roth [6], creative thinking, conceptual problem solving and concept generation are associated with spatial ability. Thus, spatial ability would seem to be very important in designers.

Since listening to music can temporarily improve spatial ability, does listening to background music help designers increase their spatial ability and indirectly improve

P.L.P. Rau (Ed.): Internationalization, Design, HCII 2011, LNCS 6775, pp. 185–191, 2011.

their design performance? The purpose of this study was to investigate whether listening to music enhances spatial ability. This study utilizes a between-subjects design similar to that used by Rauscher et al. [1].

1.1 Spatial Ability

It is said that spatial ability is important in designers. However, what is spatial ability? Spatial ability may be defined as the ability to generate, retain, retrieve and transform well-structured visual images [7]. Halpern [8] states that the term "visual-spatial abilities" it is not an easy term to define, because it is not a unitary concept. McGee [9] proposed that there are two factors of spatial ability: spatial visualization and spatial orientation. Spatial visualization refers to the ability to manipulate, rotate, change the position in mind of an object depicted as a picture. Spatial orientation is proposed to measure someone's ability to image the appearance of objects from different perspectives. Thurstone [10] suggested three space factors named mental rotation(S1), spatial visualization(S2), and spatial perception(S3). Mental rotation was described as the process of recognizing an object from different angles. Spatial visualization was imagining the movement of parts of a configuration. Spatial perception emerged as having to do with body orientation. Lohman [7] argues that there are three factors for spatial ability: spatial visualization, spatial orientation, and speeded rotation. Spatial visualization is the ability to manipulate objects in imagination or the ability to comprehend imaginary movements in a three dimensional space. Spatial orientation requires only a mental rotation of configuration. Speeded rotation is the ability by the speed in manipulating simple visual patterns such as mental rotations. According to Carroll [11], the spatial ability sub-factors include: spatial visualization, spatial relation, closure speed, closure flexibility and perceptual speed. Spatial visualization, spatial relation and perceptual speed are frequently mentioned sub-factors.

The most extensively studied factor is the spatial visualization factor [12]. Tests that identify this factor involve "processes of apprehending, encoding, and mentally manipulating spatial forms" (as cited in [13]). The spatial relation factor is similar to spatial visualization. It also requires mental transformations but differ in that it involves manipulations of two-dimensional objects that can be completed in a single step. This factor tends to emphasize speed. Perceptual speed involves no spatial transformations and primarily requires rapid matching of visual patterns. Psychometric tests that identify this factor assess individual differences in the speed or efficiency with which one can make relatively simple perceptual judgments [11]. These three factors are moderately correlated with one another. In fact, depending on the tasks included in the analysis, some factor analysis studies have failed to find a clear distinction between the Spatial Visualization and Spatial Relations factors (Lohman, 1988; Carroll, 1993) (cited in [13]).

1.2 Associations between Musical and Spatial Ability

A number of studies suggested that listening to Mozart's work may temporarily increase spatial abilities. There have been several studies that replicated the Mozart effect study [14], [15], [16]. For example, Rideout and Taylor [15] used the same

Mozart sonata and a relaxation instruction. They found that paper folding and cutting test performances were significantly higher for the Mozart group than for the relaxation group. Rideout, Dougherty, and Wernert [16] compared a Mozart sonata to Yanni Acroyali: Standing in motion and Relaxation condition. They found no difference between Mozart and the Yanni group in spatial performance, but increases occurred for both groups. Rideout et al. [16] argued that music similar to Mozart could also positively affect spatial performance. Under this perspective, a "Bach effect" [17] and "Schubert effect" [18] were also reported.

However, the results have been inconsistent, with some studies reporting that they were unable to reproduce the Mozart effect (e.g. [19], [20], [21]). For example, Kenealy and Monsef [22] were unable to produce a Mozart effect when the measurement tests were the paper folding and cutting task. Stough, Kerkin, Bates, and Mangan [21] reported no Mozart effect when the dependent variable was the Raven's progressive matrices test. Newman et al. [20] found that there was no evidence for the Mozart effect in their experiment. The results from their studies showed that participants assigned to the Mozart group scored only slightly (0.06 points) higher than participants assigned to the relaxation instruction group and only marginally (0.15 points) higher than participants in the silence group. These differences were not statistically significant. Hui [23] investigated the Mozart effect in preschool children using a maze test. His data showed no difference between the Mozart group and two control groups, also failing to support the Mozart effect.

There is no consistency in the literature regarding the relationship between music and spatial task performance. Rauscher and Shaw [24] explained that the reason for the inconsistency is that the Mozart effect only applies to spatial temporal tasks. Further analysis of the data from Rauscher et al. [1]showed the participants' scores on the paper folding task were significantly higher after they listened to Mozart sonata, but the Pattern Analysis task and Matrices task did not differ in three listening conditions. These results suggest that exposure to music may affect spatial temporal tasks but not other spatial tasks. Rauscher and Shaw [24] argued that two components of spatial temporal tasks: "spatial imagery" and "temporal order" are essential for the Mozart effect. In addition, some studies tried to replicate the Mozart effect using the Minnesota Paper Form Board Test. For example, Carstens, Huskins, and Hounshell [19] failed to found the Mozart effect. The researchers noted that the Minnesota Paper Form Board Test involves the mental rotation of two dimensional figures, making it a "Spatial Orientation" test. The Paper Fording and Cutting tasks used by Rauscher et al. [1] in their study were "Visualization" tests [19].

2 Method

2.1 Participants

A total of 90 undergraduate students (45 male, 45 female) were recruited from the National Kaohsiung Normal University, Taiwan. All of the participants were from a non-design background (i.e. from Industrial Technology Educational Department, Optoelectronics Communication Engineering Department, and Software Engineering Department). Participants in this research were randomly assigned to one of three groups: a Mozart group (n = 30), a Bach group (n = 30), or a silence group (n = 30).

2.2 Materials

Mozart's Sonata for Two Pianos, K.448 and Bach BWV 916 were used in the experimental condition. The musical excerpts consisted of 10 minutes from Mozart sonata K.448, or from Bach BWV 916. For the Mozart sonata, we recorded the entire first section (8 minutes and 24 seconds) and replayed it until 10 minutes were accumulated. The Bach BWV 916 was built in the same way.

Three spatial ability tests were used in this study. The spatial visualization factor was evaluated using a paper folding test. The spatial relation factor was evaluated using the card rotation test. The perceptual speed factor was evaluated using the hidden patterns test [25].

Paper folding test: This test consisted of two parts, each of which has 10 items. Participants were required to mentally fold a piece of paper and punch a hole in it. Participants were asked to determine the position of the hole when the paper is unfolded. For each part the participants were given 2.5 minutes to complete the task. The score was the result of the total number of correct answers minus the number of incorrect answers.

Card rotation test: A 2D mental rotation test in which participants were required to determine whether rotated figures were identical to the original figure or were a mirror image. This test consisted of two parts, each of which had 10 rows of eight test figures. The participants were given 2 minutes to complete each part of the test. The score was the result of the total number of correct answers minus the number of incorrect answers.

Hidden patterns test: This test also consists of two parts, with each part containing 200 figures composed of line drawings. Participants were asked to identify whether the model pattern was embedded in each test figure. The participants were given 1.5 minutes to complete each part of the test and asked to respond as quickly and as accurately as possible. The test was scored using the total number of correct answers minus the number of incorrect answers.

2.3 Procedure

Following the completion of consent procedures, the procedure and the purpose of the study were explained to the participants.

In the Mozart and Bach groups, the experimenter told participants that they would hear a music piece for approximately 10 minutes. While the music played participants should sit quietly and listen to the music. In the silence group, participants sat in silence for 10 minutes. A computer with a windows media player was used to play the music for the Mozart Sonata and Bach BWV 916. The music volume was adjusted for comfortable listening. After the listening or silence period, participants completed the paper folding test, card rotation test and hidden patterns test. Before taking the three tests, each participant was instructed to take a tutorial followed by the test. There was a time limit of 5 minutes for the paper folding test, 4 minutes for the card rotation test and 3 minutes for the hidden patterns test. The experiment took an average of 15-20 minutes to complete.

3 Results

The main research question about group differences in the mean scores on the paper folding test, card rotation test and hidden patterns test were addressed using one-way ANOVA with LSD post-hoc test. Table 1 shows the means and standard deviations for the Mozart, Bach and silence groups.

As shown in table 2, the one-way ANOVA revealed no significant group effects on the paper folding test [F (2, 87) = 1.64, p = 0.19], the card rotation test [F (2, 87) = 1.22, p = 0.30], or the hidden patterns test [F (2, 87) = 0.13, p = 0.88]. The ANOVA results indicated that listening to Mozart does not enhance spatial performance and provided no support for the Mozart effect.

When comparing the mean scores for the three groups, participants who were exposed to Mozart and Bach had a higher mean score on the paper folding test in comparison to the silence group. The mean scores were 14.73, 14.57, and 13.60 respectively. The card rotation test and hidden patterns test, however, did not show this phenomenon.

4 Discussion

The treatment conditions (Mozart Sonata, Bach BWV 916, and silence) did not yield significant difference between groups. This is inconsistent with the finding of Rauscer et al. [1]. However, it is consistent with reports from several studies (e.g. [19], [20], [21]). One explanation for not finding a Mozart effect could be related to the use of different dependent measures. The paper fording and cutting tasks used by Rauscher et al. [1] in their study were “Visualization” tests [19]. The most commonly used test of spatial visualization is the paper folding test. In this study, the paper folding test did not produce a significant difference between groups. In conclusion, this study found no evidence to support the Mozart effect. Listening to Mozart’s music does not enhance spatial ability.

Table 1. Descriptive statistics for the three spatial tests

	Treatment	Mean	SD	Range
Paper Folding Test	Mozart Group	14.73	2.53	9-20
	Bach Group	14.57	2.84	10-19
	Silence Group	13.60	2.46	9-17
	Total	14.30	2.63	
Card Rotation Test	Mozart Group	91.87	15.85	59-138
	Bach Group	92.17	17.88	54-128
	Silence Group	85.70	20.26	40-126
	Total	89.91	18.13	
Hidden Patterns Test	Mozart Group	127.83	27.52	64-191
	Bach Group	124.33	30.96	53-176
	Silence Group	125.87	19.91	86-162
	Total	126.01	26.28	

Table 2. ANOVA summary for the three spatial tests

		SS	df	MS	F	Sig.
Paper Folding Test	Between	22.47	2	11.23	1.64	0.19
	Within	594.43	87	6.83		
	Total	616.90	89			
Card Rotation Test	Between	799.36	2	399.68	1.22	0.30
	Within	24861.93	87	327.15		
	Total	29261.29	89			
Hidden Patterns Test	Between	184.69	2	92.34	0.13	0.88
	Within	61270.30	87	704.26		
	Total	61454.99	89			

Acknowledgment. This research was supported by the National Science Council of Taiwan under grant NSC 98-2221-E-017-008.

References

1. Rauscher, F., Shaw, G., Ky, K.: Music and Spatial Task Performance. Nature 365, 611 (1993)
2. Besterfield-Sacre, M., Atman, C., Shuman, L.: Characteristics of Freshman Engineering Students: Models for Determining Student Attrition in Engineering. Journal of Engineering Education 86, 139–149 (1997)
3. Hsi, S., Linn, M., Bell, J.: The Role of Spatial Reasoning in Engineering and the Design of Spatial Instruction. Journal of Engineering Education 86, 151–158 (1997)
4. Holliday, F.: The Relations Between Psychological Test Scores and Subsequent Proficiency of Apprentices in the Engineering Industry. Occupational Psychology 17, 168–185 (1943)
5. Finke, R.: Principles of Mental Imagery. MIT Press, Cambridge (1989)
6. Roth, S.: Visualization in Science and the Arts. In: Art, Science & Visual Literacy: Selected Readings from the Annual Conference of the International Visual Literacy Association, pp. 81–85 (1993)
7. Lohman, D.: Spatial Abilities as Traits, Processes, and Knowledge. In: Advances in the Psychology of Human Intelligence, Sternberg, pp. 181–248. Lawrence Erlbaum, Sternberg (1998)
8. Halpern, D.: Sex Differences in Cognitive Abilities. Lawrence Erlbaum Associates, Hilsdale (2000)
9. McGee, M.: Human Spatial Abilities: Psychometric Studies and Environmental, Genetic, Hormonal, and Neurological Influences. Psychological Bulletin 86, 889–918 (1979)
10. Thurstone, L.: Primary Mental Abilities. Science 108, 585 (1948)
11. Carroll, J.: Human Cognitive Abilities: A Survey of Aactor Analytic Studies. Cambridge University Press, New York (1993)
12. Just, M., Carpenter, P.: Cognitive Coordinate Systems: Accounts of Mental Rotation and Individual Differences in Spatial Ability. Psychological Review, 137–172 (1985)
13. Miyake, A., Friedman, N., Rettinger, D., Shah, P., Hegarty, M.: How Are Visuospatial Working Memory, Executive Functioning, and Spatial Abilities Related? A Latent Variable Analysis. Journal of Experimental Psychology: General 130, 621–640 (2001)

14. Rideout, B., Laubach, C.: EEG Correlates of Enhanced Spatial Performance Following Exposure to Music. Perceptual and Motor Skills 82, 427–432 (1996)
15. Rideout, B., Taylor, J.: Enhanced Spatial Performance Following 10 Minutes Exposure to Music: A Replication. Perceptual and Motor Skills 85, 112–114 (1997)
16. Rideout, B., Dougherty, S., Wernert, L.: Effect of Music on Spatial Performance: A Test of Generality. Perceptual and Motor Skills 86, 512–514 (1998)
17. Ivanov, V., Geake, J.: The Mozart Effect and Primary School Children. Psychology of Music 31, 405–413 (2003)
18. Nantais, K., Schellenberg, E.: The Mozart effect: An Artifact of Preference. Psychological Science 10, 370–373 (1999)
19. Carstens, C., Huskins, E., Hounshell, G.: Listening to Mozart not Enhance Performance on the Revised Minnesota Paper Form Board Test. Psychological Reports 77, 111–114 (1995)
20. Newman, J., Rosenbach, J., Burns, K., Latimer, B., Matocha, H., Vogt, E.: An Experimental Test of the Mozart Effect: Does Listening to His Music Improve Spatial Ability? Perceptual and Motor Skills 81, 1379–1387 (1995)
21. Stough, C., Bridget, K., Mangan, G.: Music and Spatial IQ. Personality and Individual Differences 17, 695 (1994)
22. Kenealy, P., Monsef, A.: Music and IQ Tests. The Psychologist 7, 346 (1994)
23. Hui, K.: Mozart Effect in Preschool Children? Early Child Development and Care 176, 411–419 (2006)
24. Rauscher, F., Shaw, G.: Key Components of the Mozart Effect. Perceptual and Motor Skills 86, 835–841 (1998)
25. Ekstrom, R., French, J., Harman, H., Derman, D.: Manual for Kit of Factor Referenced Cognitive Tests. Educational Testing Service, Princeton (1976)