Spring 2013

Does Music Predictability Improve Spatial-Temporal Reasoning?

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Reexamining the Mozart Effect

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Defended April 5, 2013

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Abstract

In 1993, it was found that Mozart's music temporarily enhanced performance on spatial-temporal reasoning tasks. This effect later became termed the Mozart Effect. Since then, the mechanisms of the Mozart Effect have been hotly debated among the scientific community. Recent research has called for studying the Mozart Effect by analyzing music as a series of components. The present study took the components of music into account by testing if predictable music could enhance spatial-temporal reasoning compared to non-predictable music. Participants were administered a task designed to test spatial-temporal reasoning after listening to either predictable or non-predictable music. Additionally, as a control condition, they performed the same task after listening to a short story. Listening to music did not affect reasoning performance, regardless of the predictability of the music. The results indicate that predictability in music alone may not be a major element of the Mozart Effect.

Keywords: spatial-temporal reasoning, predictability, music, Mozart

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Introduction

In 1993, Frances Rauscher, along with colleagues Gordon Shaw and Katherine Ky, published "Music and Spatial Task Performance" in *Nature* 365. Their study had a monumental influence on the way research pertaining to the influence of music on the brain was performed. Unlike previous studies that focused primarily on affective physiological responses such as heart rate, gross blood flow, breathing rate, and electrical skin conductance (Becket 1990; Davis & Thaut 1989; Pignatiello et al. 1989), Rauscher, Shaw, and Ky (1993) employed more of a psychological approach. Their work provided a new outlet for psychological research on spatial-temporal reasoning that would spur a breadth of interest from researchers in the cognitive sciences.

Rauscher, Shaw, and Ky (1993) studied the short-term effects of music on spatial-temporal reasoning in the brain by testing differences in performance on certain tasks after listening to music. They were specifically interested in spatial-temporal reasoning because listening to music had previously been predicted to activate similar areas of the brain that were involved in abstract, spatial operations such as in mathematics and chess (Leng, Shaw & Wright 1990). To test this quantitatively, the researchers measured participants' raw IQ scores on Paper Folding Tests (PFTs) from the Stanford-Binet IQ Intelligence Test (Thorndike, Hagen & Sattler 1986). PFTs consisted of a series of pictures depicting various folds on a piece of paper in a specific order. The last picture in the series also showed a small section of paper being cut or removed. Participants, given a choice of four possible answers, were asked to determine what the piece of paper would look like completely unfolded. A sample question is provided in Figure 1.

Rauscher, Shaw, and Ky (1993) used this type of test because of its ability to test spatial-temporal reasoning. PFTs effectively tested this ability because participants were required to mentally rotate and manipulate changing shapes over time in the absence of a visual cue. The researchers found that participants who listened to 10 minutes of Mozart before completing a PFT performed significantly better than those that either sat in silence or listened to relaxation instructions for the same amount of time. Rauscher argued that the music had a priming effect on the brain, enhancing the participants' ability to perform the spatial task effectively.

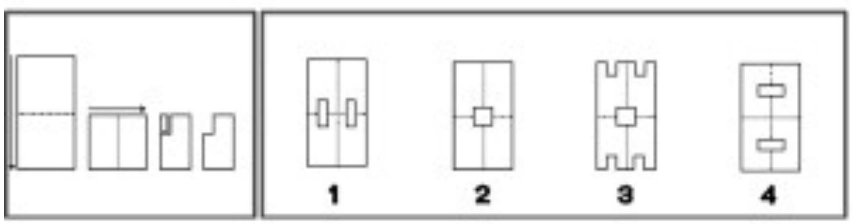

Figure 1. Sample Paper-Folding Test question taken from the Stanford-Binet IQ Intelligence Test. The answer to this example is "2".

Rauscher, Shaw, and Ky (1993) used Mozart's music because of its highly structured organization. Shaw, Silverman & Pearson (1985) proposed that music could be represented as inputs to a cortical columnar organization in the brain through what they referred to as the Trion Model. According to Shaw, Silverman & Pearson (1985), highly structured music such as Mozart's had the potential to excite the same cortical firing patterns used in spatial-temporal reasoning, and could therefore have a positive effect. Mozart's music was considered highly structured for various reasons. For one thing, it consisted almost entirely of equal 8-bar phrases separated by definitive cadence points in the harmony. In other words, it was easy to distinguish different sections of the music. There were also equal divisions of beats at constant tempi throughout. Lastly, the various instruments/voices often combined into a single, overall melodic theme.

While most research following Raucher, Shaw, and Ky (1993) used Mozart's music in their studies, they often concentrated on various methodological logistics, including the type of tests used to measure an effect quantitatively. Collectively, the positive effect on spatial-temporal reasoning became known as the Mozart Effect, although this term was first coined earlier by a French otolaryngologist examining the physiological effects of Mozart's music on body systems (Tomatis 1991).

Initial follow-up research (Carstens, Huskins & Hounshell 1995; Newman et al. 1995; Steele, Ball & Runk 1997), which focused on testing the generality of the effect, came with discouraging results. In place of using PFTs as in Rauscher, Shaw, and Ky (1993), they instead measured spatial ability using other means such as the Revised Minnesota Form Board Test (Likert, R. 1948), Backwards Digit Spans (Lumiley & Calhoon 1934), and Raven Advanced Progressive Matrices (Raven 2003). While they did not use PFTs, the researchers argued that these, too, tested a person's spatial ability. Steele, Ball & Runk (1997) questioned the validity of Rauscher, Shaw, and Ky (1993;1995), saying that, "There [seemed] to be some important methodological differences between [Rauscher, Shaw, and Ky's (1993;1995) studies] and that of other experimenters that has not yet been elucidated," (p. 1183). As a response to Steele and others' criticisms, and in an effort to explain the recent failures in replication, Rauscher and Shaw (1998) shed light on the neurophysiological background used to develop their original study, and attempted to clarify how some theoretical and experimental factors may have contributed to the various findings reported.

According to Rauscher and Shaw (1998), the aforementioned studies were failing to find significant results because the dependent variable of which they used to test for an effect was not truly measuring spatial-temporal reasoning ability. The Trion Model suggested that music had the ability to alter the synaptic weights of neurons in specific patterns due to Hebbian learning principles (Hebb 1949). These principles explained the physical mechanism by which learning took place within the brain. In forming new memories, neurons that repeatedly fired together would become more likely to fire together in the future because their association had become stronger.

Rauscher and Shaw (1998) predicted that the enhancing effects would last for, at most, ten minutes. They therefore concluded that, "[Both] components of spatial-temporal tasks – spatial imagery and the temporal ordering of spatial components – were essential for the Mozart Effect," (p. 837). Rauscher and Shaw (1998) only found a significant effect when subjects took PFTs, but not on pattern analysis tests. They explained that exercises testing pattern analysis (such as Backwards Digit Spans and Matrices) lack the temporal component illustrated in the Trion Model, and could explain the lack of reproducibility among other researchers.

In addition to methodological concerns, Steele (1999, 2000) and Chabris (1999) proposed that Rauscher's, among others', studies did not consider how participants' arousal from or preference toward the music affected test performance. Nantais & Schellenberg (1999) found that participants performed better on PFTs after listening to two different types of music than those that sat in silence. They argued that perhaps this was because participants that listened to either type of music experienced a higher level of generalized arousal and were therefore more engaged in the PFTs. They also suggested that participants performed better on the tests if they listened to music they preferred, however these results were not statistically significant.

A few years later, Thompson, Schellenberg, and Husain (2001) found that performance on PFTs was enhanced only for subjects that listened to Mozart beforehand (compared to a slow, melancholy string chorale), regardless of the participant's preference toward the music. Essentially, this suggested that the Mozart Effect was not an artifact of preference and arousal alone. Instead, they concluded that it was an artifact stemming from, "Enjoyable stimuli [inducing] positive affect and heightened levels of arousal, which lead to modest improvements in performance on a variety of tasks," (p. 251).

The arrival of advanced brain imaging techniques proved useful in this field because it allowed researchers to obtain concrete, quantitative brain information to study the Mozart Effect that, before, relied solely on the analysis of test scores. Initial research utilizing EEG recording techniques was of great importance because it provided a way to possibly determine if the Mozart Effect correlated with the "Neural Priming" theory proposed by Rauscher, or the "Preference/Arousal" theory proposed by Steele. Rideout and Laubach (1996) were the first to employ the use of EEG while examining the Mozart Effect. They found a number of reliable Pearson correlations, including increased average power in the beta (12-18 Hz) and alpha (8.5-11.5 Hz) range over the left temporal area. A year later, Sarnthein et al. (1997) observed several cortical activations while participants completed a PFT after listening to Mozart (session B) that were not present when the same participants completed a PFT after listening to spoken text (session A). In other words, some of the features found unilaterally during session A were found bilaterally during session B. Because the coherence patterns observed while listening to Mozart were very similar to the patterns observed during session B of the PFTs, Sarnthein et al. (1997) speculated that, "Listening to Mozart thus [appeared] to have an effect on patterns of cortical activation even after the exposure to the music [had] ended," (p. 111). The results of these studies indicated that the same cortical networks involved in spatial-temporal reasoning were also activated while listening to Mozart. Furthermore, they support the Trion Model of cortical organization as proposed by Leng, Shaw, and Wright (1990)

Jausovec and Habe (2003, 2005) found that participants showed induced gamma band synchronization while listening to Mozart, and gamma band desynchronization while sitting in silence. Similar changes in induced gamma band desynchronization had previously been shown to occur in subjects tested on other visual and perceptual tasks (Gruber et al. 1999; Basar et al. 2001). They concluded that the findings, "[Supported] the hypothesis that listening to a certain type of music (e.g. Mozart) increased the activity of specific brain areas and in that way facilitated the selection and 'binding' together of pertinent aspects of sensory [stimuli] into a perceived whole," (p. 215).

Finally, Jausovec, Jausovec & Gerlic (2006) specifically investigated the influence of Mozart's music on brain activity during the process of learning spatial-temporal rotation tasks. They found that the EEG provided no evidence to suggest an increased level of physiological arousal for participants in the Mozart priming group. Despite this information, however, these participants significantly outperformed participants of the non-Mozart priming group on all accounts. This discounted Steel, Ball & Runk's (1997) proposal of a Preference/Arousal theory.

While later research employing brain imaging suggested neural priming as the sole mechanism of the Mozart Effect, it did not account for the lack of reproducibility among researchers. Obviously, Rauscher and Shaw (1998) emphasized the importance of using a test requiring the use of spatial-temporal reasoning (as opposed to purely spatial), but even then did researchers experience conflicting results. Later research (Ho, Mason & Spence 2007; Suda et al. 2008) provided more support for the Neural Priming theory, but also suggested that later work focus on the specific components of music and their relation to the cortical networks in the brain. Much more could be done to assess the makeup of music and examine how its components affect spatial-temporal reasoning.

The present study focused on examining the Mozart Effect using this approach. The primary concern was to see if predictability in music made a difference in temporarily promoting positive effects in spatial-temporal reasoning. One trait of Mozart's music is that, even at its most complex points, it is comfortable sounding. The harmonic progressions and melodic lines flow in ways that seem natural to the listener. Part of the reason the melodies are easier to follow lies in the fact that they often remain within the current key signature; non-chord tones are usually only used as subtle embellishments. Also, the harmonic structure and overall phrasing cater to the melodic themes and provide a stable musical framework. This type of music is predictable sounding for this reason. It is easier for the listener to predict where the melody and other elements will "go" assuming the music follows this organization. Therefore, it was the assumption that predictable music would have more of an effect on spatial-temporal reasoning tasks than non-predictable music (which was expected to not show a significant difference from a control).

To be considered predictable, music with predominantly conjunct, chord-tone melodies was selected. Additionally, predictability was determined by also examining the harmonic structure and rhythmic organization. Predictable music would consist of a harmonic structure that followed the application of western music theory. Specifically, this meant that it would be tonal and possess definitive cadence points often following 8-bar phrases with a strophic organization. Ideally, there would be minimal "surprise" changes such as any sudden tonal modulations. Finally, music in even time signatures (i.e. duple and triple meter) would be perceived as more predictable than music in odd time signatures (i.e. 5/8. 7/8) because of its equal beat lengths. The structures dictated by these traits are highly representative of Mozart's, among others' that fulfill the structure of organization dictated by the Trion Model, music. It makes sense, then, that the components in this type of music would promote a positive effect on spatial-temporal reasoning.

Participants completed two series of PFTs, once after listening to a musical selection and once after listening to a short story. Half of the participants listened to predictable music, while the other half listened to non-predictable music. I predicted that participants would receive significantly higher PFT scores after listening to predictable music than to non-predictable music. More precisely, a predictability x music/story excerpt type interaction was predicted, such that PFT performance would be better following predicable music than following the story, but would not be better following non-predictable music than the story.

Method

Participants

Participants consisted of undergraduate students at the University of Colorado at Boulder recruited from the Psychology 1001 subject pool website (http://ucboulder.sona-systems.com/). They were given experiment credit as compensation for participating in the study. The sample consisted of 32 students (12 males and 20 females) with ages ranging from 18-29 years of age. Participants over 29 years of age were excluded to reduce age-related variability. Upon arrival, the participants were randomly divided into four groups (n=8) as described below.

Materials

Participants were administered the "Paper-Folding Test VZ-2" (PFT) from the Kit of Factor Referenced Cognitive Tests (Ekstrom, French, Harman, & Dermen, 1976). This test was chosen because it was easier and cheaper to obtain than the PFT from the Stanford-Binet Intelligence Scales, Fifth Edition (SB5). It was nearly identical to the test in the SB5, except that the paper was hole-punched instead of having sections simply cut out. The test consisted of two parts, each of which contained ten problems. Figure 2 shows an example from the test.

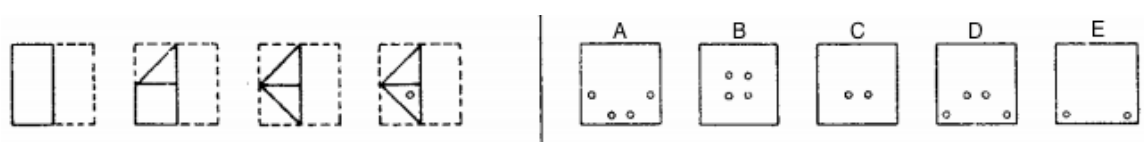

Figure 2. An example of one problem from the Paper-Folding Test. The answer in this example is "D".

The pictures on the left side of the vertical line represented a series of consecutive folds done to a piece of paper. The last frame of each example also showed a circle indicating a point at which a hole was punched through all thicknesses of the paper. During the test, participants were asked to mark the answer choice that correctly displayed the arrangement of holes on the paper after it was completely unfolded. Examples varied in difficulty throughout both parts of the test; each question was not necessarily more difficult than the last.

The listening excerpts consisted of predictable music (PM), non-predictable music (NPM), and a short story (SS). Gustav Holst's *Second Suite in F for Military Band* was used as the predictable music type because it closely followed the aforementioned description of music with predictable elements. The major thematic material consisted of conjunct melodies, a strophic structure, and classical harmonic progressions. Moreover, a listener would have an easier time following the music because of the many repeated sections. *Blue Shades* by Frank Ticheli was selected as the non-predictable music because it differed in many respects from the predictable music. While it had a similar orchestration, the melodies were much more disjunct and less structured. There were also more non-chord tones present in the melodies. Finally, the piece contained intricate rhythms resulting in unexpected accents and various harmonic shifts.

Only minor adjustments needed to be made to some of the listening excerpts for them to be the same length. The non-predictable music selection was 10 minutes long and was therefore left unedited. To make the predictable music the same length, the third movement was removed from the recording. The purpose of the short story, a "filler task", was to equalize the amount of time that elapsed before a participant began any section of the PFT. The short story came from an audio book of *Sense and Sensibility* by Jane Austen. Chapter 2 was used because it was the same length as the music selections.

Procedure

Prior to the onset of the study, a research assistant naïve about the experiment and not involved with data analyses assigned subject numbers (1-32) into one of four groups using a random number generator. To eliminate experimenter bias, the primary investigator, whom also tested all subjects, was unaware as to which group each subject was assigned until the completion of the study. The 4 groups counterbalanced the two music types (predictable or non-predictable) and the 2 listening orders (music first or story first). Those assigned to Groups 1 and 2 initially listened to music, and then to the short story. The only difference between these groups was that Group 1 listened to predictable music and Group 2 listened to non-predictable music. Groups 3 and 4 were similar to Groups 1 and 2 except that these subjects listened to the short story first, and then to their assigned music. All participants used the same set of over-ear headphones while sitting in a comfortable chair in an enclosed room for the duration of the study. They took Part 1 of the PFT after the first stimulus exposure and Part 2 after the second stimulus exposure. These procedural differences are outlined in Table 1.

Group 1 (n=8)	PM	→	PFT1	→	SS	→	PFT2
Group 2 (n=8)	NPM	→	PFT1	→	SS	→	PFT2
Group 3 (n=8)	SS	→	PFT1	→	PM	→	PFT2
Group 4 (n=8)	SS	→	PFT1	→	NPM	→	PFT2

Table 1. Procedural sequence of stimulus exposures and tests by group. PM is predictable music, NPM is non-predictable music, SS is short story, and PFT1 and PFT2 are the first and second PFTs respectively.

Prior to hearing the first auditory excerpt, participants received a short tutorial on the PFT, along with instructions. The experimenter worked them through a practice problem to ensure that the instructions were clear. Participants were informed of the scoring system (See Results) and that they would be signaled to stop when three minutes had expired. They were then instructed to put on the provided headphones and wait for the music or story (depending on group assignment) to play. They were also told to take off the headphones and raise their hand when the audio excerpt finished as a way to signal the experimenter. Before the listening example began, the experimenter advised the participant to pay full attention to the excerpt, saying that they would be asked questions regarding it at the conclusion of the study. This was done as a deceptive move to ensure that each participant paid full attention to the stimuli - no actual questions of the sort followed.

The experimenter used a timer to approximate how much time was left in the 10-minute audio sample. Near the end, the experimenter watched through a window to the room for the participant to raise their hand. Once signaled, the experimenter placed the corresponding PFT in front of the participant and simultaneously started a three-minute timer. The experimenter immediately left the room and waited until time had expired. There was approximately an 8-10 second gap between the end of the listening sample and the beginning of the PFT.

After three minutes, the experimenter signaled the participant to put down their pencil and stop the test. The process was then repeated for the next part. Again, the participant was reminded to pay full attention to the excerpt. At the conclusion of the study, participants were asked to complete a short questionnaire. The questionnaire asked them to write what they thought the hypothesis of the study was and the relation between the music and PFTs. The participant was also asked to specify if they had heard the music prior to the study.

Results

Scores were calculated using the following formula:

$$Score = N_c - \frac{N_i}{df}$$

where, N_c = Number of Correct Responses, N_I = Number of Incorrect Responses, and df = Degrees of Freedom of answer choices. Because each problem had five answer choices, df = 5 – 1 = 4 for every participant. This correction factor accounted for any randomized guessing by penalizing wrong answers. Participants earned one point for every correct response and lost a quarter-point for every incorrect response. Blank answers neither raised nor lowered their score. Possible scores therefore ranged from -2.5 (all incorrect) to 10 (all correct) per part, with a score of zero indicating chance performance.

A 2x2x2 ANOVA was performed to compare the effects of varying the order of stimuli, music type, and auditory excerpt type on PFT scores. In examining the type of music (predictable vs. non-predictable) and order of stimuli (music->story vs. story->music), between-subjects analyses were used. To test for a general Mozart Effect (music vs. story), a within-subjects analysis was used. In purely looking for a Mozart Effect, no significant difference in PFT performance following music (ignoring type) ($M = 5.41$) vs. the story ($M = 5.09$) was found, $F(1,28) = .92$, $MSE = 1.64$, $p > .05$. There also was no significant difference in PFT performance for subjects who received predictable ($M = 5.25$) vs. non-predictable music ($M = 5.26$), $F(1,28) = .04$, $MSE = 8.19$, $p > .05$ (across auditory excerpt type). Most importantly, the predicted interaction between music type (predictable vs. non-predictable) and auditory excerpt type (music vs. story) was not statistically significant as Figure 3 depicts, $F(1,28) = .04$, $MSE = 0.79$, $p > .05$. Regardless of the music type, listening to music did not improve PFT performance compared to the story control condition.

The only significant result observed can be described as an order effect from the interaction between the auditory excerpt type (music vs. story) and stimuli order (music->story vs. story->music), $F(1,28) = 8.530$, $MSE = 15.259$, $p < .01$. As shown in Figure 3, participants performed significantly better on the second part of their PFT than the first.

In the questionnaire, over half of the participants indicated that they believed the hypothesis of the study was that participants would receive higher PFT scores after listening to music than after the story. Common answers included predicting that the music, "Would make them pay more attention to the task," or that the music, "Would increase brain function." A couple of participants chose not to predict the hypothesis or wrote that it was unclear to them. No participants referenced music predictability or the order in which the audio excerpts were presented (music first or story first). Finally, only four participants (all of which in the predictable music group) indicated that they had previously listened to the music prior to the study.

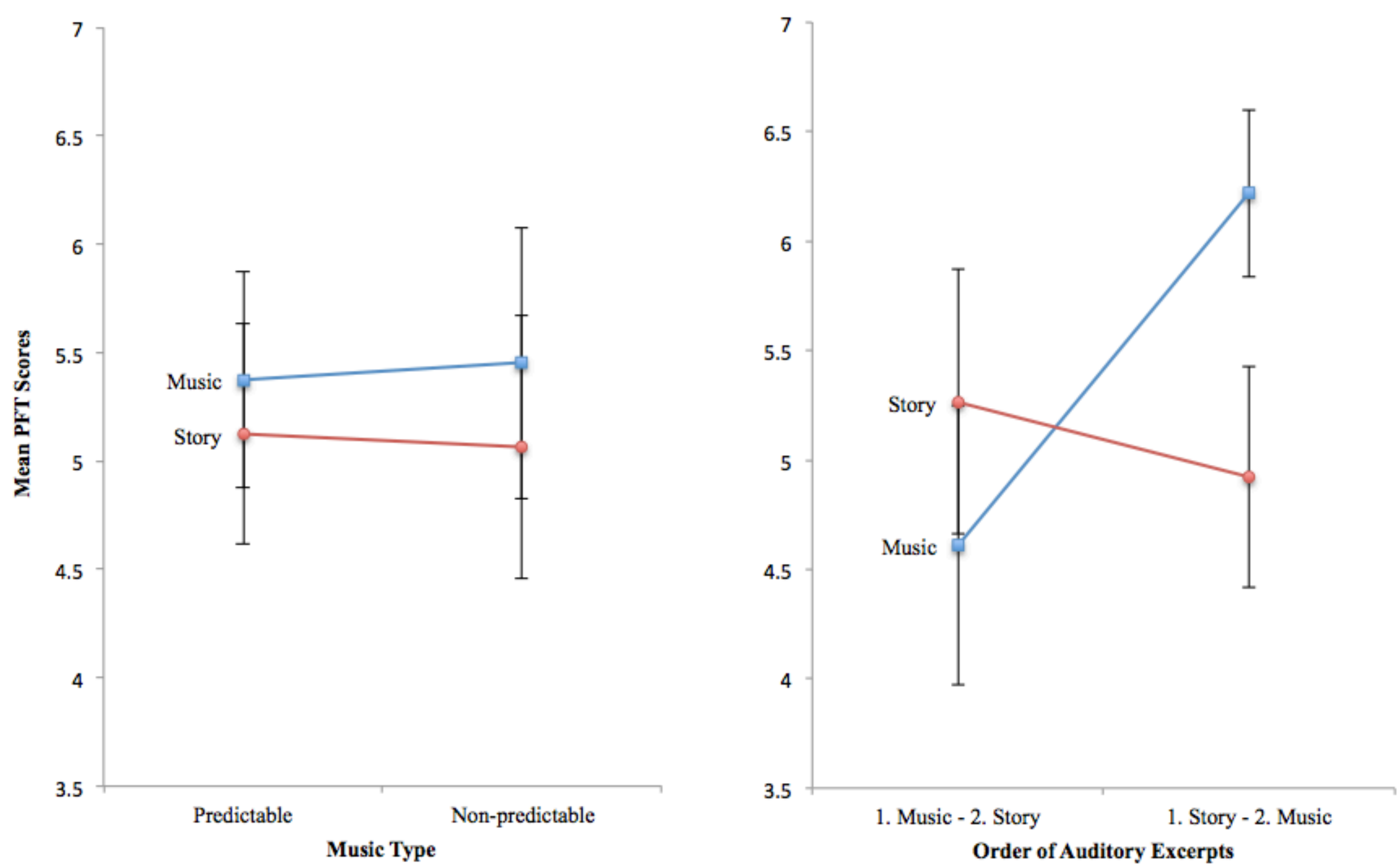

Figure 3. Graphs of interaction between music type and audio excerpt type (left) and interaction of order of stimuli and audio excerpt type (right). Standard error bars are shown.

Discussion

The results indicated that listening to predictable music did not directly evoke a Mozart Effect. Participants that listened to predictable music did not have significantly higher PFT scores than those that listened to non-predictable music. Moreover, there were no significant differences in PFT scores between audio excerpt types. Overall, participants received higher PFT scores on their second attempt regardless of either the type of music or audio excerpt type they listened to prior, indicating an order effect. As such, the original hypothesis was not supported for this sample.

Although the results were not significant, they were nonetheless important. For one thing, the present study accounted for many of the methodological and logistical concerns initially raised by Steele, Ball & Runk (1997). The participants were tested using the same test that Rauscher and Shaw (1998) concluded was necessary for testing true spatial-temporal reasoning. Additionally, the PFTs were administered immediately after the audio excerpt was finished in an attempt to maximize the carry-over effects that Sarnthein et al. (1997) described. Participants, wearing over-ear headphones and located in an empty room free of distractions, were also purposefully told that they would be asked questions about the music and story to ensure they actively listened for the entire excerpt. Finally, the primary researcher was naïve to the type of music each participant listened to until the completion of the study, thus alleviating a possible experimenter bias Steele, Ball, and Runk (1997) proposed.

Participants were asked to listen to a short story in order to equalize the amount of time that passed between each PFT trial. In addition, they were asked to pay full attention to it, much like in the music trial. Control groups for many of the studies listed above ranged from short stories and relaxation tapes to sitting in silence. The present study chose the short story as a control to minimize any differences in participants' attentiveness during the listening exposures. It was difficult to determine, though, if the lack of significant effects observed between conditions was due, in part, to having participants listen to the short story instead of sit in silence. Because the study was specifically interested in the difference in PFT scores between the predictable and non-predictable music types, it was assumed that this would not be an issue. However, it may have been better, especially because this type of control was used in Rauscher, Shaw, and Ky (1993;1995), to have had the participants sit in silence for 10 minutes instead of listen to the short story. This would have allowed for the primary investigator to obtain the average "base PFT score" – i.e. the score that participants obtained with no prior simulation beforehand.

Previous research usually administered listening exposures over the course of a few days. Participants would listen to an audio sample, perform a spatial-temporal task, and then return later in the week to repeat the process (except with a different audio excerpt). This was done to make sure that any effect observed did not carry over to the next testing phase. The present study minimized this issue by counter-balancing the order in which the audio excerpt types were presented. Only the order the PFT sections were given in was held constant throughout the study – i.e. participants were always given Part 1 of the PFT after the first exposure and Part 2 after the second.

The present study attempted to examine the Mozart Effect by specifically looking at music as a series of integrated components. Focusing on predictability provided a way to analyze these components, even though the music remained integrated as a whole. If the music were to be broken down into its components and then tested separately, the result would cease to exist as music altogether and fail to evoke any effect. Clearly, the Mozart Effect depends on the way certain musical components are perceived in the brain, yet participants consciously perceive the music as one entity. Therefore, it would be nearly impossible to accurately examine how the components of music specifically affect the brain, short of using advanced brain imaging techniques.

One major difference between the present study and past research was that Mozart's music was not used as an audio excerpt. Because predictability was the main focus of the study, it was most important to use musical selections that only differed in this respect. Other differences in the musical selections that the study attempted to minimize included variations in orchestration, quality of audio recording and performance, and length. It was easiest to satisfy these constraints by using music composed recently compared to Mozart because of the vast amount of variety available. The two selections used in this study were ideal because they (1) had similar orchestrations (2) seldom changed tempi within major sections (i.e. minimal use of accelerandos, rallentandos, etc.), (3) were less susceptible to other exaggerated expressive musical devices (compared, for example, to a sonata performed by a single musician), and (4) were both ten minutes in length (needing only the removal of one movement) - the preferred length according to Rauscher and Shaw (1998).

It should not have mattered that Mozart's music was not used because of the focus of the study. In light of the lack of statistical significance, however, a study using Mozart's music may be warranted provided special care is taken to minimize differences (other than the level of predictability) between the music selections as described above.

An example of this could be to use a Mozart symphony as the predictable music and a symphony with similar orchestration and length written by a composer of the late-Romantic or Impressionist Era (e.g. Debussy) as the non-predictable music. Compared to Mozart, a composer of the Classical era that wrote in a more conservative style, composers of these later periods often experimented with odd time signatures and phrasing, freer harmonic structure, and irregular melodic themes.

Because participants were always given Part 1 of the PFT after the first listening exposure and Part 2 after the second one, it is possible that this could have contributed to the order effect observed in the study. There were no indications in the instructional manual (Ekstrom, French, Harman & Dermen 1976) given that denoted whether one part was more difficult than the other. I assumed, because more difficult questions were distributed between both parts in no particular order, that they were nearly identical in difficulty. It was tough, though, to ensure that this was indeed the case. If more participants were available for the study, it would have been better to reverse the order the PFT sections were given in for half of the participants. This would allow the researcher to determine if the observed effect was truly due to order or if it was skewed because of variations in difficulty between the two parts.

It is also important to note a possible issue regarding the use of deception in the study. While participants were told only that they would be instructed to complete a PFT after listening to an “audio” sample, the Informed Consent that each participant was required to read and sign explained that they would specifically be listening to a “musical” selection before being administered a PFT during the study. For the participants that listened to the story first and then music afterward, it is possible, then, that they were expecting the music to have a positive effect on their test scores, introducing a bias. In the questionnaire that was administered at the conclusion of the study, many participants guessed that the hypothesis was testing for a general Mozart Effect (i.e. that the music would promote higher test scores than the story). However, there was no mention of predictability vs. non-predictability; participants were unaware that there were different types of music since they were only assigned to one type. Because of this, it can be dismissed as a non-issue since these results were not significant anyway.

While the use of the questionnaire revealed what the participants thought the purpose of the study was, additional questions could have been added to collect more pertinent information. For example, it would have been useful to ask the participant to describe their mood after listening to the music and to what degree they preferred it. This would have allowed for further analyses of the preference/arousal theory.

Ensuring that each participant was completely attentive to the auditory stimuli was also difficult to control, even with the use of deception. For one thing, the participants sat facing a wall with their back facing the door to the room they occupied. Although a window was present in the door allowing the researcher to make sure participants remained seated with their headphones on, the researcher was unable to view their faces. It may be warranted in further study to use a video camera aimed at the participants' front to determine the degree to which they seemed to be paying attention.

There is much more to explore in examining the components of music to further understand the mechanism of the Mozart Effect. Whether predictability plays a roll or not, I speculate that the most valuable results will come from studies employing the use of brain imaging. There seem to be many irregularities surrounding research relying solely on test scores to achieve a Mozart Effect. The use of EEG has allowed researchers to see, with good temporal resolution, the effect of music on the brain. The next step would be to focus on using fMRIs to obtain a higher spatial resolution. EEG is limited in its power to determine where the signal in the brain originated from. Just because a signal is read above the parietal lobe does not mean that it originated there. The use of fMRI would allow researchers to have an accurate account of the changes that occur in the brain during the process of listening to different types of music and while participants attempted to solve tasks involving spatial-temporal reasoning.

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