Improving Spatial Reasoning Through Experience: Evidence of Priming and Long-Term Effects

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Despite decades of attempts to close the gender gap in math, the gender gap continues, and since Larry Summers’ infamous explanation that it is due to innate gender differences in the brain (Ripley et al., 2005), the search for causes has intensified. Life-long educators and feminists may feel dismay at the idea of innate brain differences, but recent research has pretty well established that there are reliable gender differences, and that many of these differences are present from birth. The most reliable difference seems to involve spatial reasoning, although Newcombe makes a good case that even this difference may be more attributable to experience than was originally thought (Newcombe, 2002). Voyer and his colleagues hypothesized that among spatial reasoning tests, mental rotation tests would be the least improvable through experience (Voyer et al., 2000), but found that even on a mental rotation test there was a significant effect from prior experience with spatially-oriented toys (such as blocks and tinker toy) for both males and females. We hypothesized that participants would be better at a mental rotation task after working manually on diagram-based origami projects. Because a pilot study with promising results confounded long term effects with priming (Flanagan et al., 2005), we further
hypothesized that participants would show a priming effect of working with diagrams.

Method

Participants
Thirty-seven middle school students were randomly assigned to be tested for spatial reasoning either before (n=19) or after (n=18) two 40-minute sessions working on fairly challenging origami tasks from a diagram. The two groups, though randomly assigned, were not completely equivalent. The control group was slightly older (M_c=12.42 compared to M_T=12.19), had slightly higher (self-reported) math success generally (M_c=4.79 compared to M_T=4.38 on a scale of 1 to 10), and had a slightly better (self-reported) attitude toward math generally (M_c=7.75 compared to M_T=7.57 on a scale of 1 to 10). Because all of the differences were small and favored the control group we felt these differences were acceptable.

Materials
The origami tasks involved folding a box and folding a book. Prior to the origami sessions, all students, together, were given the opportunity to give their informed assent and were given a very brief introduction to origami and to the mental rotation task. Spatial reasoning was tested using Shepard
and Metzler’s mental rotation task (Shepard & Metzler, 1971) from Cog Lab (Francis et al., 2004). Each participant completed 80 trials of the spatial reasoning task. Priming effects were tested by randomly assigning half of each group to either a 5-minute priming task or a 5-minute reading task immediately before the mental rotation task. The priming task involved solving visualization problems. The non-priming task involved reading a brief history of origami.

Procedure

Sessions occurred as follows. The first session (Friday 1) was a general information session attended by all students. Students gave their informed assent (informed consent had been obtained from parents prior to the start of the study), and received a basic introduction to origami and mental rotation. The second session (Monday 1) consisted of the first origami session for the treatment group or the mental rotation task for the control group. The third session (Friday 2) consisted of the second origami session for the treatment group and the first origami session for the control group. The fourth session (Monday 2) consisted of the mental rotation task for the treatment group and the second origami session for the control group. The fifth session (Friday 3) consisted of debriefing for all participants.

A pilot study (Flanagan, Gurkewitz, and Wilson, 2005) indicated that priming might be an important factor, so within each group half the participants
worked on visualization problems for five minutes prior to the mental rotation task, while the other half read about the history of origami for the same five minutes.

**Results**

Twelve percent of the trials (those with reaction time greater than four seconds) were eliminated from the analysis, under the assumption that the participant was processing more than the stimuli during those trials. We regressed participant, gender, priming and treatment on reaction time by trial. There was an expected effect of participant \( F(1,2595)=26.93, \ p<.001 \). There was no difference in reaction time between male \( M=1606 \text{ ms}, \ SD=961 \) and female \( M=1658 \text{ ms}, \ SD=931 \) trials on the mental rotation task. Gender did not contribute significantly to the regression model \( F(2,2594)=13.49, \ p<.001 \). Priming had a significant effect on reaction time, however. Trials that followed the priming task \( M=1592 \text{ ms}, \ SD=983 \) were significantly faster than trials that followed the non-visual task \( M=1702 \text{ ms}, \ SD=887 \) \( F(3,2593)=13.99, \ p<.001 \). The trials of students who had completed two sessions of diagram-based origami work \( M=1519 \text{ ms}, \ SD=868 \) were significantly faster than the trials of students who had not had these sessions \( M=1783 \text{ ms}, \ SD=993 \) \( F(4,2592)=24.72, \ p<.001 \). The resulting regression equation with standardized coefficients
was Estimated Reaction Time = (participant*.115) + (primed*.08) + 
(treatment*.144), with treatment having the strongest effect.

**Discussion**

We found that priming and treatment did affect facility on a standard test of 
spatial reasoning ability (see Figure 1). Although others have found that 
slightly different parts of the brain are activated during mental rotation and 
paper folding tasks (Milivojevic *et al.*, 2003), and some have found that 
manual tasks activate different spatial representations from visual tasks 
(Yamamoto & Shelton, 2005), our results show that the tasks seem to be 
similar enough to facilitate each other. We think the results of this study are 
quite promising, and look forward to more extended examinations of using 
origami diagrams and practice as a simple, inexpensive, and content-rich set 
of experiences aimed at reducing the gender gap in spatial cognition.
References


**Figure 1: Mean Reaction Time in Milliseconds**

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<tr>
<th></th>
<th>Control</th>
<th>Treatment</th>
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<tbody>
<tr>
<td>No Prime</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>Primed</td>
<td>1500</td>
<td>2000</td>
</tr>
</tbody>
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Primed?  
- Primed  
- No Prime