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Several studies have examined the effects of music instruction on children's abilities in other disciplines. Other studies have explored the effects of listening to music on adults' spatial abilities. Findings from these two sets of studies have been confused, leading to claims that listening to music can improve children's academic abilities. This Digest evaluates these claims and discusses the evidence exploring music instruction's effects on children's spatial-temporal, mathematical, and reading abilities.

THE "MOZART EFFECT": LISTENING TO MUSIC

The term "Mozart Effect" refers to the finding that 36 college students who listened to 10 minutes of a Mozart sonata scored higher on a subsequent spatial-temporal task than after they listened to relaxation instructions or silence. The effect lasted approximately 10 minutes (Rauscher, Shaw, & Ky, 1993). Although the effect was replicated by several researchers, other researchers were unable to reproduce it (Hetland, 2000a). Research on the causes and limitations of the effect in adults is ongoing (Husain et al., 2002).
The Mozart Effect was studied only in adults, lasted only a few minutes, and was found only for spatial-temporal reasoning. Nevertheless, the finding has spawned a Mozart Effect industry that includes books, CDs, and Internet sites claiming that listening to classical music can make children "smarter." In fact, no scientific evidence supports the claim that listening to music improves children's intelligence. Two related studies tested the Mozart Effect with 103 children ages 11 to 13 years (McKelvie & Low, 2002). The researchers found no experimental support for the effect in children, concluding that "it is questionable as to whether any practical application will come from it" (p. 241). Although the Mozart Effect is of scientific interest, its educational implications appear to be limited.

MUSIC INSTRUCTION AND SPATIAL-TEMPORAL ABILITY

A meta-analysis of 15 studies involving 701 children ages 3 to 12 years suggests that children provided with music instruction score higher than controls on spatial-temporal tasks (Hetland, 2000b). Spatial reasoning is important to many fields and to core concepts in mathematics, such as proportions and fractions. Effects of keyboard instruction have been found for children ranging in age from 3 to 9 years, with the largest effects found for the youngest children (Bilhartz, Bruhn, & Olson, 2000; Costa-Giomi, 1999; Gromko & Poorman, 1998; Rauscher et al., 1997; Rauscher & Zupan, 2000). Although most studies have employed keyboard instruction, a recent study examined the effect of keyboard, singing, and rhythm instruction separately on the spatial perception of 123 economically disadvantaged 3- and 4- year-old children (Rauscher & LeMieux, 2003). The three music groups scored higher on spatial tasks following music instruction than did a control group, with the rhythm group scoring

higher than all other groups on sequencing and arithmetic tasks. Verbal, matching, and memory tasks were not significantly affected, demonstrating the specificity of the effect to tasks requiring spatial abilities. This finding suggests that different types of music instruction affect different aspects of cognition.

There has been some question as to the durability of cognitive enhancements found for children who receive music instruction. One study found that 9-year-old children who were provided with piano instruction indeed scored higher than controls on a spatial-temporal task immediately following the instruction. However, no differences between the music and control groups were found after two years of instruction (Costa-Giomi, 1999). A follow-up study revealed that participants who began music instruction before age 5 scored significantly higher on spatial tasks than those who began later or did not receive instruction (Costa-Giomi, 2000). This study did not address the possibility that other non-musical factors, such as musical aptitude, parental involvement, or socioeconomic factors may have affected the outcome. The author concluded that children who begin music instruction very early in life are likely to show the greatest benefits in spatial development. Supporting this conclusion are studies that explored the effect of classroom keyboard instruction (Rauscher & Zupan, 2000; Rauscher, 2002). Children who began instruction at age 5 scored higher on spatial-temporal tasks than children who did not receive the instruction. The scores of children who began instruction after age 7 did not differ from controls. Finally, a recent study found that children who received keyboard instruction for two years beginning at age 3 (n = 31) continued to score higher on spatial-temporal and arithmetic tasks two years after the instruction was terminated (Rauscher & LeMieux, 2003). The age at which children begin instruction appears to affect the duration of extra-musical cognitive outcomes, and longitudinal research suggests that at least two years of music instruction are required for sustained enhancement of spatial abilities (Rauscher, 2002).

MUSIC INSTRUCTION AND MATHEMATICS

Some studies have found that music instruction can also affect certain mathematical abilities. Researchers compared the proportional reasoning scores of several groups of children (n = 136, ages 7 to 9 years), including one group who received computer-generated spatial-temporal training alone and another group who received the same spatial- temporal training coupled with piano keyboard instruction (Graziano, Peterson, & Shaw, 1999). The proportional reasoning of the children was then tested. Although both groups scored higher than a control group, the group that included piano training scored significantly higher than the group that did not.

A more recent study found that at-risk children who received two years of individual keyboard instruction scored higher on a standardized arithmetic test than children in control groups, including a group that received computer instruction to rule out a possible Hawthorn effect (Rauscher & LeMieux, 2003). Children who received singing instruction also scored higher than controls. Children who received instruction on rhythm instruments performed best on a mathematical reasoning task.

A meta-analysis combining six experimental studies provides tentative support for the notion that music training affects mathematical achievement (Vaughn, 2000). However, six is a very small number, and more research is clearly needed. Several correlational studies do, however, suggest a relationship. For example, one study involving 96 children, ages 5-7 years, found that those who received 7 months of supplementary music and visual arts classes achieved higher standardized mathematics scores than children who received the schools' typical music and arts training (Gardiner et al., 1996). Unfortunately, random assignment was not possible due to logistics and the school administrators' need to keep classes intact. Furthermore, the music instruction was provided in conjunction with arts training, making it impossible to determine if the effects found were due to music instruction or arts training.

MUSIC INSTRUCTION AND READING

A meta-analysis of a set of 24 correlational studies, some involving sample sizes of over 500,000 high school students, found a strong and reliable association between music instruction and reading test scores (Butzlaff, 2000). A more recent study found that ninety 6- to 15-year-old boys with music training had significantly better verbal memory than children without such training (Ho, Cheung, & Chan, 2003). The longer the training, the better the verbal memory. These studies provide some support for a correlation between music instruction and verbal abilities.
However, a meta-analysis conducted on six experimental studies provided little evidence of a causal relationship (Butzlaff, 2000). The effect sizes were highly variable, indicating that the overall finding is not stable. Therefore, it is unwise to conclude that music affects reading ability based on this analysis.

Experimental research performed with 8- to 11-year-old children with reading problems found that the reading skills of children who received music instruction (n = 6) were significantly higher than those of children who did not receive the instruction (n = 6) (Douglas & Willatts, 1994). However, a study of nine dyslexic boys with a mean age of 8.8 years found that music instruction improved rapid temporal processing skills, phonological skills, and spelling skills, but not reading skills (Overy, 2002). Overall, the studies suggest that it is premature to conclude that music instruction affects reading ability.

CONCLUSION

The research suggests that music may act as a catalyst for cognitive abilities in other disciplines, and the relationship between music and spatial-temporal reasoning is particularly compelling. However, several concerns remain unaddressed. Little is known regarding the exact aspects of music instruction that contribute to the transfer effects. Also, further longitudinal studies are needed to determine the duration of these effects. Another concern is that currently available tests of reading and math achievement may

not be sufficiently sensitive to the complexity of language and mathematical learning potentially affected by music instruction. Although it appears that parents, educators, and policy makers can now consider enhanced spatial-temporal ability to be a viable outcome of music instruction, the evidence supporting enhanced mathematical or reading ability is equivocal. Finally, although the research has strong implications for policy and practice, care must be taken to ensure that scientific goals do not displace developmentally appropriate music instruction (see, e.g., Music Educators National Conference [1994]).

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