Spatial-temporal skills and exposure to music: Is there an effect, and if so, why?

Kristin Marie. Nantais
University of Windsor

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Spatial-temporal skills and exposure to music:

Is there an effect, and if so, why?

by

Kristin M. Nantais

B.A. (Honours), University of Windsor, 1993
B.Ed., University of Windsor, 1994

A Thesis
Submitted to the Faculty of Graduate Studies and Research
Through the Department of Psychology in Partial
Fulfilment of the Requirements for the
Degree of Master of Arts at the
University of Windsor

Windsor, Ontario
Canada
1997
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Abstract

The present study sought to replicate and extend the "Mozart effect" described by Rauscher, Shaw, and Ky (1993, 1995). Rauscher et al. reported an increase in scores on a spatial-temporal task following 10 minutes of listening to a Mozart sonata, an effect that was not evident in control conditions (e.g., 10 minutes of silence). In Experiment 1, we replicated the Mozart effect in a highly controlled environment; participants performed better on a spatial-temporal task after listening to Mozart than after sitting in silence. In Experiment 2, we found the same effect when a composition by Schubert was substituted for the Mozart sonata. In Experiment 3, performance was equivalent across conditions when we replaced the silence (control) condition of Experiment 1 with 10 minutes of a narrated short story. Moreover, performance on the spatial task was a function of listeners' preference for the Mozart or the story. These findings imply that the Mozart effect can be explained by participants' motivation and emotional state.
Acknowledgements

Having navigated the challenging road to an M.A. thesis, I am very grateful to those who have been so helpful along the way. First and foremost I would like to thank my thesis advisor, Dr. E. Glenn Schellenberg. His patience with my circuitous path, and insightful guidance and support when it was needed made this all possible.

I also extend my sincere thanks to Paul Pilon for his programming assistance and positive support. And of course, thanks to Margaret McKinnon who made everything so much easier to deal with in her own very special way. I would also like to thank my committee members for their thoughtful comments and interest in this research. Finally, I would like to thank my family and friends for their unconditional support of my endeavours.
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CHAPTER I

Introduction

The question of whether musical aptitude is associated with other skills, such as those involving spatial, verbal, or mathematical reasoning, has been the focus of recent research (Hassler, Birbaumer, & Feil, 1987; Hobbs, 1985; Karma, 1982; Lamb & Gregory, 1993). The existence of such associations could have implications for the ways in which human intelligence and learning are viewed by psychologists and educators. Recently, Rauscher and her colleagues reported that exposure to music improves performance on a spatial-temporal task (Rauscher, Shaw, & Ky, 1993, 1995; Rauscher, Shaw, Levine, Ky, & Wright, 1994). If this association can be verified and replicated in other laboratories, the educational implications for enhancing spatial intelligence and other associated abilities (logical-mathematical, etc.) would be considerable. For example, young children who have difficulty acquiring basic skills (e.g., in arithmetic) might benefit from exposure to music.

The Nature of Intelligence

Current theories of the nature of human intelligence include a variety of approaches. The basis for normal human intelligence is seen by some to be essentially innate; brain functions governing intelligent behaviour develop according to a genetic schedule, with environmental
influences operating only negatively to harm or distort development (Gazzaniga, 1985). Others theorize that interactions between genotypes and the environment produce phenotypical intelligence (Scarr & Carter-Salthzman, 1982). Still others see intelligence mainly as a product of the environment, with higher levels of intelligence resulting from a more positive and stimulating environment (Diamond, Johnson, Protti, Ott, & Kajisa, 1985; Flynn, 1984).

The nature-nurture controversy gets played out most completely in discussions of the value of compensatory education programs for preschool children who come from disadvantaged backgrounds. Hereditarian theorists, such as Jenson (1969) and Rushton (1996), maintain that the difference in intellectual performance between advantaged (higher socio-economic status) and disadvantaged (lower socio-economic status) groups is due to genetic differences, which environmental manipulations can only mitigate. There is now a growing consensus, however, that environmental influences have been underestimated (Zigler & Berman, 1983). Preschool education programs for disadvantaged children (e.g., the Headstart program in the U.S.) have positive effects on children's subsequent performance in school. Specifically, lower socio-economic status children who have participated in such programs exhibit improved performance in later grades and they are less likely to be held back or to drop out of school (Lazar & Darlington, 1982). In fact,
children enrolled in preschool programs tend to have higher scores on intelligence tests compared to other children (McKay, Sinisterra, McKay, Gomez, & Lloreda, 1978; Garber & Herber, 1982). Hence, exposure to positive as well as negative influences in the environment can influence children's overall intelligence and achievement.

Evidence from animal studies demonstrates that environmental factors influence neocortical development (Diamond et al., 1966; Diamond et al., 1985; Kempermann, Kuhn, & Gage, 1997). For example, rats from an enriched and stimulating environment have increased numbers of glial cells and more dendritic spines on neurons. Continuous stimulation of brain areas (through the processing of information) may increase connections between neurons, and, consequently, influence the development of intelligence. Thus, cognitive stimulation could induce permanent and positive changes in brain structure and organization (Diamond et al., 1985; Kempermann, Kuhn, & Gage, 1997). Scheibel (1988) studied humans and reported a positive correlation between dendritic branching and level of education. Nonetheless, it is unclear whether formal education actually keeps the brain healthy, or whether it results in a more interesting and intellectually vital life that stimulates brain development.

More recent evidence using MRI (magnetic resonance imaging) techniques revealed that the cortical
representation of the digits of the left hand of string players was larger than that of control (non-musician) participants (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995). Furthermore, the amount of cortical reorganization in the representation was associated with the age at which the person had begun to play.

If the areas of the brain stimulated by music processing are similar to those that are important in the acquisition of language and mathematics, musical training could promote cortical development and the acquisition of skills with similar neural substrates. Thus, training in musical skills or exposure to complex musical selections could facilitate the development of related abilities, such as those involving spatial-temporal or mathematical reasoning.

Models of Intelligence

Older models of intelligence, such as Spearman's g, tend to view intelligence as a unitary construct. According to Spearman (1927), general intelligence (g) varies across individuals and is responsible for many different abilities. More recent models of intelligence differ by describing discrete or overlapping sets of functions, collections of processes, areas of localization, distinct abilities, and modules of functioning (Waterhouse, 1988). For example, there may be multiple primary mental abilities rather than a single entity (Gardner, 1983; Guilford, 1967; Thurstone,
1938). Tests of these "separate" factors show, however, that ability in one area is usually correlated with abilities in others. Gardner (1983, 1993) argues for a set of seven discrete abilities or intelligences, each of which is said to be independent of the others to a significant extent. This set includes linguistic intelligence, musical intelligence, logical-mathematical intelligence, spatial intelligence, bodily-kinaesthetic intelligence, interpersonal intelligence (knowledge of others), and intrapersonal intelligence (knowledge of self). An eighth intelligence, labelled "naturalist intelligence," has recently been added (Gardner, 1996), representing the extent of our knowledge of the world around us. According to Gardner, the different intelligences can vary independently from below-average to above-average levels depending on the person.

Evidence consistent with the notion of discrete and multiple intelligences comes from studies of brain-damaged adults, which have demonstrated that particular faculties can be lost while others are spared (Gazzaniga, 1988). Such independence implies that a particularly high level of ability in one area (e.g., mathematics) need not predict a similarly high level in another area (e.g., language or music). Although the high correlations usually found among subtest scores of traditional IQ-measures appear to contradict theories of multiple and separate intelligences,
these findings could stem from the fact that IQ-tests measure the ability to respond rapidly to items of a logical-mathematical or linguistic nature (Gardner, 1993).

Sternberg's (1977) view of intelligence is a synthesis of the unitary and faculty approaches. He believes that human intelligence consists of an executive unitary function that supervises a set of multiple functions. These multiple functions or abilities share some cortical matter; hence, there is some overlap with certain adjacent abilities but not with others (Sternberg & Powell, 1982). For example, numerical and musical abilities could share certain functions (e.g., both rely on pattern recognition) but not others (e.g., only music evokes emotional responses). Functional anatomical units may combine to produce a "whole" central nervous system. In short, there may be a biological basis for specialized intelligences.

Models of Processing

The brain is viewed by some researchers as a highly organized complex of specialized, interacting systems that selectively mediate cognitive functioning (Fodor, 1983; Gazzaniga, 1985, 1988). Specialized brain systems are not just distinct modules. Rather, they interconnect with other brain regions, frequently with reciprocal pathways that allow dynamic interaction among brain structures through non-modular functions (Sejnowski & Churchland, 1989).

The modular structure of the brain permits parallel or
simultaneous processing such that different systems can run concurrently (Gazzaniga, 1985). Over the course of evolution, humans have come to possess a number of special-purpose information-processing devices, termed "computational mechanisms" by Fodor (1983). The operation of these mechanisms may be considered autonomous in two ways: (1) each mechanism operates according to its own principles and is not "harnessed" to any other module, and (2) individual information-processing modules operate without being directed to do so, responding to specific forms of information that are analyzed quickly and automatically. Although brain damage usually affects modular functions in an all-or-none fashion, with non-modular functions the amount of damage determines the amount of impairment (Fodor, 1983). Functions appearing relatively less efficient after brain damage are considered non-modular, whereas functions that are lost in their entirety are considered modular.

**Music and the Brain**

Studies of children with Williams syndrome shed some light on the nature of intelligence. These children are mentally retarded but exhibit relatively intact linguistic skills with articulate and fluent speech. By contrast, their visual-spatial and motor abilities are poor, and scores on standard intelligence tests are in the mild to moderately mentally retarded range (Hickok, Bellugi, &
Jónes, 1995; Udwin, Yule, & Martin, 1987). Such a discrepancy appears to provide support for a modular theory of mental functions, whereby the module for language function is intact and independent of other skills that show marked deficits. Nonetheless, children with Williams syndrome are also relatively musical (Don, 1997; Udwin et al., 1987), which could indicate a fundamentally intact ability to process and represent auditory patterns regardless of whether such patterns take the form of speech or music.

Leng and Shaw (1991) proposed that exposure to music might excite and enhance the same cortical firing patterns used in spatial-temporal reasoning. Such exposure could affect cognitive abilities in tasks that share this complex spatial-temporal neural code. The trion model (Leng & Shaw, 1991) of the cortex proposes that the inherent firing patterns resulting from the columnar structure of the cortex (Mountcastle, 1978) can be enhanced by small changes in connection strengths. Neuronal firing patterns may also evolve, forming the internal neural language of the cortex (McGrann, Shaw, Shenoy, Leng, & Mathews, 1994). When these researchers mapped evolutions of the firing patterns predicted by the trion model onto patterns of pitch, the resulting pitch patterns correspond with specific styles of music (i.e., Baroque, New Age, Eastern) (Leng, Shaw, & Wright, 1990). Consequently, music may influence brain
organization, such that abilities in other cognitive functions can be improved through exposure to music.

For most adults, the left hemisphere of the brain is primarily responsible for language and speech abilities, the ability to perform complex mathematical calculations, and the ability to solve problems requiring deductive logic (Churchland, 1988). By contrast, the right hemisphere houses spatial and perceptual abilities, appreciation of the arts, and inductive and creative thinking. Nonetheless, both hemispheres appear to play some role in most activities. Indeed, neither hemisphere has a monopoly on any particular function, although each side is relatively specialized in certain abilities.

Music and Language

Speech and music require similar types of processing, such as analysis of the structure of complex sounds and stress patterns and the perception and memory of pitch and temporal elements. Indeed, there is now some evidence suggesting that music and language processing may occur in a single relatively localized area of the brain. For example, musical ability appears to be associated with increased leftward asymmetry of the planum temporale, the area of the brain subserving music-related functions (Schlaug, Jancke, Huang, & Steinmetz, 1995). Musicians with perfect pitch have increased leftward lateralization of this area of the auditory association cortex in contrast to other musicians.
and non-musicians. Similar results have been reported from children with Williams syndrome (Hickok et al., 1995), who appear to exhibit greater leftward asymmetry than that of the musicians in the Schlaug et al. study, but less than that of the musicians with perfect pitch. Moreover, surface areas of the planum temporale do not differ between Williams syndrome and control children despite the fact that overall cerebral volume is reduced in Williams syndrome (Hickok et al., 1995).

According to Schlaug et al. (1995), asymmetry of the planum temporale provides an anatomical basis for left-hemisphere dominance of language processing. Similarly, preliminary data indicate that this asymmetry is related to the relatively spared language abilities of children with Williams syndrome (Hickok et al., 1995). Hence, these findings suggest that music and language abilities are jointly subserved by a single neural substrate, which helps to explain the relatively good music and language abilities evident among children with Williams syndrome (Don, 1997). Other findings from the neuropsychological literature are consistent in this regard. For example, amusia (lack of musical abilities) is commonly accompanied by aphasia (lack of linguistic abilities) (Marin, 1982). Thus, music and language abilities may represent a unitary mental faculty that is relatively independent of other abilities.
Music and Spatial-Temporal Processing

Music processing also shares some features common to spatial and mathematical reasoning. Indeed, the activities of comparing, classifying, and seriating are basic to all three abilities. For example, logical-mathematical intelligence typically requires spatial information for many solutions, even for something as simple as visually processing numbers. The localization of certain musical and spatial functions in the right hemisphere of the brain implies that these abilities may be closely related. In an eight-year longitudinal study of adolescents and adults (Hassler, 1992), musicians attained higher scores on spatial tests compared to nonmusicians. Such evidence has been reinforced with recent confirmations of an association between exposure to music and performance on a spatial-temporal task (Rauscher et al., 1993, 1995).

Rauscher et al. (1993) reported that listeners demonstrate a significant improvement in spatial IQ scores after listening to a Mozart piece, but not after exposure to either relaxation music or silence (Rauscher et al., 1993). The "Mozart" condition resulted in increases of eight to nine points in spatial IQ scores relative to the other two conditions. In order to investigate whether arousal was responsible for these results, pulse rates were taken before and after each condition (Rauscher et al., 1993). No significant results were noted, hence the researchers
excluded arousal as the source of the effect. In a follow-up study (Rauscher et al., 1995), increases in spatial ability were evident after listening to a Mozart composition but not after listening to a taped short story, a composition by Philip Glass, or a highly rhythmic dance piece.

Stough, Kerkin, Bates, and Mangan (1994) failed to replicate these results, however, after they presented their listeners with the same Mozart Sonata used by Rauscher et al. (1993, 1995), popular dance music, or silence. This apparent discrepancy may have been due to the different measures used to assess spatial ability. Stough et al. (1994) used the Raven's Advanced Progressive Matrices (APM), whereas Rauscher et al. (1993, 1995) used the spatial tasks from the Stanford-Binet intelligence scale. Tasks measuring spatial recognition (such as the APM) are generally a one-step process involving simple recognition of similarities and differences among objects. By contrast, spatial-temporal tasks (such as the paper-folding-and-cutting subtest of the Stanford-Binet) usually require several successive steps -- each dependent on the previous one -- and the participant must mentally combine separate elements into a single whole. Other spatial-temporal tasks involve mental manipulation and rotation of visually presented objects (e.g., Shepard & Metzler, 1971). Because the potential ramifications of the "Mozart effect" could be
profound, it is important to ensure that it is replicable, especially in light of Stough et al.'s (1994) failure to replicate.

Although the facilitation in spatial-temporal skills following exposure to music (Rauscher et al., 1993, 1995) was temporary (it lasted only 10 to 15 minutes), longer term improvements in spatial-temporal reasoning have also been reported (Rauscher et al., 1994, 1997). Specifically, preschoolers who completed nine months of piano lessons exhibited significantly improved spatial-temporal scores compared to their counterparts without lessons. Music lessons may produce long-term modifications on underlying neural circuitry in regions of the brain that are concerned with spatial-temporal processing in general.

Hurwitz, Wolff, Bortnick, and Kokas (1975) also reported that a seven-month Kodály-based program of music instruction improved first-grade children's performance on temporal and spatial tasks. Kodály music programs involve systematic presentation of rhythmic elements as well as pitch and tone patterns, and music lessons are usually initiated when children are in kindergarten. The researchers also noted a transfer effect of accelerated reading skills for those who had received the music instruction.

More recently, Gardiner, Fox, Knowles, and Jeffrey (1996) found that first-grade children who participated in a
seven-month intensified music and visual arts program demonstrated greatly improved reading and mathematical abilities following the program, despite the fact that the sample included children who had performed at a below-average level in kindergarten. These children caught up to their peers in reading and exceeded them in mathematics. Indeed, mathematical abilities improved more than reading abilities for the sample as a whole.

Conclusions

Although some cognitive abilities may be independent of a general intelligence factor, they may also overlap to some extent. For example, musical, spatial, and verbal abilities may be associated. Learning in one area may facilitate the development of other abilities. Detecting specific associations among certain abilities could also help to unravel the mysteries of the underlying structure of human intelligence.

In the present study, we examined the relation between music and spatial-temporal reasoning. Specifically, we sought to replicate and extend Rauscher et al.'s (1993, 1995) results by examining the effects of exposure to music on a subsequently presented spatial-temporal task. We were also interested in determining whether this effect would be specific to Mozart or music from the Classical era (early 1800s), or whether a composition from the Romantic era (late 1800s, e.g., Schubert) could produce a similar effect.
Finally, we attempted to determine whether the reported spatial-temporal enhancement could be due to participants' inattention or boredom following the silence condition compared to the more stimulating music condition.
CHAPTER II
Experiment 1

The purpose of the present experiment was simply to replicate the Mozart effect reported by Rauscher et al. (1993) in a completely controlled testing environment. Participants were required to complete a spatial-temporal task immediately after listening to either 10 minutes of a Mozart sonata or 10 minutes of silence.

Method

Participants. The participants were 28 students recruited from introductory psychology classes at the University of Windsor. The students received partial academic credit for their participation.

Apparatus and stimuli. The first 10 minutes of Mozart's Sonata for Two Pianos in D major, K. 448 were digitally re-recorded from a compact disc (Sony SK 39511, performed by Murray Perahia and Radu Lupu) onto a Power Macintosh 7100/66 AV computer using the SoundEdit 16 software program. The sound quality was not adversely affected during the re-recording process (i.e., 16-bit sound files, sampling rate of 44.1 KHz). Stimulus presentation and a record of participants' responses were controlled by a customized program created with PsyScope 1.1 software (Cohen, MacWhinney, Flatt, & Provost, 1993) installed on the same computer. During testing, the auditory signal was sent in stereo to a Yamaha MR 842 Mixing Console and then to
lightweight personal stereo headphones (Sony CD550). Participants wore the headphones in a sound-attenuating audiometric booth manufactured by Eckel Industries. They could see the computer monitor (Apple Multiple Scan 17 Display monitor, M2494) through a window in the booth. Participants used a mouse connected to the computer to initiate a 10-minute waiting period and to record their responses on the subsequent spatial-temporal task.

The spatial-temporal task consisted of 34 paper-folding-and-cutting items that were scanned into PICT files using an Apple OneScanner with Ofoto 1.1 software. Twenty of these were taken directly from the Stanford Binet Intelligence Scale; an additional 14 were created for the experiment. As shown in Figure 1, each item had an upper panel that showed a rectangular piece of paper and a series of folding and cutting manipulations, and a lower panel with five possible outcomes of the manipulations. The relative difficulty of the items was determined in a pilot study in which 20 graduate and undergraduate students completed the entire set of items presented in random order. Following the pilot study, the 34 items were ranked from least difficult to most difficult and the two 17-item subsets (subset A and subset B) of equal difficulty were formed.

**Design and procedure.** Each student participated in both conditions but on separate days. The two testing days always fell within a two-week period. In both conditions,
Figure 1. The upper section illustrates how a piece of paper was folded and cut. The bottom section shows five possible outcomes, from which participants made their selection.
the spatial-temporal task was administered after a 10-minute waiting period.

In the Mozart condition, participants listened to the Mozart sonata during the waiting period and completed the spatial-temporal task immediately afterward. Each of 17 paper-folding-and-cutting items (from subset A or subset B) was displayed on the computer monitor for a maximum of 1 minute. For each item, the participants' task was to choose which of the five unfolded displays would be the outcome of the folding and cutting manipulations (see Figure 1). Responses were made by using the mouse to click on the appropriate choice. Participants could make their response at any time during the 1-minute display period and a warning beep was sounded 7 s before the end of the period. Immediately after a selection was made, the next item appeared on the screen and participants were again given a maximum of 1 minute to select their response. This process continued until all 17 items had been presented. No feedback was provided. The 17 items were ordered from least difficult to most difficult (as determined from results of the pilot study). Sessions took approximately 25 minutes to complete.

The silence condition was identical to the Mozart condition except that participants sat in silence wearing headphones during the waiting period. Participants were tested with different subsets of the 17 paper-folding-and-
the spatial-temporal task was administered after a 10-minute waiting period.

In the Mozart condition, participants listened to the Mozart sonata during the waiting period and completed the spatial-temporal task immediately afterward. Each of 17 paper-folding-and-cutting items (from subset A or subset B) was displayed on the computer monitor for a maximum of 1 minute. For each item, the participants' task was to choose which of the five unfolded displays would be the outcome of the folding and cutting manipulations (see Figure 1). Responses were made by using the mouse to click on the appropriate choice. Participants could make their response at any time during the 1-minute display period and a warning beep was sounded 7 s before the end of the period. Immediately after a selection was made, the next item appeared on the screen and participants were again given a maximum of 1 minute to select their response. This process continued until all 17 items had been presented. No feedback was provided. The 17 items were ordered from least difficult to most difficult (as determined from results of the pilot study). Sessions took approximately 25 minutes to complete.

The silence condition was identical to the Mozart condition except that participants sat in silence wearing headphones during the waiting period. Participants were tested with different subsets of the 17 paper-folding-and-
cutting items during the two conditions.

Before the participants entered the sound attenuating booth, two practice examples of the task were provided as specified in the oral directions for the Stanford-Binet paper-folding-and-cutting subtest. The participants were in the sound-attenuating booth for the subsequent testing session and the entire experiment was controlled by the computer. Order of conditions (Mozart followed by silence or vice versa) was counterbalanced with order of paper-folding-and-cutting subset (subset A followed by subset B or vice versa). Hence, one-quarter of the participants were in the Mozart condition with subset A on the first testing day, and in the silence condition with subset B on the second testing day. Another quarter were in the silence condition with subset A on the first day and in the Mozart condition with subset B on the second day, and so on.

**Results and Discussion**

A mixed-design analysis of variance (ANOVA) was used to examine performance on the spatial-temporal task as a function of one within-subjects variable: the treatment of interest (Mozart or silence), and two between-subjects variables: presentation order of the treatment and silence conditions (Mozart on the first day and silence on the second day or vice versa) and order of the paper-folding-and-cutting subsets (subset A on the first day and subset B on the second day or vice versa). In this analysis, the
test of the main effect due to order (i.e., differences in performance from the first testing day to the second) is provided by the test of the interaction between testing order and the treatment of interest. Participants' scores in the Mozart and silence conditions are illustrated in Figure 2. Results of the ANOVA are summarized in Table 1.

The main effect of the treatment of interest (Mozart vs. silence) was significant. Participants scored significantly higher on the spatial-temporal task after listening to 10 minutes of Mozart than after 10 minutes of silence. This effect is illustrated in Figure 2 by the greater number of points above the diagonal than below. On average, participants' scores increased by almost one item from the silence condition (M=11.89) to the Mozart condition (M=12.75). Considering that the standard deviation on the task was 1.54 items (i.e., the square root of the within-subjects error term), the effect size is .56 standard deviations, which would be equivalent to 8.4 IQ points (based on a standard deviation of 15 points for the Stanford-Binet test).

None of the other main effects or interactions were significant. In short, the Mozart effect reported by Rauscher et al. (1993) was successfully replicated in a completely controlled laboratory setting. Indeed, the effect size we observed was virtually identical to that reported by Rauscher et al. (1993).
Figure 2. Participants scores on the spatial-temporal task in Experiment 1. Points above the diagonal indicate better performance in the Mozart condition than in the silence condition.
Table 1

ANOVA table for Experiment 1 (Mozart vs. Silence)

<table>
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<td>57.14</td>
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</table>

* p<.05
CHAPTER III

Experiment 2

The purpose of Experiment 2 was to investigate whether the Mozart effect observed in Experiment 1 would extend to music written by another composer (Schubert) from a different historical period (i.e., Romantic instead of Classical).

Method

Participants. A new group of 28 listeners was recruited in a manner identical to that of Experiment 1.

Apparatus and stimuli. The apparatus and stimuli were identical to Experiment 1 except that the Mozart excerpt was substituted with the first 10 minutes of Schubert's Fantasia for piano, four hands in F minor, D940. The Schubert piece came from the same compact disc as the Mozart sonata and was performed by the same two pianists.

Design and procedure. The design and procedure were identical to Experiment 1 except that the Mozart condition was replaced by a Schubert condition.

Results and Discussion

The results were analyzed as in Experiment 1. The ANOVA is summarized in Table 2. The Mozart effect extended beyond pieces composed by Mozart: Participants scored significantly higher on the spatial-temporal task after listening to the Schubert excerpt ($M=12.34$ items) than after sitting in silence ($M=11.04$ items). Participants' scores in
Table 2

ANOVA table for Experiment 2 (Schubert vs. Silence)

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<th>SUM OF SQUARES</th>
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<td>12.60**</td>
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</table>

* p < .05

** p < .005
the Schubert and silence conditions are illustrated in Figure 3. The effect size for the present experiment (0.94 standard deviations) was equivalent to 14.0 IQ points. Hence, the Mozart effect reported by Rauscher et al. (1993, 1995) does not require music written specifically by Mozart, nor does it require music written in the Classical style.

The interaction between testing order (Schubert on first day and silence on second day vs. Schubert on second day and silence on first day) and the treatment of interest (Schubert or silence) was also significant. Due to the design of the data matrix, this interaction actually reveals differences in performance between the first and second testing days. Performance was better on the second testing day ($M=12.22$) than it was on the first day ($M=11.17$), indicating that participants improved as they had more practice with the task. The remaining main effect and interactions were not significant.

A comparison of Experiments 1 and 2

Although participants in Experiments 1 and 2 performed better on a spatial-temporal task following exposure to music than exposure to silence, the analyses suggested that the pattern of findings differed between experiments. Specifically, the effect size of the treatment of interest appeared to be larger in Experiment 2 than it was in Experiment 1. Moreover, performance improved from the first to the second testing day in Experiment 2 but not in
Figure 3. Participants' scores on the spatial-temporal task in Experiment 2. Points above the diagonal indicate better performance in the Schubert condition than in the silence condition.
Experiment 1. Accordingly, an aggregate analysis of the combined data sets examined performance as a function of the different experiments, the treatment of interest, and testing order. The ANOVA is summarized in Table 3. The testing-subset factor was excluded because it failed to make a difference in either of the previous analyses.

A mixed-design ANOVA with one within-subjects factor (music or silence) and two between-subjects factors (Mozart or Schubert, testing order) revealed that the treatment of interest was significant once again. Participants performed better on the spatial-temporal task following exposure to music rather than silence.

The interaction between testing order (Schubert or Mozart on first day and silence on second day vs. Schubert or Mozart on second day and silence on first day) and the treatment of interest (music or silence) was also significant. Thus, the combined data set also demonstrates significantly improved scores on the second testing day ($M=12.36$) compared to the first ($M=11.66$). The interaction between the treatment of interest (music or silence) and the musical excerpt (Mozart or Schubert) was not significant; the Schubert and Mozart compositions did not differ significantly in the strength of their spatial-temporal facilitation.
Table 3

**ANOVA table of an aggregate analysis of Experiments 1 and 2**

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<th>MEAN SQUARES</th>
<th>F-RATIO</th>
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</tr>
<tr>
<td><strong>Within Subjects</strong></td>
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<td></td>
</tr>
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<td>15.16**</td>
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<td>3.22</td>
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</tr>
</tbody>
</table>

* p < .05

** p < .005
CHAPTER IV

Experiment 3

The purpose of Experiment 3 was to test the hypothesis (henceforth referred to as the "boredom hypothesis") that the Mozart effect reported by Rauscher et al. (1993) might represent a decrement in spatial-temporal performance due to boredom, frustration, or apathy created by their comparison conditions, rather than an increment in performance due to exposure to music. For example, comparison conditions used by Rauscher et al. included a silence condition and a relaxation condition. In a subsequent experiment (Rauscher et al., 1995), comparison conditions included silence and a "mixed" condition, which consisted of a taped short story, a piece composed by the contemporary minimalist composer Philip Glass, and a piece of repetitive dance music. Unfortunately, this design precluded a direct comparison of the short-story and music conditions. Thus, there is no way of knowing whether performance on the spatial-temporal task following exposure to a short story was actually more similar to performance in the silence condition than it was to performance in the Mozart condition. In the present study, we directly tested the "boredom hypothesis" by comparing performance on a spatial-temporal task following exposure to Mozart with performance following exposure to a short story.
Method

Participants. A new group of 28 listeners was recruited in a manner identical to that of Experiments 1 and 2.

Apparatus and stimuli. The apparatus and stimuli were identical to Experiment 1 except that the silence condition was substituted with a "story" condition. In the story condition, participants listened to an excerpt from a story narrated by John Glover (The Last Rung on The Ladder written by Stephen King) that lasted for exactly 10 minutes. This particular narrative was selected because it was considered to be engaging without being overly arousing.

Design and procedure. The design and procedure were identical to Experiment 1 except that 10 minutes of listening to a short story replaced the 10 minutes of silence. In addition, after finishing the second test session, participants were asked which condition (story or music) they thought was more interesting and which condition they preferred.

Results and Discussion

Participants' scores on the spatial-temporal task in the story and Mozart conditions are illustrated in Figure 4. A mixed-design ANOVA revealed that none of the main effects or interactions was significant. The results from the ANOVA are summarized in Table 4. Scores following exposure to the Mozart sonata were not significantly higher than scores following the short story. In short, the substitution of
Figure 4. Participants' scores on the spatial-temporal task in Experiment 3. Points above the diagonal indicate better performance in the Mozart condition than in the story condition.
Table 4

ANOVA table for Experiment 3 (Mozart vs. Story)

<table>
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<th>MEAN SQUARES</th>
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* p = .05
the story for the silence negated the Mozart effect.

The interaction between testing order and the treatment of interest approached statistical significance, however, indicating that performance may have improved slightly from the first testing session ($M=12.50$) to the second ($M=13.43$), as it did in Experiment 2 and in the aggregate analysis of Experiments 1 and 2.

**Further tests of the boredom hypothesis.** The findings of the present experiment imply that the Mozart effect reported by Rauscher et al. (1993) actually stems from a decrement in performance in their comparison (control) conditions, which their participants may have found to be relatively unstimulating. Thus, it might be possible to demonstrate that performance on a spatial-temporal task depends on the motivation afforded by stimuli that are presented during the preceding waiting period.

An aggregate analysis was used to determine whether response patterns differed between Experiment 1 (control condition = silence) and Experiment 3 (control condition = story). An ANOVA with one within-subjects variable (Mozart vs. silence or story) and two between-subjects variables (testing order, silence vs. story) revealed that the interaction between the treatment of interest and the order of presentation effect was significant, indicating once again that participants improved from the first testing day ($M=12.32$) to the second ($M=12.96$). The main effects in the
analysis and the other interactions were not significant. The results of the ANOVA are summarized in Table 5.

The next analysis examined the influence of participants' preference for the story or the sonata on their subsequent performance in the spatial-temporal task. Each participant responded identically when asked which condition was more interesting and which condition they preferred, so their answers were considered simply as a "preference" factor. Thirteen participants preferred the 10-minute excerpt from the Mozart sonata; 15 preferred the excerpt from the short story. Results from a mixed-design ANOVA with one within-subjects factor (story vs. music) and two between-subjects factors (testing order, preference for story vs. music) are summarized in Table 6.

Consistent with the boredom hypothesis, the interaction between the main effect of interest and participants' preference was significant. Thus, the size of the Mozart effect depended on whether or not participants preferred the Mozart excerpt over the story. The interaction is illustrated in Figure 5. Whereas participants who reported a preference for the Mozart excerpt scored higher in the Mozart condition (M=14.62) than in the story condition (M=13.23), participants who preferred the short story performed better in the story condition (M=12.67) than in the Mozart condition (M=11.60). The interaction was explored further by conducting separate analyses for the
Table 5

ANOVA table of an aggregate analysis of Experiments 1 and 3

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* p < .05
Table 6

**ANOVA summary table of the influence of preferred condition (Mozart or Story) on performance**

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<td>12.58</td>
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* p<.05
Figure 5. Scores on the spatial-temporal task as a function of condition and participants' preference.
participants who preferred Mozart and for those who preferred the story. For both groups, an ANOVA with one within-subjects factor (music or story) and one between-subjects factor (testing order) was conducted. Results from the ANOVAs are summarized in Table 7. Participants who preferred Mozart had significantly higher scores on the spatial-temporal task following the Mozart condition compared to the story condition. By contrast, the difference between the Mozart and story conditions was not significant for participants who preferred the story. It is possible that the Mozart excerpt inspired more interest than the story. Alternatively, exposure to the Mozart excerpt may facilitate performance on a subsequently-presented spatial-temporal task, provided that participants enjoy the excerpt.
Table 7

ANOVA summary table of an aggregate analysis of participants' preference (Mozart or Story)

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* p<.05
CHAPTER V

General Discussion

The present study examined the effects of exposure to music on a subsequently presented spatial-temporal task. In Experiment 1, participants' performance was better on the task after listening to 10 minutes of a Mozart sonata than after sitting through 10 minutes of silence. In Experiment 2, the advantage for music over silence was found to extend to a piece composed by Schubert. In Experiment 3, we compared performance in the Mozart condition of Experiment 1 with a more appropriate (i.e., not so boring) control condition: exposure to 10 minutes of a narrated story. Performance in the Mozart and story conditions did not differ. A subsequent analysis demonstrated, moreover, that advantages on the spatial-temporal task after listening to Mozart were evident only among participants who preferred the Mozart sonata to the story. Across the various analyses, performance on the spatial-temporal task tended to improve from the first testing session to the second.

The present investigation was motivated by Rauscher et al.'s (1993, 1995) extraordinary findings of an increase in spatial-temporal IQ following exposure to a Mozart sonata. If such an association were shown to be robust and reliable, it would be of interest to researchers and practitioners across many disciplines (e.g., education, psychology). Rauscher et al.'s interpretation of their findings is
essentially a claim of cross-modal (auditory-visual) priming, which is said to apply to domains (i.e., listening to music and performance on a spatial-temporal task) that do not have an obvious or well-documented association. The authors speculate that this association can be explained by the trion model of cortical processing (Leng, & Shaw, 1991; Rauscher, et al., 1995). The model posits that patterns of neuronal connections generated when listening to certain types of music are similar to those evoked when performing a task involving spatial-temporal reasoning.

The claim of cross-modal priming for two diverse areas of processing is notably different from other observations of cross-modal priming that have been documented in the literature (Bajo, & Canas, 1989; Goshen-Gottstein, & Moscovitch, 1995; Klimesch, 1994; Wyer, Jr., & Srull, 1989). In general, priming is said to occur when recognition of a stimulus is facilitated (e.g., made faster) as a consequence of previous presentations of the same stimulus or another related stimulus (Klimesch, 1994). When the priming stimulus is encoded, other related concept nodes (representations in the brain that are associated with the priming stimulus) become preactivated or partially "lit up" and are therefore easier to recognize because they have been primed. The extent of preactivation in priming experiments depends on the number of features shared by the priming and the to-be-primed (i.e., target) stimuli. When the prime and
the target have more features in common, the priming effect is stronger.

Cross-modal priming can occur in several ways. For example, in a lexical-decision task, participants can more readily identify if a visually presented string of letters is an actual word when they have been primed by an auditory presentation of the target word (Hernandez, Bates, & Avila, 1996; Kintsch, & Mross, 1985). Cross-modal priming is also evident for pictures and spoken words (Bajo, & Canas, 1989; Goshen-Gottstein, & Moscovitch, 1995), with the facilitating effect of picture-to-word priming exceeding that of word-to-picture priming (Stenberg, Radeborg, & Hedman, 1995). Cross-modal priming has also been identified when the association between the prime and the target is idiomatic rather than literal (Cacciari, & Tabossi, 1988). Thus, although there is compelling evidence of cross-modal priming, there is no evidence that priming can occur between unassociated or tenuously associated stimuli -- other than that provided by Rauscher et al. (1993, 1995). Indeed, the notion that a particular pattern of neuronal firing is similar across modalities such that a priming stimulus can facilitate performance on a subsequent but unrelated task seems questionable at best.

The story condition of Experiment 3 was included in the present study to determine if the Mozart effect reported by Rauscher et al. (1993, 1995) might stem from boredom or
frustration following 10 minutes of silence rather than from cortical priming following exposure to the sonata, as suggested by the trion model. Another possibility is that participants experienced an elevated state of mood in the music condition, and hence were more positive and willing to participate in the subsequent task. It is well known that certain musical selections can elevate mood. Indeed, affective states may be inherently sensitive to stimuli such as musical excerpts (Wyer, Jr., & Srull, 1989). For example, Parrott and Sabini (1990) found that lively, "upbeat" music successfully induced happiness, while gloomy music produced sadness. Many adults report using music as an agent of emotional change (Sloboda, 1992). Physiological responses to music (Pignatiello, Camp, & Rasar, 1989) provide corroborating evidence of music's influence on a listeners' state. Following exposure to "elated" music, heart rate and systolic blood pressure tend to increase, whereas the opposite is true for "depressing" music. Following exposure to "happy" music, participants tend to be more persistent at tasks and faster at solving them (Kavanaugh, 1987). Indeed, Kavanaugh (1987) found that happy subjects were more likely than sad subjects to persist at a problem-solving task (anagrams) and to solve more anagrams. Thus, happy or motivated people perform more accurately and are willing to work longer than their sad or unmotivated counterparts.
Both the Mozart and Schubert excerpts are lively or "upbeat" and stimulating pieces of music. By contrast, the 10 minutes of silence in the control conditions of Experiments 1 and 2 may have put participants into neutral or negative affective states. Hence, the "Mozart" and "Schubert" effects of Experiments 1 and 2, respectively, may have stemmed from: (1) the positive or elevated mood state created by the music, which facilitated performance on the spatial-temporal task, (2) the negative mood state created by the 10 minutes of silence, which had a detrimental effect on performance, or (3) a combination of both of these factors. In Experiment 3, participants who preferred the music condition may have experienced elevated mood states after listening to the Mozart sonata but not after hearing the story, which could explain the significant effect observed for those participants.

Other evidence confirms that states of boredom can result in poor performance (O'Hanlon, 1981). Boredom may decrease the efficiency of information processing relative to positive affective states (Wyer, Jr., & Srull, 1989). Negative affective states (frustration, annoyance, etc.) can also result in a decrement in learning performance (Boyle, 1983; Friedrich, 1992; Mascord, & Heath, 1992; Pan, Shell, & Schleifer, 1994). Hence, if participants' emotional states are likely to be influenced by certain experimental manipulations, these states must be taken into account when
differential responding is observed.

Although the findings of the present study raise serious doubts about the association between short-term exposure to music and subsequent performance on a spatial-temporal task, they do not speak to the possibility of beneficial effects that could result from longer-term exposure to music training (Gardiner et al., 1996; Hurwitz et al., 1975; Rauscher et al., 1994, 1997). Early training in music could very well have benefits for learning in other areas. For example, music education could be a means of reinforcing mathematical skills based on patterning and order, in addition to having personal and social benefits. Music education could also promote the ability to discriminate sounds and patterns of sounds, which could, conceivably, augment language or second-language development. Indeed, music may be a privileged organizer of cognitive processes, particularly among the young (Gardner, 1996).

Suggestions for Future Research

Future research that explores the possibility of an association between spatial-temporal reasoning and exposure to music should measure general interest and mood status of participants across the various experimental conditions. This approach could help to clarify their influence on accurate completion of an experimental task. An investigation into individual differences that distinguish
participants who are most affected by the music from other participants would also be interesting to educators. Pertinent information (e.g., music background, kinds of music listened to in the home, citizenship status, etc.) could be taken before the session begins. More challenging paper-folding-and-cutting items (in the number and difficulty of the steps to the solution) and larger subset sizes would also be useful in these types of investigations.

Conclusions

The findings from this study do not support the claim that the observed increase in spatial-temporal scores reported by Rauscher et al. (1993, 1995) is due to the priming of particular brain areas that are used both in processing music and in spatial tasks. Rather, these data suggest that such increases are due to the boredom of participants tested in inappropriate control conditions. At the very least, the findings reported here suggest that participants' motivation and affect play an important role in their subsequent performance on a spatial-temporal task.
References


Vita Auctoris

Kristin Nantais was born on November 29, 1961 in Windsor, Ontario. She has lived in several places, including northern Ontario, Africa, and Alberta. Following high school she attended the University of Windsor part-time while working full-time. She returned to school full-time in 1992 and received her Honours Bachelor of Arts in Psychology from the University of Windsor in 1993. She then went on to complete her Bachelor of Education with Primary/Junior and Special Education qualifications the following year. Currently, she is enrolled in the doctoral program in developmental psychology at the University of Windsor.