Abstract Title Page
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Title: Does spatial training improve children's mathematics ability?

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Abstract Body

Limit 4 pages single spaced.

Background / Context:

Description of prior research and its intellectual context.

Children's early mathematics ability is an important predictive factor to later math achievement (Aunio & Niemivirta, 2010; Byrnes & Wasik, 2009; Jordan et al., 2009; Krajewski & Schneider, 2009), so the question of how to promote children's early math competency is of critical importance. Previous research has established a link between spatial ability and mathematics —both children and adults with better spatial abilities also have higher math scores (Burnett, Lane, & Dratt, 1979; Casey et al., 2001; Casey et al., 1992; Casey et al., 1995; Delgado & Prieto, 2004; Geary et al., 2000; Lubinski & Benbow, 1992; Robinson et al., 1996) even in early childhood (Kyttälä et al., 2003, Geary et al., 2007; Rasmussan & Bisanz, 2005; McKenzie et al., 2003; Mclean & Hitch, 1999; Holmes et al., 2008; Alloway, 2007). Based on these findings, the National Council of Teachers of Mathematics (NCTM, 2010) announced its support of developing spatial reasoning as part of math learning in the first grade.

The connection between space and math may be based on shared underlying processes, suggesting a potent avenue for mathematical improvement. Neuropsychological and brain imaging studies have revealed that similar circuity is activated when people process both spatial and number tasks (Walsh, 2003; Hubbard et al., 2005). There also is behavioral evidence that numerical magnitudes are mentally represented in a spatial format (i.e., the SNARC effect) (Dehaene, Bossini, & Giraux, 1993). This evidence of shared mental processing raises the possibility that math can be improved with spatial training.

Purpose / Objective / Research Question / Focus of Study:

Description of the focus of the research

Our primary aim was to investigate a potential causal relationship between spatial ability and math ability. To do so, we used a pretest-training-posttest experimental design in which children received short-term spatial training and were tested on problem solving in math. We focused on first and second graders because earlier studies suggested significant relations between mental rotation ability and early math ability in this age group (Guay et al., 1997; Kyttälä et al., 2003).

Setting:

Description of the research location.

The research took place in Michigan. All children completed the study in a quiet room in their schools.

Population / Participants / Subjects:

Description of the participants in the study: who, how many, key features, or characteristics.

Fifty-nine children participated (M = 6.8 years old, range = 6 to 7.8 years old). An additional 6 children were excluded because they performed above 75% on the math pretest. Thirty-two children were in the experimental group and 27 children were in the control group. Children were randomly assigned to both groups. The ethnicity of the sample was mixed but predominantly Caucasian. The distribution of gender in the experimental and control groups was roughly equal.

Intervention / Program / Practice:

Description of the intervention, program, or practice, including details of administration and duration. .

Intervention

The spatial training task has improved spatial reasoning scores in previous research (e.g., Ehrlich et al., 2006). In this task, children are shown two parts of a flat object and choose which of several drawings depicts the object as a whole. To choose correctly, children must mentally slide and rotate the parts to make the whole. After pointing to the shape, they were given a set of paper-made pieces. Children were instructed to put these pieces together and pointed to the right shape on the page again. Feedback was given until children correctly pointed to the right shape.

Pretest and Posttest

Spatial tests

To check whether the training task succeeded in improving spatial ability, we gave children two spatial tests. The first was a mental transformation test based on the spatial task we used in training (i.e., Ehrlich et al., 2006). Rather than using moveable pieces, all the materials were printed on paper and children were asked to circle the right shapes based on pieces at the bottom of each page. There were 16 items for the pretest and an additional 16 for the posttest, presented in a counterbalanced order across children. The second test was the spatial relations subtest from the primary mental ability test (Thurstone, 1974). This test consists of 27 items. Children practiced the first four items to become familiar with the procedure and then had six minutes to complete the rest.

Mathematics tests

To test the effects of spatial training on math performance, we also gave two math tests that were based on Michigan Grade Level Content Expectation. The first mathematics test consisted of 27 simple addition and subtraction problems. The second mathematics test had 16 items that measured children's place value concepts. Cronbach's alpha inter-item reliability coefficients for the first mathematics test and the second mathematics test were .92 and .60, respectively.

Research Design:

Description of the research design.

We used a pretest-training-posttest design with two groups of children—(1) spatial training and (2) no-training control. In the spatial training group, children completed a mental rotation task for 40 to 50 minutes. The task is based on those shown in previous research to improve spatial reasoning scores (e.g., Ehrlich et al., 2006). In the control group, children completed crossword puzzles. Crossword puzzles have been used as filler tasks in previous research on spatial ability (Cherney, 2008; Rizzo et al., 1999). Both groups completed tests of spatial ability and simple mathematics (calculation and place value concepts), before and after training.

Data Collection and Analysis:

Description of the methods for collecting and analyzing data.

Children were recruited from a medium sized city in Michigan. Parents were contacted through their children's schools, written consent was obtained from them, and children were randomly assigned to the experimental and control groups. We analyzed our results using multivariate analysis of covariance (MANCOVA) and analysis of covariance (ANCOVA) using pretest scores as a covariate for increased sensitivity (Raykov & Marcoulides, 2008). We also conducted paired sample *t*-tests to compare pre- and posttest scores.

Findings / Results:

Description of the main findings with specific details.

We first conducted a MANCOVA with children's four posttest scores as dependent measures and their pretest scores as covariates. The MANCOVA revealed a significant main effect for condition (Wilks's $\lambda = .64$), $F(3, 52) = 9.65$, $p < .001$, $\eta^2 = .36$) favoring the experimental group. As the follow-test, we carried out an ANCOVA that included the two spatial tasks as well as specific problem types from the math posttest. First, we found that the spatial training group outperformed the control group on the mental transformation task ($F(1, 56) = 16.46$, $p < .001$, $\eta^2 = .23$), indicating that the spatial training was effective; however, this improvement did not transfer to the second, less directly related spatial test ($p = .81$).

With respect to our main research question, there was clear evidence that mental rotation training increased children's math performance. First, there was a significant overall difference favoring the spatial training group on the posttest ($F(1, 56) = 8.42$, $p = .005$, $\eta^2 = .13$). Second, this overall advantage seemed to concentrate on certain problem types. Specifically, spatial training children significantly outperformed control children on missing term problems, such as 2 + ____ = 7 or ____= 9 - 4 ($F(1, 56) = 8.23$, $p = .006$, $\eta^2 = .13$). Furthermore, spatial training children significantly improved on their scores on these problems from pre- to posttest, ($t(31) = 3.587$, $p = .001$), whereas children in the control group did not ($t(26) = .635$, $p = .53$).

Conclusions:

Description of conclusions, recommendations, and limitations based on findings.

We found that even a short amount of spatial training can increase children's math performance. This result contributes to the growing literature that links spatial cognition to mathematical representation and problem solving, but is one of the only to demonstrate a causal link from one area to the other.

Interestingly, the spatial training effect was most evident on missing term problems. Previous research has shown that children have an inflexible understanding of the equal sign and tend to prefer solving equations in a predictable, left-to-right order wherein the answer is provided at the end (Knuth et al., 2006; McNeil & Alibali, 2005). Perhaps our results reflect children's attempts to solve missing terms problems by mentally rotating the equation into this conventional format (e.g., 2 + ___= 7 becomes ____= 7 – 2 or 9 – ___= 5 becomes ___= 9 – 5). If so, mental rotation practice likely facilitates or primes this underlying process.

Appendices

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Appendix A. References

References are to be in APA version 6 format.

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Appendix B. Tables and Figures

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