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The "Mozart Effect" and the Mathematical Connection

*Educators are always looking for ways to enhance the performance of students on outcome assessments. There is a growing body of research showing the benefits of music on educational performance. The purpose of this study was to determine if a "Mozart Effect" improves student performance on outcome assessments in mathematics. In this study, during the six major tests that were given for three college trigonometry classes (*n *= 69) a CD of Mozart music was played for the duration of the test. The results were compared to three trigonometry classes (*n *= 59) that were given six major trigonometry tests with no music playing. The results indicate that students performed significantly better when Mozart was being played as background music during the outcome assessment. This study adds validity to the "Mozart Effect" and considers improved effectiveness for some learners through altered assessment environments.*

Over the last 17 years, researchers have claimed that the "Mozart Effect" accomplished everything from temporary increases in IQ to creating the mental mechanism needed for infants to develop reasoning and analytical prowess. The term "Mozart Effect" relates specifically to the Rauscher, Shaw, and Ky (1993, 1995) neuropsychology research that reported temporary increases in college students' ability to perform spatial-temporal tasks as evidenced by increased IQ scores after passively listening to 10 minutes of Mozart's sonata K. 448. Spatial-temporal reasoning is the ability to visualize spatial patterns and mentally manipulate them over a time-ordered sequence of spatial transformations. Following Rauscher's initial report, a rigorous scientific discussion ensued in the psychological and educational literature with findings that supported the Rauscher studies

(Rauscher & Shaw, 1998; Rideout, Dougherty, & Wernert, 1998; Rideout & Laubach, 1996; Rideout & Taylor, 1997; Sarnthein et al., 1997; Wilson & Brown, 1997) and those that repudiated Rauscher's findings (Newman et al., 1995; Steele, Ball, & Runk, 1997; Steele, Brown, & Stoecker, 1999; Stough, Kerkin, Bates, & Mangan, 1994).

The inability of some to replicate the Mozart Effect in similar laboratory experiments (Steele, 2000, 2001, 2003, 2006; Steele, Brown, & Stoecker, 1999) served only to fuel the Rauscher camp's staunch replies and extensions of the Mozart Effect evidence (Rauscher, 1997, 1999, 2000, 2002, 2006; Rauscher & Hinton, 2006; Rauscher, Robinson, & Jens, 1998; Rauscher & Shaw, 1998; Rauscher & Zupan, 2000; Rauscher et al., 1997; Rideout, 1999). The controversy over the Mozart Effect exists as a result of the misconception that listening to Mozart can enhance general intelligence (Newman et al., 1995; Rauscher, 1999; Steele, Ball, & Runk, 1997). Rauscher, Shaw, and Ky (1993, 1995) only claimed temporary increases in college students' ability to perform spatial-temporal tasks as evidenced by increased IQ scores after passively listening to Mozart. Conflicting results from meta-analyses and rebuttals furthered the debate (Chabris, 1999; Hetland, 2000; Rauscher, 1999; Steele et al., 1999) and spurred continued investigation into the Mozart Effect phenomenon resulting once again in mixed results (Bridgett & Ceuvas, 2000; Hui, 2006; Jausovec & Habe, 2004; Jausovec, Jausovec, & Gerlic, 2006; McKelvie & Low, 2002; Standing, Verpaeist, & Ulmer, 2008; Zhu et al., 2008). Chabris (1999) conducted a meta-analysis of 16 Mozart Effect studies that found no change in IQ or spatial reasoning ability. According to Rauscher and Hinton (2006), Chabris used "inappropriate tasks, music, and diverse research methods" (p. 233). A more recent meta-analysis conducted by Hetland (2000) that included 36 studies and involved 2,465 participants found that the Mozart Effect does exist, but "is limited to a specific type of spatial task that requires mental rotation in the absence of a physical model" (p. 136). The theoretical and educational questions regarding the existence and applicability of the Mozart Effect remain unresolved.

Even though the controversy over the Mozart Effect continued, some were willing to take the risk. The thought of a quick solution to better develop babies' minds captured the public's attention. Lending credibility to the public's Mozart Effect furor, Zell Miller, governor of Georgia at the time, required the distribution of classical music CDs to all infants born in Georgia (Winner & Hetland, 1999). Other states soon followed, requiring classical music to be played in daycare centers and even for inmates in prison (Bangerter & Heath, 2004). At its peak, the popularized notion of the Mozart Effect morphed into a scientific legend (Bangerter & Heath, 2004), driving a huge electronic media market that coupled classical music and simple imagery in a variety of videos and other products promoted to expedite education for babies and toddlers. The popular market bubble burst when the American Academy of Pediatrics released its recommendation that children under the age of two not be exposed to television or video screen time (Wolf, 2010). In an effort to avoid significant losses in a class-action lawsuit, the Walt Disney Company (current distributor of the *Baby Einstein* videos) raised the white flag and offered to refund the full purchase price to all who bought the *Baby Einstein* videos since 2004 (Lewin, 2009).

Although listening to Mozart may not turn infants into mathematical geniuses, there is a significant literature base developing in both basic and applied research considering the efficacy of music, in general, and Mozart, in particular, in therapeutic and educational settings. Spatial-temporal reasoning is used to suggest an even higher level of scientific thought. This ability is important for generating and conceptualizing solutions to multistep problems that arise in areas such as architecture, engineering, science, mathematics, art, games, and everyday life. Spatial-temporal reasoning can have as much or more to do with one of the other five main modes of thought: the logical (mathematical/systems), visual, verbal, physical (kinesthetic), and aural (musical) modes. Rauscher conducted a series of studies considering the impact of music instruction on spatial-temporal cognition and the resulting impact on early education (Rauscher, 1997; Rauscher et al., 1997; Rauscher & Zupan, 2000). Based on the Leng and Shaw (1991) trion model, Rauscher (1997) postulated that musical activity strengthens neural firing patterns in large regions of the brain's cortex, which are the same type of firing patterns required for spatial-temporal reasoning tasks. Rauscher and Shaw (1998) defined the trion model as

> a highly structured mathematical realization of Mountcastle's organizational principle for the cerebral cortex. Mountcastle proposed that the cortical column, the basic neural network of the cortex, can be excited into complex firing patterns which, in the trion model, are exploited in the performance of tasks requiring ability to recognize and classify physical similarities among objects—*spatial recognition tasks*. (p. 835)

Rauscher theorized that listening to music or participating in music instruction excites and primes the cortical firing patterns necessary for spatial-temporal reasoning. Rauscher and Zupan's (2000) results supported the Leng and Shaw (1991) model, reporting that early music training enhanced spatial-temporal reasoning in kindergarten children.

Background Music

Research investigating the effects of music on moods, emotions, and behavior is addressed in many fields including business, education, psychology, and others (Gaston, 1968; Hargreaves & North, 1997; Merriam, 1964). Background music is widely used by individuals personally and is also common in most public arenas: grocery stores, malls, airports, waiting rooms for all types of offices, and a wide variety of other venues. In that background music plays a significant role in an individual's everyday private and public life, it is a natural progression for educational researchers to question whether using background music will stimulate learning in the classroom. Such questions have been investigated for many years with mixed results (Fogelson, 1973; Hall, 1952; Kiger, 1989; Mitchell, 1949). More recent studies have found positive results that background music enhances performance on cognitive tasks as a result of arousal or mood (Hallam & Price, 1998; Hallam, Price, & Katsarou 2002; Isen, 2000; Savan, 1999). This finding concurs with the extant arousal-mood literature supporting the Mozart Effect (Nantanis & Schellenberg, 1999; Thompson, Schellenberg, & Husain, 2001). Recent literature also concludes that background music in educational settings reduces anxiety (Crncec, Wilson, & Prior, 2006; Graham, Robinson, & Mulhall, 2009; Hallam & Price, 1998; Hallam et al., 2002).

The Mozart Effect Mosaic

Ivanov and Geake (2003), in a recent study of the Mozart Effect, concluded that there are a number of issues surrounding the Mozart Effect that justify its further investigation. Overy (1998), in an editorial discussion of the Mozart Effect, emphasized that the link between music and the development of cognitive processes is not clearly established. She questioned not only the development of the cognitive processes, but the transferability to other learning areas. Finally, Rauscher (2000) stated, "The Mozart Effect is neither magic nor an article of faith, but the subject of ongoing serious research." As such, Rauscher (2000) asserted that it "is worthy of ongoing research not only for its theoretical importance but also its potential practical implications, especially in education" (para. 17).

The extant literature regarding the Mozart Effect has become a mosaic: internationally flavored with research from Australia, Canada, China, Europe, Japan, New Zealand, and the United States, and generationally pertinent to grandparents, parents, educators, and children. It bridges both basic and applied research and stretches across a variety of disciplines such as psychology, the neuro-sciences, music, education, business, and law.

Our contribution to the Mozart Effect mosaic primarily builds upon the cross-modal priming effect (Leng & Shaw, 1991; Rauscher & Zupan, 2000), investigating the indirect impact of the Mozart Effect on the assessment of mathematics performance by college students. Cross-modal priming is a memory effect in which exposure to some type of stimulus enhances recall of previously learned information. Linking to the arousal and mood literature (Nantanis & Schellenberg, 1999; Thompson et al., 2001), we used a modified background music approach, allowing the music treatment to extend the full 55-minute interval required by the mathematics performance assessment. We based our decision to elongate the music exposure time on suggestions made by Jenkins (2001).

Our music treatment students as well as our control group students completed the mathematics performance assessment in the natural setting of their regular classroom. Thus, the control group "silence" is routine background noise in the classroom setting (Ivanov & Geake, 2003; Jackson & Tlauka, 2004). Standing, Verpaeist, and Ulmer (2008) reported that participants displayed higher spatial and verbal intelligence scores when a neutral announcement regarding the effect of the music was given versus either a positive or negative announcement. To avoid any form of interpretation by students that would bias their response to the music treatment, we chose to make no announcement either before or after administering the mathematics performance assessments regarding the expected effect of the background music.

Finally, we considered which music to play in the background during the assessment. Hughes and Fino (2000) determined that a large number of Mozart selections and two Bach selections have a high degree of long-term periodicity, which is interpreted by Jenkins (2001) as the essential element that makes Mozart's music effective in cross-modal priming. Marsden (1987) studied the complexity of Mozart music, and found that Mozart's music neither bores the listener with low cognitive demand nor overstimulates the listener with high cognitive demand. In Marsden's words, "pieces of music by Mozart…maintain a constant level of cognitive demand throughout" (p. 57). Thus, we decided to use Mozart music. To eliminate listener boredom that might be induced by repeating the same short Mozart selection throughout the 55 minutes and to explore the use of selections other than Mozart sonata K. 448, we determined to play a larger selection of music by Mozart. The combination of these factors in the experimental design adds one more piece to the Mozart Effect mosaic by extending the extant literature.

The present study sought to answer the question: Is there a "Mozart Effect" for outcome assessments for students taking a trigonometry course?

Method

Participants

The participants were 128 undergraduate aviation students (25 females and 103 males) who received course credit. There were 59 (nine female and 50 male) students in the group who tested in silence and 69 (16 female and 53 male) students who listened to Mozart while they tested. The students were enrolled in a required trigonometry class. The course was chosen for the study at the discretion of the researcher. The researcher teaches three trigonometry classes each spring, which would allow for a larger sample size. SAT scores were obtained for as many of the participants in the study as possible to test for homogeneity of groups.

Materials

The mathematics performance assessment is a composite score made up of the sum of scores on six trigonometry tests administered to each student during the trigonometry course spaced throughout the semester. Each test included between 25 to 35 questions indicative of the concepts covered in the relevant chapters of the trigonometry course. For the music treatment, the background music was played for the duration of each of the tests on a regular quality CD player at a reasonably low volume that could be heard by all individuals in the classroom. The music played included 12 Mozart pieces (see Appendix).

Procedure

Each participant was given a total of six tests over the course of a semester. The sum of the scores of the six tests comprised the mathematical performance assessment variable in the experiment. During the two semesters in which the experiment occurred (spring 2008 for the silence control group and spring 2009 for the music treatment group), all participating students received mathematics instruction from the same professor; they were assigned exactly the same homework, and they were given exactly the same six tests.

The control group (henceforth referred to as the silence group) completed all six tests comprising the mathematical performance assessment in the spring semester, 2008. The tests were administered in their regular classroom without background music. By experimental design, the natural setting of the classroom with the common sounds of a classroom-testing environment substitutes for music in the control group. In the spring of 2009, the music treatment group (henceforth referred to as the Mozart group) completed all six tests comprising the mathematical performance assessment. The Mozart group listened to low-volume background Mozart music, and the professor handed out the tests without comment regarding the music. A student in the second class entered the room while the music was playing and asked the instructor if that music was going to be played during the test. The instructor told the student if the music was a distraction, the student could go to a testing center to take the test. If students questioned the benefit of the music, or thought that the music would not benefit them, they were allowed to take the test at an alternative location in silence. Although no students in the Mozart group requested to take the tests at an alternative location, such accommodations had been prearranged in case that request was made.

At the end of the semester, the professor explained to the Mozart group that there was a body of research suggesting that listening to Mozart during testing may enhance their ability to think through mathematical problem solving. Following the explanation, students were given the opportunity to allow their test scores to be used for analysis purposes. The students signed a consent form giving the researcher permission to use the scores for analyses.

Analyses

Using SPSS, a least-squares regression analysis and analysis of variance were conducted. Descriptive statistics were reported. The null hypothesis (H0) on the regression on the music variable was that it would have no significant effect. The alternative (H1) for the regression on the music variable was that it would have a significant effect.

For the analysis of variance, the null hypothesis (H0) was that there would be no significant difference in the mean performance on the mathematical assessment between the silence and Mozart groups across tests. The alternative hypothesis (H1) was that there would be a significant difference in the mean performance on the mathematical assessment between the silence and Mozart groups across tests. An ANOVA requires the following: one independent, categorical variable that has two levels and one dependent variable. The ANOVA requires that the dependent variable be approximately normally distributed within each group (Pallant, 2001). In order to determine normality, a normal Q-Q Plot can be created. The Q-Q plots for the Mozart Effect data were approximately normally distributed and met the requirement to run an ANOVA.

Results

Descriptive Statistics

The means for the six tests for students who listened to Mozart were 81.55, 94.06, 73.16, 80.70, 94.83, and 71.67 respectively (*SDs* 14.59, 16.15, 20.47, 18.79, 16.91, and 15.99); see Table 1. The combined mean for all

Table 1
Descriptive Statistics for Music and Silence Scores for Experimental, Control, and Both Groups for Six Trigonometry Tests

Trigonometry Tests

	Test 1			Test 2			Test 3		
	Exp (n = 69)	Control (n = 59)	Both (n = 128)	Exp (n = 69)	Control (n = 59)	Both (n = 128)	Exp (n = 69)	Control (n = 59)	Both (n = 128)
Mean	81.55	79.73	80.71	94.06	88.10	91.31	73.16	56.36	65.41
SD	14.59	13.56	14.10	16.15	19.06	17.73	20.47	25.07	24.13
SE	1.77	1.77	1.25	1.95	2.48	1.57	2.47	3.26	2.13

	Test 4			Test 5			Test 6		
	Exp (n = 69)	Control (n = 59)	Both (n = 128)	Exp (n = 69)	Control (n = 59)	Both (n = 128)	Exp (n = 69)	Control (n = 59)	Both (n = 128)
Mean	80.70	83.64	82.05	94.83	89.03	92.16	71.67	69.93	70.87
SD	18.79	18.27	18.54	16.91	16.10	16.74	15.99	17.65	16.73
SE	2.26	2.39	1.64	2.04	2.10	1.48	1.92	2.30	1.48

	All Tests		
	Exp (n = 69)	Control (n = 59)	Both (n = 128)
	(n = 69)	(n = 59)	(n = 128)
Mean	82.66	77.80	80.42
SD	19.41	21.78	20.67
SE	.95	1.16	.75

scores for the music treatment group was 82.66 with a standard deviation of 19.41. The means for the six tests for students who took the test in silence were 79.73, 88.10, 56.36, 83.64, 89.03, and 69.93 respectively (*SDs* 13.56, 19.06, 25.07, 18.27, 16.10, and 17.65). The combined mean for all scores for the silence control group was 77.80 with a standard deviation of 21.78.

SAT scores were obtained for as many of the participants in the study as available. Any student for whom an SAT score could not be obtained was excluded from the analyses. SAT scores were used to ensure the homogeneity of the silence group and the Mozart group. The assumption of homogeneity of variance can be tested by using Levene's Test of Equality of Variance. Levene's Test indicated equal variance ($F = 1{,}766$, $p = .12$). There was no significant difference in the means of the SAT scores of the two groups.

Analyses of the Experiment

A least-squares regression analysis and an analysis of variance were conducted using SPSS to explore the impact of listening to Mozart and SAT scores on the composite mathematics performance assessment score. The dependent variable was the mathematics performance assessment score, which was comprised of the scores on six trigonometry tests as measured by professor-created exams that were indicative of the mathematical concepts covered in each trigonometry chapter. Test scores were totaled for all six exams to create the mathematics performance assessment measure. The independent variables were SAT score and Music. Music was a binary variable where 1 indicated the Mozart group with background music during assessment and 0 indicated the silence group without background music during assessment. Participants were divided into two groups. The silence group ($n = 59$) tested in silence, while the Mozart group ($n = 69$) listened to twelve Mozart selections as background music while testing.

In the least-squares regression, the model fit (the impact of listening to Mozart and SAT scores on the composite mathematics performance assessment score) was statistically significant [$F(2{,}765) = 32.947$, $p < .0001$] with an adjusted R-square of .077; although the individual variable in this model was significant, there still remained 93 percent of the variability in test scores that were unexplained. Both the SAT variable and the Music variable were statistically significant ($p < .0001$ for both), with positive coefficients. The SAT variable functions as a control variable. The regression coefficient for SAT variable was .08. The positive, statistical significant coefficient (5.52) for the Music variable indicates a positive Mozart Effect for the Mozart group.

The mathematics performance assessment mean was higher for the Mozart group (82.66) than for the silence group (77.80). The analysis of variance resulted in a statistically significant difference for the Mozart variable $F(1, 766) = 10.68$, $p = .001$, indicating that there was a Mozart Effect for the mathematics performance assessment measure; see Table 2.

The results indicate that the mean difference in performance on mathematics assessments was statistically significant.

Discussion

Our investigation of three college trigonometry classes brings together diverse research to consider temporal cognitive effects of passive music intervention in assessing learning in mathematics. The purpose of this study was to determine if a Mozart Effect might improve college student performance on outcome assessments in mathematics. Based on previous work in the Mozart Effect mosaic, we took into consideration which music to play, when it should be played, for what duration it should be played, and in what setting it should be played. Our decisions in these design elements allow our study to make a unique contribution to the current literature base. First, we considered the impact of the Mozart Effect indirectly as it manifested in the actual assessment of a learning experience. Second, we determined to elongate the listening time to 55 minutes and to play a wide selection of Mozart, based on prior research that indicated Mozart music is most efficient in priming cross-modal brain activities. Third, we chose to locate our study in the natural setting of a classroom in order to test the generalizability of the previous lab experiments into the more common classroom environment. Finally, we linked the arousal-mood literature and the trion model literature to help explain the Mozart Effect.

Our findings indicate that the Mozart Effect does impact the demonstration of learning in mathematics. Whether it is through priming cortical firing patterns, reducing anxiety, and/or generating arousal is a theoretical matter beyond the scope of this experiment. Of most importance to educators is that the Mozart Effect is not merely a lab experience, but has potential to assist students in performing their best on mathematical assessments.

Further study is needed in how to best use the Mozart Effect in other areas such as during the instruction phase as well as in the assessment phase. Other modalities could consider whether the Mozart Effect is present in applied disciplines such as accounting, business management, or finance. Finally, further consideration could seek to determine other types of music that facilitate the learning process.

Table 2
One-Way Analyses of Variance of Music and Silence on Six Trigonometry Tests and All Tests

Variable and source	df	SS	MS	F	Sig.
Test 1					
Between groups	1	105.57	105.57	.53	.47
Within groups	126	25140.73	199.53		
Test 2					
Between groups	1	1128.34	1128.34	3.66	.05
Within groups	126	38813.15	308.04		
Test 3					
Between groups	1	8920.88	8920.88	17.42	< .0001
Within groups	126	64958.77	515.55		
Test 4					
Between groups	1	276.48	276.48	.804	.37
Within groups	126	43356.13	344.10		
Test 5					
Between groups	1	1067.03	1067.03	3.90	.05
Within groups	126	34503.85	273.84		
Test 6					
Between groups	1	95.68	95.68	.34	.56
Within groups	126	35449.06	281.34		
Test All					
Between groups	1	4507.26	4507.26	10.68	.001
Within groups	766	323041.74	421.72		

The results of this study imply that playing Mozart during mathematics outcome assessments improves student scores. Students in trigonometry classes did statistically significantly better on a mathematics outcome assessment while listening to Mozart. This study adds one more colored tile to the Mozart Effect mosaic, validating the Mozart Effect and suggesting a method for improving learner performance through altering the assessment environment.

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Appendix

Twelve Mozart Pieces

"Eine Kleine Nachtmusik," Romance;

Sonata for Violin and Piano in G, K. 301, Allegro;

Sonata for Piano No. 11 in A Major, K. 331;

Ronda alla Turca; Quartet for Oboe, Violin, Viola and Cello in F Major, K. 370;

Quartet for Flute, Violin, Viola and Cello No. 1 in D Major, K. 285, Adagio;

String Quartet No. 14 in G Major, K. 387—"Spring," Allegro vivace assai;

Divertimento in D Major—"Salzburg Symphony No. 1," K. 136, Andante;

Quintet for Clarinet, Violins, Viola and Cello in A Major, K. 581, Larghetto;

String Quartet No. 4 in C Major, K. 157, Allegro;

String Quartet No. 17 in B Flat Major, K. 485—"Hunt," Minuetto moderato;

Sonata for Piano No. 8 in A Minor, K. 310, Andante cantabile con espressione;

Sonata for Violin and Piano in B Flat Major, K. 378, Andantino sostenuto e cantabile.