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AUTHOR	Brownlow, Sheila; Miderski, Carol Ann
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ABSTRACT

Deficits in spatial abilities, particularly Mental Rotation (MR), may contribute to women's avoidance of areas of study (such as chemistry) that rely on MR. Those women who do succeed in chemistry may do so because they have MT skills that are on par with their male peers. We examined MR ability on 12 items from the Vandenberg and Kuse MR test (1978) in a group of male and female students with advanced chemistry background and no college chemistry experience. Students with chemistry experience got more items right and were less likely to omit correct items than those without similar academic background, and men with chemistry training made wrong choices less often than men without chemistry experience. Contrary to most findings in this area, no overall gender differences emerged. These findings suggest that MR skill can either lead women and men to pursue chemistry, or that experience with chemistry may develop and hone that skill. (Contains 29 references.) (Author)

Running Head: GENDER AND COLLEGE CHEMISTRY EXPERIENCE

How Gender and College Chemistry Experience Influence Mental Rotation Ability.

Sheila Brownlow and Carol Ann Miderski

Catawba College

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Abstract

Deficits in spatial abilities, particularly Mental Rotation (MR), may contribute women's avoidance of areas of study (such as chemistry) that rely on MR. Those women who do succeed in chemistry may do so because they have MR skills that are on par with their male peers. We examined MR ability on 12 items from the Vandenberg and Kuse MR test (1978) in a group of male and female students with advanced chemistry background and no college chemistry experience. Students with chemistry experience got more items right and were less likely to omit correct items than those without similar academic background, and men with chemistry training made wrong choices less often than men without chemistry experience. Contrary to most findings in this area, no overall gender differences emerged. These findings suggest that MR skill can either lead women and men to pursue chemistry, or that experience with chemistry may develop and hone that skill.

How Gender and College Chemistry Experience Influence Mental Rotation Ability

Success in fields that require scientific knowledge may be a function of spatial abilities (Alington, Leaf, & Monaghan, 1992), particularly Mental Rotation (MR). MR is the mental transformation of multi-dimensional figures (Voyer, Voyer, & Bryden, 1995), normally involving rotation of three dimensional objects. Research has shown that gender differences in MR are among the strongest documented in the psychological literature, as men generally rotate objects faster (Kail, Carter, & Pellegrino, 1979; Petrusic, Varro, & Jamison, 1978) and more accurately (Bodner & Guay, 1997; Luehring & Altman, 2000; Masters, 1998; Resnick, 1993; Voyer et al., 1995; Walter, Roberts, & Brownlow, 2000) than women. Several factors may attenuate or exacerbate gender differences in MR, such as time allotted for tasks (Resnick, 1993), pressure to perform (Scali & Brownlow, in press), scoring methods used to assess ability (Goldstein, Haldane, & Mitchell, 1990; Scali, Brownlow, & Hicks, 2000), and explicit designation of tasks as "spatial" rather than merely cognitive (Sharps, Price, & Williams, 1994).

One important consideration to understanding the root of male superiority in MR is the role of practice and training in MR ability. Some research indicates that training is more helpful to women than men (Alington et al., 1992); other studies suggest that benefits are equal, leaving men superior on these tasks (Baenninger & Newcombe, 1989; Coleman & Gotch, 1998). Type of training may be important, as women can perform on par with men on spatial tasks if training is on the actual task in question (Kass, Ahlers, & Dugger, 1998).

Practice may be different from training in that it is less formal, and so facility with spatial tasks may be a function of engaging in everyday activities that necessitate its use. Such activities may begin in childhood, perhaps as a result of tacit or explicit parental approval (Oosthuizen, 1991). Many view girls as less able with masculine tasks (Beyer, 1995; Jacobs & Eccles, 1992), many of which develop spatial abilities. Male children and adolescents who use spatial skills during leisure may then take academic courses (such as chemistry, physics, and engineering) that require those abilities (Stericker & LeVesconte, 1982), and their school choices may then lead them to pursue related careers (Newcombe, Bandura, & Taylor, 1983; Voyer et al., 1995). Discouragement (where overt or covert) may lead girls and women to doubt their skills at tasks that require spatial competence (Alington et al., 1992), and such doubt may extend into academic course work necessitating MR (Newcombe et al., 1983). Women's self-doubts about performance are, perhaps, further reinforced and maintained by gender-typed beliefs about the characteristics and abilities of their group, which, when strong enough, can result in underperformance to "meet" the diminished expectation (Brown & Josephs, 1999).

One activity that necessitates the use of MR is chemistry, traditionally the domain of men. Indeed, fewer than 25% of the professionals in the physical sciences in 1997 were women (American Psychological Association, 2000). Success in chemistry--particularly organic chemistry--is related to MR ability (Bodner & Guay, 1997; Bodner & McMillen, 1986). Students with good MR skill do well in chemistry, and MR ability increases as chemistry exposure intensifies (Coleman & Gotch, 1998). The link between chemistry and MR skill may be a function of problem-solving approaches, as those better at MR use a holistic rather than algorithmic approach (Carter, LaRussa, & Bodner, 1987), allowing them to perform better on novel tasks, multi-stage problems, and on problems that involve 3-dimensional items. A rote, algorithmic approach to problem-solving in both science and math is typically preferred by women (Kimball, 1989), which may partially account for gender differences in both MR ability and chemistry performance.

Clearly, several factors influence women's ability to perform spatial tasks and their propensity to pursue science. Those women who have good MR abilities may be more efficacious in science courses such as chemistry, and may therefore persist in the field. We examined gender differences in MR in students with advanced chemistry training and with no college chemistry background. We predicted that men would outperform women when neither had background, but that there would be no gender differences in MR among those who had extensive chemistry background. We also studied whether different scoring methods (one of which deducted points for items omitted, another which penalized incorrect choices) influenced the pattern of findings, as women and men may take different approaches to solving MR problems which could result in different types of errors made.

Method

Participants

Students ($\underline{N}$ = 44; 20 men, 24 women) enrolled in either Organic Chemistry or a psychology course participated. Participants from Organic Chemistry ($\underline{n}$ = 22; 14

women, eight men) and psychology (n = 22; 10 women, 12 men) each received course credit for their service. None of the psychology students had taken chemistry and none were majoring in a natural science; students in organic chemistry had taken at least two chemistry courses.

Stimuli

Students completed 12 MR items from the Vandenberg and Kuse Mental Rotation Test (Vandenberg & Kuse, 1978). The task included six three dimensional figures; a target figure on the left side with four other figures on the right, two of which were rotated versions of the target figure. The participants' job was to find any figure that was a rotated version of the figure on the left, although we did not inform them that there were two rotated versions to each figure (and, hence, 12 total figures that should be circled).

Scoring

Several measures of MR performance were taken, including task time, number correct (raw score), raw score minus correct items omitted (errors of omission), and raw score minus items improperly chosen (errors of commission). These varied scoring methods were employed because research (e.g., Goldstein et al., 1990; Scali et al., 2000) has shown that different techniques produce different patterns of gender differences in MR performance.

Procedure

Students participated individually after being told that they would be tested on their MR abilities. Each completed the MR activities, as well as other activities not pertinent to this study, after receiving full instructions. Participants realized that they were being timed, as they had to ring a bell to signal both the start and completion of their work. After completing the study, students were debriefed and dismissed.

Results

Measures of performance (time-to-complete, raw score, and scores correcting for errors of omission and commission) were separately entered into 2 (Gender) x 2 (Organic Chemistry Experience) ANOVAs. The means from these analyses are located in Table 1.

There were no main effects of gender in any analysis, all $Fs(1, 40) \leq 2.12$, ns. Those with organic chemistry background performed better when raw and corrected for omissions scoring were used, both $Fs(1, 40) \geq 4.25$, both $ps < .05$. An interaction emerged when scoring for items incorrectly chosen, $F(1, 40) = 5.23$, $p < .05$. Post-hoc Scheffé tests showed that men who had experience with chemistry ($M = 9.75$) performed better than their peers who had no experience ($M = 3.92$), whereas ability of women was unaffected by experience ($Ms = 5.70$ and 4.71 for no experience and experience). No other main effects or interactions on these measures were significant.

Discussion

These data demonstrate that men and women with chemistry background are better at MR than their peers who lack similar exposure, suggesting that training and practice in MR may be beneficial to both men and women, or that students who are better at MR are more likely to choose, and persist at, chemistry. Those with relevant background performed better in that they got more items right, and they were less likely to omit correct items. Men without science background made more errors by choosing incorrect items than men with science background, although women varying in chemistry background did not show similar performance disparities.

Our results are consistent with those of Bodner and his colleagues (Carter et al., 1987; Pribyl & Bodner, 1987), whose studies of spatial skills in students with general and organic chemistry background have revealed relative parity in the performance of men and women on MR tasks. We used a different set of MR items than was employed in those studies (the Purdue Visualization of Rotations Test; Bodner & Guay, 1997), further supporting the idea that gender differences in MR may not be strong when people have extensive background in the sciences, particularly chemistry. One study of chemistry students' MR abilities does not support ours. Coleman and Gotch (1998) found consistent gender differences in MR among chemistry students, whom they followed in classes over the course of several years, through many different types of chemistry courses. Those researchers did find that the gender gap has decreased over the past 20 years, with men's abilities declining toward the level of women's. However, Coleman and Gotch's findings are based on a selected sample (12) of Piagetian spatial items that are not used widely in MR research, and thus results may not be analogous.

Contrary to most research (e.g., Bodner & Guay, 1997; Halpern, 1986; Masters, 1998; Resnick, 1993; Voyer et al., 1995) men were not uniformly better than women at MR. Varied scoring techniques did not alter the gender-related results (cf. Masters, 1998; Scali & Brownlow, in press). The women from the chemistry courses were told explicitly that they would be rotating items, which has created in other populations of women performance anxiety, resulting in underperformance (see Brown & Josephs, 1998; Sharps et al., 1994). Moreover, although no time limits were given to the students, they knew they were being timed, and salient time constraints can also increase performance anxiety among women (Resnick, 1993). Despite these conditions, women--with and without background in science--performed statistically on par with men. Our small sample size makes it difficult to determine why the predicted gender difference did not emerge and to examine other factors specific to the sample that may have influenced the gender-linked MR findings.

The superior performances of chemistry students, regardless of gender, indicate that training and practice may be key to MR performance. Chemistry, particularly organic chemistry, requires MR skills (Bodner & Guay, 1997). Moreover, students in upper-level courses have shown obvious success in their training (by virtue of continuance in the program), perhaps because they either naturally employ, or have learned to employ, holistic approaches to problem-solving, which lead to success in the field (Carter et al., 1987). Whether the students who chose chemistry and persevered at it were more skilled at this problem solving approach to start, or whether they acquired the skill through training is not known. Research to address this question is in progress.

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Table 1

Mental Rotation Performance as a Function of Organic Chemistry Experience and Gender

	Organic Chemistry Experience: No			Organic Chemistry Experience: Yes		
Gender	Men (n = 12)	Women (n = 10)	Mean (n = 22)	Men (n = 8)	Women (n = 14)	Mean (n = 22)
Time (in s)	173.34	213.99	191.82	169.09	193.67	184.73
Raw Score	6.25	7.90	7.00_a	10.00	8.79	9.23_b
Corrected for Errors of Omission	-.42	3.60	1.41_a	8.00	5.57	6.45_b
Corrected for Errors of Commission	3.92_a	5.70	4.73	9.75_b	4.71	6.55

Note. Different subscripts within rows indicate that numbers differ at the .05 level. Score ranges are: Raw (0-12), Corrected/Omissions (-12 to 12), and Corrected/Commission (-48 to 12).

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