Is the Mozart Effect "Debunked"?

Frances H. Rauscher • *Department of Psychology • University of Wisconsin Oshkosh*

OVERVIEW

The "Mozart effect"—the finding that spatial-temporal reasoning is enhanced following exposure to the first 10 min of Mozart sonata K448 (Rauscher, Shaw, & Ky, 1993)—has been challenged (Chabris, 1999; Steele, Bass, & Crook, 1999; Steele, Brown, & Stoecker, 1999; Steele et al., 1999). These reports have generated media accounts claiming that the Mozart effect is "debunked." Unfortunately, affirmations of scientific discoveries are not as newsworthy as their purported refutations. Two independent meta-analyses report that the Mozart effect has been replicated 29 times in 13 independent laboratories (Block & Grosfield, 2000; Hetland, in press). "It is a moderate effect, and it is robust" (Hetland, in press, p. 33). The purpose of this paper is to outline five experimental factors that may account for differences in the findings of studies attempting to replicate the effect.

BACKGROUND

Research on the Mozart effect was motivated by a highly structured neural network model of higher brain function (Shaw, Silverman, & Pearson, 1985). Based on Mountcastle's columnar principle of cortex, the model proposed that families of neural networks respond to and compare spatial features of objects. By mathematically deriving their firing probabilities, the researchers determined that the networks evolved according to symmetries modified by Hebb learning rules. These neural network patterns (lasting tens of seconds over large cortical areas) corresponded to spatial-temporal task performance (requiring the transformation of mental images over time). Leng and Shaw (1991) predicted certain musical forms might excite these firing patterns, thereby enhancing spatial-temporal performance.

In the first behavioral study to explore Leng and Shaw's (1991) hypothesis, 36 undergraduates listened for 10 min to each of three listening conditions: Mozart Sonata K. 448, relaxation instructions, and silence (Rauscher et al., 1993). The students' spatial skills were then tested using three tasks taken from the Abstract/Visual Reasoning sub-test of the Stanford-Binet Intelligence Scale: the Paper Folding and Cutting task, the Matrices task, and the Pattern Analysis task. A one-factor (Listening Condition) repeated-measures analysis of variance (ANOVA) found a significant main effect for Listening Condition ($F(2,35) = 7.08, p = .002$), with the Mozart group scoring higher than the relaxation or silence groups (Scheffe's $t = 3.41, p = .002$ and $t = 3.67, p = .0008$, respectively). The effect was not present after approximately 10 min.

We later analyzed the three tasks separately, and discovered that the significance of the effect was due to the Paper Folding and Cutting task scores (Figure 1) (Rauscher & Shaw, 1998). This task, a spatial-temporal task, requires spatial imagery, mental rotation, and the ordering in time of item parts in the absence of a physical model. Other types of spatial tasks, such as block matching tasks or matrix tasks, do not require these mental operations.

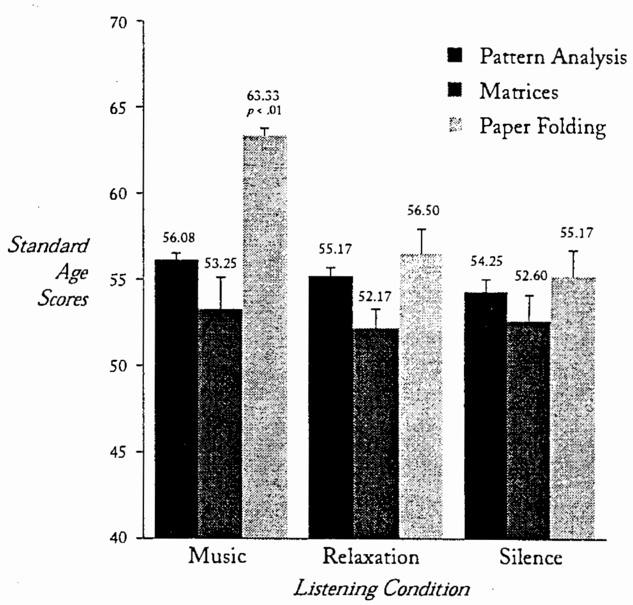

FIGURE 1. Mean standard age scores (SAS) of participants in the Mozart, relaxation, and silence listening conditions for the Pattern Analysis, Matrices, and Paper Folding and Cutting tasks. Vertical bars depict standard error of the mean.

Despite the excitement generated by exaggerated media reports claiming "Mozart makes you smarter," attempts to replicate the effect have been inconsistent. For example, Steele and his colleagues reported failure to replicate the effect in three independent laboratories (Steele et al., 1999). Although more research is needed, we suggest the presence of five experimental factors may have contributed to negative findings.

EXPERIMENTAL FACTORS

Task Validity.

Perhaps the most important choice confronting researchers exploring the "Mozart effect" pertains to task validity. Although the "Mozart effect" has been replicated by researchers using spatial-temporal tasks (Booksh, 1999; Gilleta & Vrbancic, 2000; Nantais & Schellenberg, 1999; Rauscher et al., 1993, 1995; Rideout, Dougherty, & Wernert, 1998; Rideout & Laubach, 1996; Rideout & Taylor, 1997; Siegel, 1999; Twomey, 2000; Wilson & Brown, 1997), researchers using other types of visuospatial tasks report failure to replicate (Newman et al. 1995; Stough, Kerkin, Bates, & Mangan, 1994; Kenealy & Monsef, 1994; Steele, Ball, & Runk, 1997).

A recent study illustrates the importance of task choice (Rauscher & Hayes, 2000). A Solomon Block design was used to contrast the effects of listening to music on a spatial-temporal task to its effects on a non spatial-temporal task in the same experimental design. We compared the scores of 360 college students after listening to a Mozart sonata, relaxation instructions, or silence using two tasks—a spatial-temporal task requiring mental rotation and symmetry operations (Greenbox), and a spatial recognition task requiring pattern matching (Pattern Analysis). We pretested half the students prior to the listening condition to examine the effects of pretesting on the data. Results revealed a "Mozart effect" for the animated spatial-temporal task only, an effect that was not substantially weakened by the pretest (Figure 2).

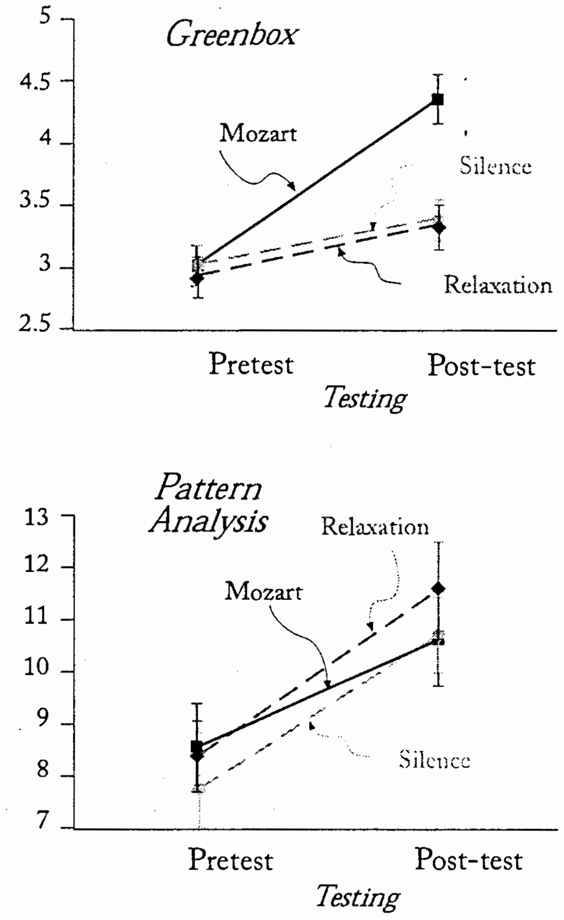

FIGURE 2. Mean Pretest and Post-test Greenbox and Pattern Analysis scores (n=180) of participants in the Mozart, relaxation, and silence listening conditions. Vertical bars depict standard error of the mean.

Expectancy Effects.

Experimenters' beliefs about the outcome of a study can affect its actual outcome (Rosenthal & Rubin, 1978). Researchers exploring the Mozart effect have rarely employed designs in which the experimenter is blind to the study's hypotheses and condition assignment. However, of the four experiments that controlled for expermenter expectancies, all found a Mozart effect (Nantais & Schellenberg, 1999; Rauscher et al., 1993; Rauscher and Hayes, 2000; Rauscher & Ribar, 2000).

We used an expectancy control design to test directly the contribution of experimenter expectancies to the "Mozart effect" (Rauscher & Sparr, 2000). Seventy-nine undergraduate freshmen served as both experimenters and participants. We manipulated the beliefs of our "experimenter-subjects" by assigning them to one of three expectancy conditions: High Expectancy, Low Expectancy, and Blind. Under the guise of informed consent, we asked experimenter-subjects in the High Expectancy condition to read a newspaper article supporting the notion that listening to Mozart would improve task performance. We told these subjects that we expected their partners to perform better following listening to music than following silence. Those in the Low Expectancy condition read an article stating that the Mozart Effect had been "debunked," and were told that we expected to find no difference between their partners' scores in the two listening conditions. Finally, experimenter-subjects in the Blind condition read an article about research methods, and were told nothing regarding the possible outcome of the study. We then provided our experimenter-subjects with identical instructions and scripts.

Each "participant-subject" was exposed to two listening conditions: Mozart and Silence. After each condition he/she answered 16 Paper Folding and Cutting items. All groups evidenced a Mozart effect. However, the scores of participants tested by the high expectancy and blind experimenter-subjects were significantly higher than the scores of participants tested by the low expectancy experimenters (Figure 3). Subjects in the high expectancy group scored significantly higher than those in the low expectancy group. These data suggest that experimenter expectancies probably contribute to the outcome of Mozart Effect experiments, even when experimenters are provided with identical instructions and scripts.

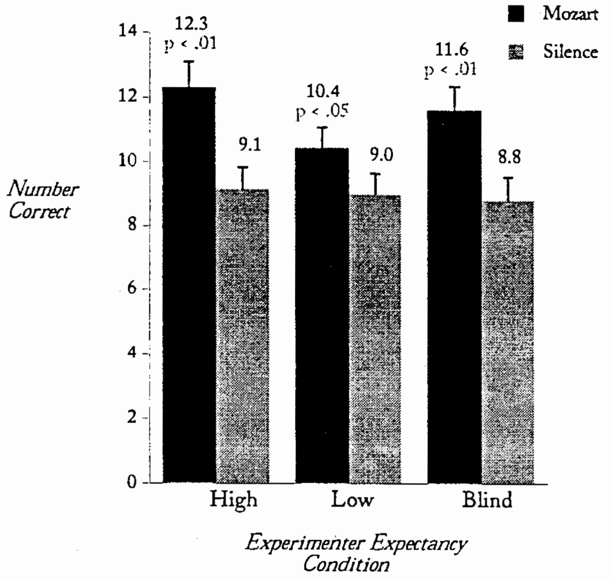

FIGURE 3. Mean Paper Folding and Cutting scores (n=79) of participants in the High, Low, and Blind experimenter expectancy conditions. Vertical bars depict standard error of the mean.

Instructions to Participants.

Hetland's (in press) meta-analysis suggests that researchers who instruct participants to listen carefully to the auditory selections (instead of playing them without instructing subjects) find larger effects, perhaps due to attention. Attention may either permit a more complete neural activation of the networks involved in processing musical and spatial information, or it may increase arousal. In either case, it seems unlikely that a Mozart effect would be found for participants who did not actively process the music. Although research is needed to assess directly the effects of informing subjects to attend to the music, we suggest researchers consider this factor in future experiments.

Item Difficulty.

Another important consideration is the difficulty level of the task. If the spatial-temporal measure is too easy, subjects may rely on relatively automatic processes that are not facilitated by listening to music. For example, the easy Paper Folding and Cutting item depicted in Figure 4 can be solved without mentally unfolding the object, whereas the more difficult item requires processes of imagery and rotation. Block & Grosfield (2000) found a positive relationship between effect size and item difficulty. The size of the Mozart effect was larger in experiments that used more difficult tasks

Practice Effects.

Finally, in studies using pretest post-test designs, it is important to control for practice effects. Some tasks, such as the Paper Folding and Cutting task, are highly susceptible to practice effects. Thus, when subjects are pre-tested and then post-tested, there can be a ceiling effect which obscures any post-test group differences which might be present (Rauscher & Shaw, 1998). Block and Grosfield's (2000) meta-analysis supports this notion. Stronger Mozart effects were found in studies in which task performance was furthest from the ceiling.

CONCLUSIONS

Since the original article was published, our understanding of the Mozart effect has evolved. Although the term "Mozart effect" initially referred to the transitory increase of certain visuospatial task scores following listening to a particular Mozart sonata, the phrase has generalized to include, for example, the effects of music instruction on spatial-temporal task performance. In numerous studies preschoolers, kindergartners, and second-graders who received piano instruction scored higher on spatial-temporal tasks than control groups who received other instruction or no training (see, for example, Rauscher, 1999). These effects appear to last only if the instruction begins before age seven, and if it continues for two or more years. The effect of music instruction has been replicated in several laboratories and may last at least three years.

The Mozart effect has also generalized over different dependent measures and types of subjects. For example, Alzheimer patients who listened to the Mozart sonata or silence demonstrated improved spatial-temporal performance following Mozart (Johnson, Cotman, Tasaki, & Shaw, 1998; Johnson, Shaw, Vuong, Vuong, & Cotman, 1999). Neuroscientists have investigated the effect using electroencephalogram (EEG) and functional magnetic resonance imaging (fMRI). EEGs of subjects who performed a spatial-temporal task after listening to the Mozart sonata revealed a carry-over effect in parietal and frontal cortex; no carry-over was found when reading a story was substituted for the task (Sarnthein et al., 1997). EEGs of epilepsy patients, some comatose, showed decreased seizure activity during exposure to the sonata compared to silence or control music (Hughes, Daaboul, Fino, & Shaw, 1998; Hughes, Fino, & Melyn, 1999). Furthermore, fMRI found significantly more active brain areas while students listened to the sonata compared to a Beethoven composition or popular 1930s music (Bodner, Muftuler, Nalcioglu, & Shaw,

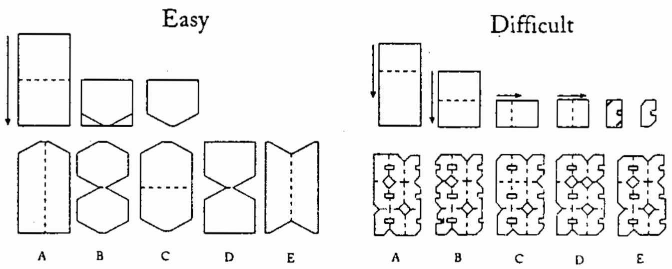

FIGURE 4. Easy and difficult Paper Folding and Cutting items.

1999). The compositions differentially activated the prefrontal, occipital, and cerebellar regions—all regions associated with spatial-temporal reasoning. Finally, rats exposed to the Mozart sonata learned a maze faster and with fewer errors than rats exposed to minimalist music, white noise, or silence (Rauscher, Robinson & Jens, 1998). Given the accumulation of research corroborating the enhancement of cognitive performance following exposure to the Mozart sonata, the claim of debunking the Mozart effect is unwarranted.

Although an accumulation of data convinces us that the Mozart effect is "real," the full explanation and limitations of the phenomenon are not yet known. Some investigators have suggested that the effect is epiphenomenal to a more instrumental induction of positive mood by music or by any other preferred cognitive activity (Nantais & Schellenberg, 1999; Steele, Bass, & Crook, 1999). We welcome alternative explanations for the data. However, those explanations should be weighed against other relevant research. For example, fMRI found no differences between conditions in brain regions characteristically associated with emotion, suggesting changes in music-activated regions were not induced by mood (Bodner et al., 1999). Similarly, subjects' mood ratings following a Mendelssohn composition were higher than those following the Mozart sonata, but spatial-temporal task performance was higher following the Mozart work (Rauscher & Ribar, 2000). Regarding the preference hypothesis, two studies found subjects preferred other listening conditions to the Mozart sonata, and yet the effect was found for the Mozart composition only (Bodner et al., 1999; Rauscher et al., 1995). Obviously, the detection of the Mozart effect in comatose patients and in animals should also be considered when mood or preference explanatory hypotheses are advanced.

The Mozart effect is worthy of ongoing research not only for its theoretical importance, but also its potential practical implications, especially in education. The enhancement of spatial-temporal reasoning through music may facilitate learning in other areas. Students' understanding of science is frequently mediated by mental imagery that takes the form of "runnable" mental models. Imagery is also likely to support certain kinds of mathematical reasoning and the construction of "situation models" of text. More generally, spatial-temporal reasoning is probably underexploited in educational settings, especially in comparison to verbal and numeric representational forms.

The Mozart effect is neither magic nor an article of faith, but the subject of ongoing serious research. We urge investigators not to yield to pressures to sensationalize their findings, but to go about their research cognizant of the corpus of literature bearing on their research question. In the end, it is the accumulation of data that confirms, denies, explains, and delimits any psychological phenomenon of importance.

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