SEX DIFFERENCES ON A COMPUTERIZED MENTAL ROTATION TASK DISAPPEAR WITH COMPUTER FAMILIARIZATION\textsuperscript{1,2}

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Summary.—The area of cognitive research that has produced the most consistent sex differences is spatial ability. Particularly, men consistently perform better on mental rotation tasks than do women. This study examined the effects of familiarization with a computer on performance of a computerized two-dimensional mental rotation task. Two groups of college students ($N = 44$) performed the rotation task, with one group performing a color-matching task that allowed them to be familiarized with the computer prior to the rotation task. Among the participants who only performed the rotation task, the 11 men performed better than the 11 women. Among the participants who performed the computer familiarization task before the rotation task, however, there were no sex differences on the mental rotation task between the 10 men and 12 women. These data indicate that sex differences on this two-dimensional task may reflect familiarization with the computer, not the mental rotation component of the task. Further research with larger samples and increased range of task difficulty is encouraged.

Since the seminal publication by Maccoby and Jacklin (1974), sex differences on spatial tasks, and particularly mental rotation tasks, have been systematically studied. Research has been conducted using different types of spatial tasks, although there have been inconsistent results. Recent meta-analyses (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995) documented an overall male advantage on spatial tasks, with the most consistent male advantage found on mental rotation tasks in adult populations. In contrast, only inconsistent sex differences among prepubescent boys and girls have been found (Linn & Petersen, 1985; Voyer, et al., 1995). Although meta-analyses indicate an overall male advantage on mental rotation tasks, it is interesting to note that some of the studies using mental rotation tasks do not show superior performance by males. For example, out of the 50 mental rotation studies reviewed in Voyer, et al. (1995), no significant differences were found for male and female participants in 16 of the studies. That is, in about 32\% of the studies reviewed by Voyer, et al. (1995), there were no sex differences in mental rotation performance.

There have been some data to indicate that women may differentially

\textsuperscript{1}These data were presented at the annual meeting of the American Psychological Society, Washington, D.C., May 1998. We thank William Overman for the use of his mental rotation task and for his continued support throughout our project. We also thank Bobby Carlisle for his valuable assistance designing the familiarization computer task.

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benefit from practice on spatial tasks. One such study examined practice effects on both a computerized two-dimensional mental rotation task and a paper-and-pencil rotation task (Saccuzzo, Craig, Johnson, & Larson, 1996). In this two-session study, the common male advantage was found on both tasks during the first session. On the paper-and-pencil task, both men and women improved during the second session, but men still outperformed women. On the computerized task men and women both improved, but the women improved at a much greater rate and to the extent that there was no difference in performance during the second session. It appeared that the practice from the first session of the mental rotation task differentially helped women. While some studies using spatial tasks have yielded similar findings (e.g., Alderton, 1989; Alington, Leaf, & Monaghan, 1993), other studies have shown that both men and women improve at equal rates (e.g., Kaplan & Weisberg, 1987; Baenninger & Newcombe, 1989; Schaeffer & Thomas, 1998). This suggests that the type of spatial task employed affects the rates of improvement.

The results of the Saccuzzo, et al. (1996) study are particularly intriguing because women differentially improved on the computerized rotation task but not on the paper-and-pencil task. Research has indicated that men typically have more experience than women playing computer games (e.g., Dominick, 1984; Greenfield, Camaioni, Ercolani, Weiss, Lauber, & Petrucchini, 1994; Phillips, Rolls, Rouse, & Griffiths, 1995; Barnett, Vitaglione, Harper, Quackenbush, Steadman, & Valdez, 1997). Likewise, men score higher than women on computer games (Greenfield, et al., 1994; Brown, Hall, Holtzer, Brown, & Brown, 1997) and are more confident about their computer skills (Nelson & Cooper, 1997). Thus, the use of a computer-based task may differentially affect men and women because they have different amounts of practice and different ratings of confidence with computers in general. Allowing women to become acquainted with the required manipulations and demands of the computer may provide further evidence for differential improvements on computerized tasks.

While using a computerized two-dimensional rotation task in another study (Roberts & Bell, 2000), we noticed casually that women had a more difficult time with the physical demands of the computerized task. Specifically, some women reported that they felt they could perform the task but had difficulty manipulating the computer correctly. Saccuzzo, et al.'s findings (1996) support that women improved at a higher rate than men on a computerized rotation task. Furthermore, research indicating a male advantage for computer experience and performance (e.g., Barnett, et al., 1997; Brown, et al., 1997) suggests it may be fruitful to examine whether practice effects (such as those documented in Saccuzzo, et al., 1996) were the result of computer familiarization rather than the rotation component of the task.
Here we hypothesized that, among the groups who were not familiarized with computers, usual sex differences should be found. However, among the groups who are familiarized with the specific demands of the computer task, differences between men and women on the mental rotation task should be eliminated.

METHOD

Participants

Forty-four right-handed college students (21 men, 23 women) were recruited through their courses in psychology and were compensated for their participation with extra credit in their psychology class.

Procedure

Many different types of tasks have been used to study sex differences, and males have performed better on the task used in this study (Epting & Overman, 1998; Roberts & Bell, 2000). This particular task was developed to be simple enough to be performed by children (Roberts & Bell, 2000).

Participants were seated in front of a computer and were shown the Overman Mental Rotation Task (Epting & Overman, 1998). This mental rotation task consisted of a “gingerbread man” (later referred to as “figure”) presented at the top of the computer screen, with two choices, one of which matched the original figure, presented at the bottom of the screen. The figures (original and choices) were computer-generated so that each had the same amount of area within its borders. The figure had four possible positions. While either the left or right arm was extended straight out, the opposite arm was either in an “up” or “down” position. During task performance, the participant was asked to match the original figure at the top to one of two figures at the bottom. The original figure was always in an upright position, while the subsequent Choice figures at the bottom were either rotated 90° to the right, 90° to the left (270°), or 180° (for a picture, see Roberts & Bell, 2000). Participants were asked to decide which Choice figure was the same as the original figure. Specifically, the instructions on the computer (and repeated verbally) were to “choose as quickly and accurately as you can.” The entire keyboard was covered except for two keys, one on the right and one on the left side of the keyboard. Participants used the keys to choose the figure that correctly matched the original. Also, the space bar allowed participants to self-paced trials. All trials were randomized so correct responses were equally divided between the right and left choices, and the Choice figures were turned equally often to each side.

To control for differences due to general attention or reaction time, a match-to-sample task with the same stimuli was randomly mixed within the testing session. These trials were the same as above except that the figures at
the bottom of the page were not rotated but remained in a 0° (nonrotation) condition. This match-to-sample task allowed us to measure general reaction time. Assuming that there were no sex differences in reaction time in the nonrotation condition, this task allowed us to ensure that any group effects in rotation were due specifically to mental rotation of objects and not group differences in reaction time.

After two familiarization pretrials, the testing phase was begun. Participants were given two blocks of 16 trials. Only 32 total trials were given because prior data showed that after 30–40 trials, the task becomes one of memory rather than rotation (W. H. Overman, personal communication, September 1998). Performance was measured by number of correct trials, as well as mean latency to respond. Participants' responses were recorded automatically by the computer and saved for later analysis. The computer program was set up so the participant could respond any time after the Choice figures were displayed on the screen. However, the figures disappeared after 2 sec., displaying the message "please make a choice now" to the participant. During the familiarization trials, the participants were told that if they had not answered in 2 sec., that the screen would disappear and they would have to make a choice. After making a choice, the computer screen displayed feedback to the participant to indicate whether the response was correct or incorrect. The participant was then allowed to start the next trial by pressing the space bar. Most participants completed the mental rotation task in two or three minutes.

In the Nonfamiliarization condition, 22 participants (11 men, 11 women) completed the mental rotation task described above. In the Familiarization condition, 22 participants (10 men, 12 women) followed the same procedures, except they were allowed to practice a color-matching task for 32 trials preceding performance on the mental rotation task. The color-matching task performance requirements were motorically identical to those for the rotation task but required no rotation and consisted of matching yellow or blue squares to a sample.

In the computer familiarization color-matching task, participants were seated in front of a computer and were shown a computer screen with three colored squares. This task required matching a sample figure presented at the top of the computer screen, with two choices, one of which matched the original, presented at the bottom of the screen. The figures, original and choices, were squares of the same area and were either blue or yellow. The entire keyboard was covered except for two keys, one on the right and one on the left side of the keyboard. These were used to choose the figure that correctly matched the original. The space bar allowed participants to selfpace trials. All trials were randomized so correct responses were equally divided between the right and left choices. The computer program permitted
response at any time after the squares were displayed on the screen. However, the figures disappeared after 2 sec., displaying the message “please make a choice now” to the participant. Before beginning the task, the participants were told that, if they had not answered in 2 sec., then the screen would disappear and they would have to make a choice.

Results

For all analyses discussed below, see Table 1 for group means and standard errors.

<table>
<thead>
<tr>
<th>Group</th>
<th>Reaction Time</th>
<th>Number Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>SE</td>
</tr>
<tr>
<td>Nonfamiliarization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0° (nonrotation)</td>
<td>1956</td>
<td>213</td>
</tr>
<tr>
<td>90°</td>
<td>2026</td>
<td>155</td>
</tr>
<tr>
<td>270°</td>
<td>1891</td>
<td>143</td>
</tr>
<tr>
<td>180°</td>
<td>2100</td>
<td>135</td>
</tr>
<tr>
<td>Familiarization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0° (nonrotation)</td>
<td>1574</td>
<td>151</td>
</tr>
<tr>
<td>90°</td>
<td>1902</td>
<td>139</td>
</tr>
<tr>
<td>270°</td>
<td>1869</td>
<td>133</td>
</tr>
<tr>
<td>180°</td>
<td>2083</td>
<td>167</td>
</tr>
</tbody>
</table>

Nonrotation (0°) Condition

Reaction time.—To assess the effects of group (Familiarization, Nonfamiliarization) and sex on reaction time, an analysis of variance was performed using reaction time on all trials as the dependent variable. Analyses indicated a main effect of group, with the participants who performed the color-matching task being faster on the rotation task than the participants who did not perform the color-matching task ($F_{1.62} = 12.38, p = .001$). There was no main effect for sex ($F_{1.62} = .62, ns$) or interaction of group × sex ($F_{1.62} = .75, ns$).

Total number correct.—An analysis of variance of the effects of group and sex on the total number of correct responses yielded no main effects or interactions.

Mental Rotation Condition

Reaction time.—To assess the effects of group, sex, and angle of rotation on the reaction time, a multivariate analysis of variance was performed using angle as the within-subjects variable, group and sex as the between-subjects variables, and reaction time on all trials as the dependent variable.
Analyses indicated a main effect of angle (Wilks \(\lambda = .570\), approximate \(F_{2,59} = 14.72, p < .001\)). Planned contrasts indicated a quadratic relationship (\(F_{1,40} = 28.94, p < .001\)) as reaction time at 180° was slower than reaction time at 90° or 270°, but the reaction times at 90° and 270° did not differ. There was also a main effect of group reflecting the participants who performed the color-matching task were faster than the participants who did not perform it (\(F_{1,40} = 5.60, p = .02\)). Finally, there was no group \(\times\) sex interaction (\(F_{1,40} = 3.80, p = .058\)).

Given that the interaction fell short of statistical significance but interested us, simple effects testing was performed anyway. As expected in the nonfamiliarization group sex differences were found, with men responding faster in the 180° (\(F_{1,21} = 6.14, p = .02\)) and 270° (\(F_{1,21} = 4.58, p = .04\)) rotation conditions but not in the 90° (\(F_{1,21} = 1.48, ns\)) condition. In the group who performed the mental rotation task after the color-matching task, sex differences were not found. Men and women did not differ in the 90° (\(F_{1,21} = 1.31, ns\)), 180° (\(F_{1,21} = .04, ns\)), or 270° (\(F_{1,21} = .19, ns\)) rotation conditions.

**Total number correct.**—To assess the effects of group, sex, and angle of rotation on the total number of correct responses, a multivariate analysis of variance was performed using angle as the within-subjects variable, group and sex as the between-subjects variables, and number of correct responses as the dependent variable. There were no main effects or interactions.

**General Discussion**

Analysis of the mental rotation data yielded four main findings. First, since the initial publication by Shephard and Metzler (1971), it has been generally accepted that increases in angle of rotation are associated with increases in reaction time to make decisions about objects. The current data replicate these findings on a two-dimensional rotation task as participants took longer at 180° than at 90° to the right or 90° to the left (270°). Second, previous literature using this same gingerbread man task with adults has shown sex differences favoring men at the 180° condition (Epting & Overman, 1998; Roberts & Bell, 2000). This finding was replicated in the no-familiarization group but not in the group given computer familiarization with the nonrotation color-matching task. Third, there was a main effect of group such that the familiarization group as a whole performed faster than the nonfamiliarization group. Finally, there was an interaction for group \(\times\) sex, which was significant only at \(p = .06\) and so was explored because it appeared to be driven by familiarity on the nonrotation task differentially helping women on the mental rotation task. These results are important to explore further because previous research using a different computerized rotation task had shown that women improve to score like men after practice on the task (Saccuzzo, et al., 1996). The current data suggest that, while practice may affect performance, the crucial component may be practice.
with the computer and not necessarily practice with the rotation task. Further study is required.

Previous literature has indicated that women have less experience performing computer games than men (Dominick, 1984; Phillips, et al., 1995). Likewise, data have indicated that men perform higher than women on new computer games (Greenfield, et al., 1994; Brown, et al., 1997). In light of these data, it may be that the men without familiarization had an advantage over women on the portion of the task that required computer manipulation. Instead of having to perform two cognitively challenging tasks (a rotation task and a computer-manipulation task), the demands of the computer task were simple enough that the men may have been only performing one challenging task (the rotation task). On the other hand, the women may not have been as experienced with computer games and were performing the rotation task plus the computer manipulation task. The superior performance by men was eliminated, however, when the women were given the opportunity to familiarize themselves with the requirements of the computer task. After this, the women were also performing only one cognitively challenging task, the mental rotation task. It appears that once women were more comfortable with the computer and could focus their attention on the rotation task, they performed at the same level as men. One exception was found; for men and women performance did not differ on the 0° (nonrotation) condition in the nonfamiliarization group. We propose that the 0° (nonrotation) condition was not cognitively challenging for either men or women. Thus, the women could allocate all of their resources toward the computer demands of the task, allowing them to perform at rates equal to those of the men.

Three limitations of the current study must be addressed. First, we have no information about the prior computer skills of either of the groups, which may affect the results. However, at least two other studies using this same task with adults showed better performance by men (Epting & Overman, 1998; Roberts & Bell, 2000) when no opportunity for practice on a nonrotation task was provided. This supports the hypothesis that our results are based on the effects of the familiarization task. Second, the current results do not address how different types of practice may differentially affect men and women on other types of mental rotation tasks. The current results can only be applied to this particular computerized two-dimensional rotation task. Finally, there is no way to rule out the possibility that women had more experimental (possibly computer-related) anxiety and that this anxiety was alleviated by familiarization with the experimental situation in general, and not by practice with the computer demands of the task.

The current results suggest that, on this particular computerized two-dimensional mental rotation task, sex differences may be a function of dif-
ferential computer experience or comfort with computerized tasks. Allowing the women to become more comfortable with the procedure and task demands of the computerized task differentially improved their performance compared to that of men. These findings are particularly important because the color-matching task did not have a mental rotation component. These data from a two-dimensional rotation task add valuable information to the literature on sex differences because sex differences appear to be associated with computer familiarization and not the result of the mental rotation component of the task. Replication with a larger sample and a range of task difficulty would be expected to strengthen this observation.

REFERENCES


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Accepted November, 13, 2000.