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How Important Is the Digital Divide? The Relation of Computer and Videogame Usage to Gender Differences in Mental Rotation Ability

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Researchers interested in the associations of gender with spatial experience and spatial ability have not yet focused on several activities that have become common in the modern digital age. In this study, using a new questionnaire called the Survey of Spatial Representation and Activities (SSRA), we examined spatial experiences with computers and videogames in a sample of nearly 1,300 undergraduate students. Large gender differences, which favored men, were found in computer experience. Although men and women also differed on SAT scores, gender differences in computer experience were still apparent with SAT factored out. Furthermore, men and women with high and low levels of computer experience, who were selected for more intensive study, were found to differ significantly on the Mental Rotations Test (MRT). Path analyses showed that computer experience substantially mediates the gender difference in spatial ability observed on the MRT. These results collectively suggest that the "Digital Divide" is an important phenomenon and that encouraging women and girls to gain spatial experiences, such as computer usage, might help to bridge the gap in spatial ability between the sexes.

KEY WORDS: gender differences; spatial ability; mental rotation; computer experience.

Spatial ability can be described as skill in representing and transforming symbolic or nonlinguistic information through space. It is important for functioning in a wide variety of areas, from everyday tasks such as installing electrical equipment to more technical areas, such as surgery. Spatial ability shows wide individual differences, including an advantage for men/boys over women/girls, especially on tasks of mental rotation (e.g., De Lisi & Cammarano, 1996; Linn & Petersen, 1985; Masters, 1998; Moody, 1997; Nordvik & Amponsah, 1998; Stumpf & Eliot, 1995; Vandenberg & Kuse, 1978; Voyer, Voyer, & Bryden, 1995). To understand these individual differences in ability, it is important to know if and to what extent spatial activities or experiences may foster them. Such knowledge can help to shape spatial experiences in order to improve spatial abilities and to close the performance gap between men and women.

Many studies have shown that experiential factors, including computer and videogame usage, are related to spatial skill, such as mental rotation (MR; De Lisi & Cammarano, 1996; De Lisi & Wolford, 2002; Duesbury & O'Neil, 1996; Larson et al., 1999; McClurg & Chaille, 1987; Okagaki & Frensch, 1994; Rizzo et al., 1999; Roberts & Bell, 2000; Saccuzzo, Craig, Johnson, & Larson, 1996; Sims & Mayer, 2002). Likewise, studies that were focused on the impact of training with computers (including videogames) have shown increases spatial ability. For instance, children who have had videogame training with age-appropriate spatial videogames have been shown to outperform their age-matched peers on various spatially related tasks (De Lisi & Wolford, 2002; McClurg & Chaille, 1987; Subrahmanyam & Greenfield, 1996). Computer videogame training

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with older populations has also yielded increases in spatial performance (De Lisi & Cammarano, 1996; Greenfield, Brannon, & Lohr, 1994; Joseph & Willingham, 2000; Okagaki & Frensch, 1994).

The facilitation of computer experience through training may have differential effects on men's and women's spatial performance. Men not only perform at higher levels than women on tests of spatial ability, but they also tend to have had more spatial experiences (Baenninger & Newcombe, 1995; De Lisi & Cammarano, 1996; Grimshaw, Sitarenios, & Finegan, 1995; Nordvik & Amponsah, 1998; Tracy, 1990; Voyer, Nolan, & Voyer, 2000), including more computer and videogame usage (De Lisi & Cammarano, 1996; Dominick, 1984; Greenfield et al., 1994; Morlock & Yamanaka, 1985; Peters et al., 1995; Subrahmanyam & Greenfield, 1996). It has been suggested that those individuals with lower levels of computer or videogame experience, such as women, may have more room for improvement, and thus may improve more on spatial tasks as a result of computer use (Alington, Russell, & Monaghan, 1992; Gagnon, 1985; Rizzo et al., 1999; Saccuzzo et al., 1996; Subrahmanyam & Greenfield, 1996). Elevated performance on spatial tasks has even been elicited by simply facilitating familiarity with computers (Larson et al., 1999; Roberts & Bell, 2000). However, some studies have shown that both men and women can benefit from computer experience, such as videogame playing (De Lisi & Cammarano, 1996; Dorval & Pepin, 1986; Larson et al., 1999; Lawton & Morrin, 1999; McClurg & Chaille, 1987; Okagaki & Frensch, 1994; Subrahmanyam & Greenfield, 1996). Thus, it is reasonable to conclude that computer usage (including videogame playing) can increase spatial aptitude in both men and women, though perhaps rates of improvement may differ.

Many have become concerned about what has been termed the "Digital Divide." According to Digital Divide theorists (Akhter, 2003; Barron, 2004; Drori & Jang, 2003; Livingstone, 2003), increasing rates of computer facilitation (related to both business and personal use) are deepening the economic and educational rift between those who use computers regularly and those who do not or cannot (due to lack of resources). For instance, roughly 429 million people globally are on-line, but 41% of those people reside in North America; only 4% are in South America (Global Internet Trends, 2001). The Pew Internet and American Life Project (2001) reported that 57% of those not on-line have no intention of acquiring the capability. Thus, as technology and industry continue to grow, those who are unable to, or uninterested in, taking advantage of the internet may be left behind.

Existing work does not, however, well document the extent of gender differences in computer experience. Although many people believe that men have more videogame and/or computer experience than women do, according to the 2000 U.S. Census (Global Internet Trends, 2001), women have marginally surpassed men in internet access and usage (51–49%, respectively). Perhaps the motivation behind computer use and the application of computer software is different for men and women. For instance, studies show that women report less confidence and more anxiety with usage of spatially-related materials and computer software (De Lisi & Cammarano, 1996; James & Greenberg, 1997; Lawton, 1994; O'Laughlin & Brubaker, 1998). This difference may also be related to the fact that both men and women regard many spatial activities (in general) to be masculine in quality (Klatzky, Golledge, Loomis, Cicinelli, & Pellegrino, 1995). Likewise, much of the current computer videogame genre is geared toward masculine interests, such as aggression or violence (Hess & Niura, 1985; Provenzo, 1991; Rushbrook, 1986). Thus, girls and women may be less likely to engage in spatially related computer activities, such as videogame playing.

In summary, it is clear that gender differences in spatial ability exist, and these differences may be related to differential levels of computer experience, especially those computerized activities that are most spatial in nature (e.g., videogame playing). In this study, we empirically assessed gender differences in computer and videogame usage in a diverse college population using the Survey of Spatial Representation and Activities (SSRA). In addition, we studied Mental Rotation Test (MRT) performance as a measure of spatial ability in subgroups who scored "high" or "low" on the SSRA. Thus, the major goal of this study was to assess to what extent gender differences in computer and videogame usage may mediate the gap between the sexes in spatial ability, namely mental rotation ability.

METHOD

Participants

Nearly 1,300 undergraduates (370 men, 908 women) enrolled in an Introductory Psychology course (across three semesters) at Temple University completed the SSRA. Participants were of diverse ethnic backgrounds: 54% European American; 22% African American; 10% Asian American; 5% Hispanic; and 9% other. Participants' academic majors were 17% Education; 11% Psychology; 8% Nursing; 8% Journalism; 5% Biology; 4% Kinesthesiology; 2% each Communication, Film, and Social Work; 1% each Music and Physical Therapy; and 20% Undeclared. Other majors were less than 1% each. Participants' ages ranged from 17 to 44 years, with a mean of 18.23 years ($SD = 1.83$).

Each semester, two groups of students were identified as "high in spatial experience" (those who scored within the upper 15% on the SSRA) or "low in spatial experience" (those who scored within the lower 15% on the SSRA) on the SSRA, and these students were invited to return for testing on the MRT. The range of SSRA scores was from 0 to 18 points. High spatial experience participants (83 women, 167 men) obtained scores of 15 to 18, whereas low spatial experience participants (218 women, 19 men) obtained scores of 0–3. Men and women were over- and underrepresented, respectively, in high and low spatial experience groups relative to the base rates within the Introductory Psychology classes. Men made up 29% of the whole sample, and women made up 71%, but the high spatial experience group was 59% men and 41% women, whereas the low spatial experience group was 13% men and 87% women. The distribution of gender in the high and low experience groups was significantly different from the base rates in the Introductory Psychology population, $\chi^2(2, N = 1765) = 208.79, p < .001$. Across groups, distributions of SSRA and SAT scores were normal.

Materials

The Survey of Spatial Representation and Activities (SSRA), which was designed for this study, is a 17 item questionnaire that includes both open-ended and multiple-choice questions. The first five questions gather participant demographic information, SAT scores, involvement in recreational sports and game activity, and computer/videogame preferences (Section A; see Appendix). There are then 12 questions that assess frequency of computer, videogame, and map usage as well as perceived efficacy related to their usage (Section B). For this study, answers to the SSRA questions related to ownership of computer games and artwork software, ownership of game systems, frequency of game system usage, and how skilled individuals believed they were at using/playing videogames/game systems were analyzed. Factor analyses showed these computer/videogame experience questions to be grouped together (and apart from other questions that assessed map usage; see Table I). A scree plot showed two factors to be retained (computer/videogame experience questions and map questions). Rotated component matrices showed that each of the sections loaded on the two different factors. Again, here we were only concerned with the computer/videogame questions. Other questions regarding computer usage in general were not analyzed due to the general nature of "computer usage" responses, which may have included relations to nonspatial word processing. Likewise, other portions of the SSRA questionnaire were not analyzed in this study, but may be applied for future studies.

Table I. Factor Analysis Rotated Component Matrix for SSRA Factors (Computer and MapVariable)

	Component	
Variable name	1	2
Comp 1	.501	
Comp 2	.684	
Comp 3	.802	
Comp 4	.624	
Map 1		.775
Map 2		.780

Note. Comp 1–4 represents the loading for the four computer experience questions and Map 1–2 represents the loadings for the 2 map questions which were not included in the present analysis.

Across all participants, a coefficient alpha of .57 was found as the level of reliability for computer and videogame experience on the SSRA. Although somewhat low (acceptable levels should reach .70; Nunnally, 1967), it should be considered that very few items concerned estimations of computer and videogame usage; further refinements may produce higher levels.

Scores related to these questions (on Likert-type scales) allowed us to place participants into high or low spatial experience groups. A minimum score of zero and a maximum score of 18 points on these measures was obtained (as some SSRA questions could earn more than one point).

The Mental Rotations Test (MRT; Shepard & Metzler, 1971; Vandenberg & Kuse, 1978) is a spatial task that involves the ability to imagine how objects will appear when they are rotated in 2- or 3-dimensional space. The MRT has 20 items (five sets of four items each). Each item consists of a "criterion" figure (composed of radials of 10 connected cubes) presented to the left and four alternatives to match on the right. Two of the alternatives are the same (yet rotated at different angles about the vertical axis); another two are distracters (one mirror image and another different criterion figure). Participants were given 3 min for the first 10 problems and another 3 min for the remaining 10 problems (for a total of 6 min for the 20 item test). The maximum score on the test was 40 points. Points were given for each correct response.[3]

Design and Procedure

At the beginning of each semester, potential participants were given the SSRA as part of a packet of psychological research questionnaires administered during their first week of classes. The packet of questionnaires was completed to fulfill mandatory requirements for research credit. Students had approximately 3 weeks to fill out all questionnaires within the packet and return them to the Psychology Department (return rate was approximately 91%). Although the entire packet required some time to go through, the SSRA itself only took approximately 5 min to complete (according to pilot trials). Once packets were returned, questionnaires were separated and individually scored.

Those who scored "high" or "low" in spatial experience were contacted and invited to participate in a further study, in which they would get paid for their participation. Those who agreed to participate were given the MRT (either individually or in small groups). Individuals were given instructions (including several practice items) and then were timed for completion on the MRT.

RESULTS

Gender Differences in Spatial Experience

One thousand two hundred and seventy-eight participants were screened across three semesters. The relationship between gender and spatial experience was examined by analyses of variance (ANOVAs). The difference in computer/videogame experience between men and women, as indicated by SSRA scores, was significant, $F = 169.52, p < .01, \eta^2 = .12$; the mean was 9.38 ($SD = 3.87$) for men and 6.24 ($SD = 3.91$) for women. The size of this effect is small.

We also needed to consider whether this gender difference in spatial experience was secondary to a gender difference in academic achievement, because there was a significant gender difference for total SAT scores, $F = 7.54, p < .01, \eta^2 = .01$, though this effect is also small. The SAT score mean for men was 1069 ($SD = 204.47$), and it was 1000 for women ($SD = 457.85$). In addition, SAT scores tended to be related to high or low levels of computer experience on the SSRA. Individuals classified as high and low in computer experience scored significantly differently on the SAT, $F = 9.20, p < .01, \eta^2 = .01$. This effect is small; high experience participants obtained a mean SAT score of 1094 ($SD = 658.54$), and low experience participants obtained a mean SAT score of 976 ($SD = 268.54$). Gender differences in spatial experience did not, however, appear to be secondary to gender differences in SAT scores. A univariate analysis of variance, with SAT covaried out, showed gender to have a significant relation to SSRA scores, $F = 145.41, p \leq .01, \eta^2 = .11$, though this effect is again small.

MRT Performance

Analyses of variance also showed that gender differences in spatial experience were related to MRT performance; of the 180 participants who took the MRT (119 women, 61 men), there was an expected gender difference in performance, $F = 28.14, p \leq .01, \eta^2 = .14$, though this effect is small. Men scored an average of 23 of a possible 40 on the MRT ($SD = 7.14$), and women scored an average of 17 of a possible 40 on the MRT ($SD = 5.71$). People with high and low computer experience on the SSRA also scored significantly differently on the MRT, $F = 44.66, p \leq .01, \eta^2 = .20$, and this effect was larger than the effect for sex, though still small in magnitude. High computer experience individuals scored an average of 22 of a possible 40 on the MRT ($SD = 6.62$) and low computer experience individuals scored an average of 16 of a possible 40 on the MRT ($SD = 5.35$).

[3]Scores on the MRT can be calculated with 20 possible points (one point if both items are correct in each question; Talbot & Haude, 1993; Vandenberg & Kuse, 1978; Vandenberg, Kuse, & Vogler, 1985) or with 40 possible points (one point given per correct item, two per question) (Casey, Colon, & Goris, 1992; McClurg & Chaille, 1987). A meta-analysis of gender differences among 35 different studies using the MRT showed significant gender differences with both scoring methods (Voyer, Voyer, & Bryden, 1995).

Correlations showed that these differences in mental rotation ability were not simply due to differences in academic achievement as measured by the SAT. MRT performance and SAT score were not significantly related, $r = .06, p = .46$.

As noted above, an observed relation of gender to both MRT ability and computer experience was found. We considered the correlations of these effects within sex, to discover if the relationship between MRT ability and computer experience differed among the men and women. After we controlled for sex, SSRA, and MRT performance remained significantly correlated, $r = .28, p < .01$. Within both men, $r = .29, p < .05$, and women, $r = .27, p < .01$, computer experience was significantly correlated with MRT performance. Hence, the relation of spatial experience to spatial performance on the MRT was not due simply to being male or female.

Path Analyses

A structural equation model was used to examine the hypothesized relations among sex, MRT performance, and spatial experience. Goodman's test statistic was used to examine the statistical significance of indirect (mediated) effects (Goodman, 1960; MacKinnon, Warsi, & Dwyer, 1995). The direct effect of sex on MRT performance was significant, $\beta = -.39, p < .05$, and it explained roughly 40% of the variance. This beta value was negative; because of the way gender was scored in our analysis (men were given a lower numerical value than women for the assignment of gender as a variable), this signifies that being male is associated with higher MRT scores. Indirect path analysis showed the effect of gender on MRT performance to be partially mediated by computer experience (SSRA score), which when added to the model, reduced beta levels for the effect of sex to $\beta = .21, p < .01$ (see Fig. 1), which explained roughly 20% of the variance. This beta value had become positive, meaning that the mediation of computer experience had a bigger impact on women; women with computer experience score higher on the MRT. Introducing computer experience as a predictor, thus, had less effect on men because, according to our sample, most men already had large amounts of computer experience (whereas women were more variable). Indirect pathways for the effect of gender on computer experience, $\beta = -.57$, and the effect of computer experience on MRT performance, $\beta = .32$, were both significant ($p < .01$). Both direct and indirect path analyses of gender to mental rotation performance fit the data well.[4]

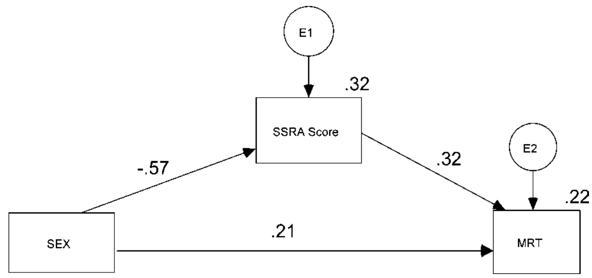

Fig. 1. Path analysis of computer experience as a mediator of gender on mental rotation ability.

DISCUSSION

The results of this study show a substantial difference in how much the men and women in our sample use computers and videogames, and indicate what effects this may have on differences in spatial ability, such as MRT performance. Previous speculation about a Digital Divide is reinforced by our observation, especially when coupled with the fact that spatial experience of this kind was shown to behave as a mediator of the observed gender difference in mental rotation ability, especially for women. Our correlational study cannot rule out self-selection of videogame and computer use by high spatial-ability individuals as an explanation of the data. However, coupled with previous experimental work that shows that the facilitating spatially related computer experience (through spatial training) leads to increases in spatial ability for both genders (Baenninger & Newcombe, 1989; De Lisi & Cammarano, 1996), a strong case can be made for the relevance of gender differences in the use of digital media in creating, maintaining, or even increasing the size of any preexisting gender differences in mental rotation ability.

Motivational factors may underlie differences in spatial experience, namely computer experience. It is likely that men and women commonly use computers for different tasks and interact differently with computer software and videogames, which may foster differential skill acquisition and maintenance. More research is needed to understand specifically why individuals differ in computer usage

[4]Several fit indices in structural equation modeling can be used to evaluate model fit of proposed models to data. According to CMIN, RMSEA, CFI, and AIC values, the path analysis without the mediating effects of computer experience explained the relation of gender to MRT performance slightly better (although the mediating path analysis also fits the data well).

and gaming and how we can increase participation and motivation for spatial activity with digital media (e.g., computers), especially girl's and women's participation.

In line with Digital Divide theories (Barron, 2004; Cooper, 2003; Drori & Jang, 2003), if boys and men continue to choose to be involved in computer experiences that foster spatial ability, and girls and women do not, the gap in spatial performance may continue to grow. Training studies could help to determine if exposing girls and women to spatially related experiences (such as nonsexist computer videogames) would enhance growth in spatial ability, perhaps even to the level of higher spatially experienced boys and men, and, thus, potentially close the gender gap in performance.

Appendix

Survey of Spatial Representation and Activities (SSRA)

Name:______________________________________Date:______________

Gender (please circle one): M / F Age:________________________

Phone # (including area code): ( ) ______________________________

Email address:____

Major:__________________________Minor (if any):____________________

SECTION A

1. Have you taken any math or science related courses within the past year (circle one)?
Yes / No

If so, how many of each type? Math____________Science____________

2. What were your SAT scores (try to average to the best of your knowledge)?

SAT Math____________SAT Verbal______________________

3. What type of computer software do you own or use? (for each, list the top three titles you most frequently use)?

a. Word processing (1)____________(2)______________(3)____________

b. Statistics programs(1)____________(2)______________(3)____________

c. Games (1)____________(2)______________(3)____________

d. Art/drawing (1)____________(2)______________(3)____________

e. Other? ____

4. Do you participate in any extra-curricular sports? (circle all that apply; if none, leave blank)

Professional sports College-level sports Intramural team

Other (please list)?____

5. Do you own any video game systems? (circle all that apply; any version of these systems)

Nintendo Playstation Sega X-Box

Other?____

SECTION B

1. Do you own a computer ? **A** - yes
B - no

2. What brand computer do you own/use (darken all that apply)?

A – IBM

B – MAC

C – Other

3. How long have you owned / been using a computer?

A – less than a month **D** – 1 to 3 years

B – 1 to 6 months **E** – 3 or more years

C – 6 mos. to 1 year

For question #'s **4** through **9**, please use the following rating scale:

A – daily **D** – 1 to 2X in 6 mos.

B – weekly **E** – 1 to 2X a year

C – 1 to 2X a month **F** – once every few years to not much at all

4. How often do you use a computer?

5. How often do you purchase software?

6. How often do you use the internet?

7. How often do you use any game systems (Nintendo, Sega, etc.)?

8. How often do you play boardgames?

9. How often do you use maps?

For question #'s **10** through **12**, please use the following rating scale:

A – Very skilled **C** – Not very skilled

B – Moderately skilled **D** – No skill

10. How proficient or skilled do you believe you are at using maps?

11. How proficient or skilled do you believe you are at using computers?

12. How proficient or skilled do you believe you are at playing video games?

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