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Female advantage for spatial location memory in both static and dynamic environments

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Abstract

A female advantage has previously been found for spatial location tests of object memory. Previous studies have used static, 2-D tasks to test this advantage. This study used a computerized adaptation of the game Concentration to test object location memory in both a static and dynamic array of 24 pairs of line drawings. The dynamic version of this task was used to better reflect the dynamic real world in which we usually use object location memory. Consistent with previous research, we observed a female advantage. This advantage was found to a similar extent in both the static and dynamic versions of the task. The female advantage for object location memory is a concrete advantage in spatial cognition that females show on the Concentration Task, regardless of the nature of the presentation environment.

1. Introduction

Numerous studies have demonstrated that there are sex differences in cognitive abilities. In general males have been found to outperform females on tasks of spatial ability and mathematical reasoning, whereas females have been found to outperform males on tasks of verbal ability (for review see Halpern, 2000; Kimura, 1999). However, there are exceptions to these general classifications of cognitive ability. Though spatial ability is generally thought to show a male advantage, it can be further divided into different subdivisions of spatial ability that typically exhibit either male or female advantages dependent on the task. For example, males have been found to perform better at spatial tests of mental rotations and embedded figures, and females have been found to perform better on tasks of spatial representation, such as recall of landmarks and recognizing displaced objects (Galea & Kimura, 1993; Kimura, 1996; Vandenberg & Kuse, 1978).

The fact that there is a subdivision of spatial ability in which there is a female advantage is quite striking considering that the male advantage is quite reliable across cultures (Mann, Sasanuma, Sakuma, & Masaki, 1990), and even across species (for review see Sherry, Jacobs, & Gaulin, 1992). Although a male advantage has been shown on spatial tasks across species, humans are rarely tested on spatial tasks in a way that is similar to animals. Human spatial ability is typically assessed using 2-D, static, paper and pencil tests (e.g., Galea & Kimura, 1993; Moffat, Hampson, & Hatzipantelis, 1998) whereas non-human spatial ability is typically assessed using the emersion of the non-human animal into real mazes or routes to be learned. In other words, the way that we assess animal spatial ability is more like what they would encounter in the real-world, whereas the way we assess human spatial ability is through a flat, 2-D representation of the 3-D real-world. Furthermore, unlike the real-world, the stimulus arrays in pencil and paper tasks are not dynamic; they do not change with the movement of the observer.

In this study we used a spatial cognition test of object location memory, which females usually excel at (Eals & Silverman, 1994). McBurney, Galin, Devineni, and Adams (1997) had previously used the game *Memory* (also known as Concentration) to test object location memory in humans, and also found that females did outperform males. However, their version of the task was static, and therefore not very representative of the real world, which is dynamic. We had participants

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perform the Concentration Task on a computer in both dynamic and static conditions. In the dynamic condition a distortion effect was applied to the array, which enlarged the item the cursor was on, while making the surrounding items smaller. This gave the illusion of movement around the screen. The purpose of such an effect was to create a dynamic environment in which the typically static game of Concentration could be played, thus creating a test of object location memory that was more representative of the real world. Through using this dynamic version of Concentration, we tested whether or not there would still be a female advantage for object location memory.

2. Methods

2.1. Participants

Thirty-one females and 31 males were recruited from the University of Saskatchewan introductory psychology participant pool for course credit. The mean age of the females was 19.4, and the mean age of the males was 19.7. Most participants were right handed, ($n = 60$, 1 female left-handed, 1 male left-handed) as assessed by questionnaire (Elias, Bryden, & Bulman-Fleming, 1998).

2.2. Task

Concentration Task. The object location memory test was a computerized version of the game Concentration. There were 48 yellow squares (1.25 cm^2, arranged in a 7×7 grid with the central square blackened and unselectable), each of which concealed a picture (a total of 24 pairs). For each trial, participants chose a yellow square, with the use of a mouse, to reveal a picture. Then they had to choose another yellow square in order to try and find the matching picture. Only two squares could be chosen per trial. After two pictures had been successfully matched, they would become black squares, identical to the middle one, and they would no longer be selectable. Participants could return to previously viewed squares as many times as they wished, as long as they remained unmatched. The computer recorded the total number of trials (minimum = 48 trials), the time per session, and the average number of times each image was revealed. The task was performed on a Pentium II computer (450 MHz) with a 19 in. monitor.

The distortion effect was created using an information visualization technique that is known as a "fisheye" view. The fisheye is designed to show both local detail and global context in the same view. It provides a user-controlled focus point for indicating which part of the data is to be shown in detail. The fisheye view employed in this experiment is that defined by Sarkar and Brown (1992). The focus of the fisheye magnifies the selected item, and demagnifies unselected items (although they are still present and visible on the screen). Moving the focus of the fisheye thus produces both movement and distortion of the items not selected. Importantly, the relative positions of the items do not change.

2.3. Procedure

All participants were tested individually by the same experimenter. The testing session began with the completion of a questionnaire containing questions regarding demographic information, laterality, and computer skill (the average number of hours/week spent on the computer, and a subjective judgment of participant's own mousing skill). Computer skill was taken into account because the entire testing session (aside from the questionnaire) took place on the computer. A Likert scale was used by the participants to rate their own skill level at using a mouse. Following completion of the questionnaire, participants performed either the static or dynamic version of the Concentration Task. Then they were given an unrelated distractor task. Then the participants were given a second Concentration Task; participants were presented with the version that they had not experienced initially. The order of the Concentration Tasks (static or dynamic) was counterbalanced across participants. Different pictures were used for the first and second tasks, and the order in which the pictures were laid out in the matrix was random. Finally, the participants responded to questions regarding how they went about doing the Concentration Task.

3. Results

Differences between the groups were analyzed using a 2×2 repeated-measures analysis of variance (ANOVA) using sex (male, female) as a between-subjects variable and level of distortion (no distortion, distortion) as a within-subjects repeated measure. The dependent measure was the efficiency for each version of the Concentration Task, which was calculated as: the total number of trials/total time (s).

Results indicated that there was no significant main effect of the level of distortion, $F(1,60) = 0.384$, $p = .538$, nor was there a significant interaction between the level of distortion and sex, $F(1,60) = 0.181$, $p = .672$. However, there was a main effect of sex, $F(1,60) = 8.067$, $p = .006$, indicating that males were significantly less efficient ($M = 0.692$, $SD = 0.101$) than females ($M = 0.611$, $SD = 0.120$) when completing the task, regardless of the level of distortion (keep in mind that a high score indicates worse performance than a low score). In addition, a separate ANOVA indicated that there was no significant sex difference in the total number of times that a square was visited, $F(1,60) = 0.107$, $p = .745$ (male $M = 2.973$,

$SD = 0.607$; female $M = 2.923$, $SD = 0.591$). As a covariate, neither mousing ability, $F(1, 60) = 0.149$, $p = .701$ (male $M = 5.770$, $SD = 0.990$; female $M = 5.970$, $SD = 0.980$) nor the average number of hours/week spent on the computer, $F(1, 60) = 1.854$, $p = .178$ (male $M = 6.770$, $SD = 5.570$; female $M = 6.940$, $SD = 5.060$), significantly influenced the results of the Concentration Tasks (with or without distortion).

4. Discussion

The results of this study replicate the results of McBurney et al. (1997), with a novel computerized version of Concentration. Furthermore, a female advantage in object location memory was observed on the Concentration Task, regardless of whether it was static or dynamic. In using the dynamic version of the task we were attempting to test object location memory in a way that was more representative of reality than the traditional static version of the task. The dynamic version of the task required the participants to remember the relative position of the pictures with regards to each other, because the absolute position of the pictures appeared to be constantly changing as the participant went about the task. In this respect this task was more representative of object location memory in a real-life environment because as we look around our environment and move through it, wherein we perceive the absolute position and size of object appears to change, whereas what the object is close to (relative position) stays the same. The findings of this study suggest that the female advantage shown for object location can be observed in both static and dynamic environments.

The McBurney et al. study (1997) differed from this study in one other way aside from the computer format and distortion effect; in their study the cards were "on the table in a quasi-random order and an irregular pattern" (169). In our study the pictures were presented in a random order, however they were arranged in a very geometric pattern, a 7×7 grid. This Euclidean design may have helped the males perform the object location memory task better than they would have if it had been presented in a random order, as it has been found that males benefit from Euclidean features on some tasks (Galea & Kimura, 1993; Miller & Santoni, 1986). However, this should have, if anything, resulted in a bias that would have worked against the observation of a female advantage.

In future, this computerized version of the Concentration Task will be given to participants both with and without distortion, however the pictures will be presented in an irregular, non-Euclidean pattern, to see if the female advantage will be even greater. As well, future research will examine whether this female advantage on the Concentration Task will prevail if the task is presented in extrapersonal space, as opposed to the intrapersonal realm in which almost all spatial tests are done in. Other future testing will involve the use of the distortion effect, however, it will be applied to other tests of object location memory, such as the Eals and Silverman incidental object location memory task, to see if the female advantage will prevail.

References

Eals, M., & Silverman, I. (1994). The hunter-gatherer theory of spatial sex differences: Proximate factors mediating the female advantage in recall of objects arrays. *Ethology and Sociobiology, 15*, 95–105.

Elias, L. J., Bryden, M. P., & Bulman-Fleming, M. B. (1998). Footedness is a better predictor than is handedness of emotional lateralization. *Neuropsychologia, 36*, 37–43.

Galea, L. A. M., & Kimura, D. (1993). Sex differences in route learning. *Personality and Individual Differences, 14*, 53–65.

Halpern, D. F. (2000). *Sex differences in cognitive abilities* (3rd ed.). Mahwah, NJ: Erlbaum.

Kimura, D. (1999). *Sex and cognition*. Cambridge, MA: The MIT Press.

Kimura, D. (1996). Sex, sexual orientation and sex hormones influence human cognitive function. *Current Opinion in Neurobiology, 6*(2), 259–263.

Mann, V. A., Sasanuma, S., Sakuma, N., & Masaki, S. (1990). Sex differences in cognitive abilities: A cross-cultural perspective. *Neuropsychologia, 28*(10), 1063–1077.

Miller, L. K., & Santoni, V. (1986). Sex differences in spatial ability: Strategic and experimental correlates. *Acta Psychologia, 62*(3), 225–235.

Moffat, S. D., Hampson, E., & Hatzipantelis, M. (1998). Navigation in a "virtual" maze: Sex differences and correlation with psychometric measures of spatial ability in humans. *Evolution and Human Behavior, 19*, 73–87.

McBurney, D. H., Galin, S. J. C., Devineni, T., & Adams, C. (1997). Superior spatial memory of women: Stronger evidence for the gathering hypothesis. *Evolution and Human Behavior, 18*, 165–174.

Sarkar, M., & Brown, M. (1992). Graphical fisheye views of graphs. In *Proceedings of ACM CHI'92 conference on human factors in computing systems* (pp. 83–91). New York: Association for Computing Machinery Press.

Sherry, D. F., Jacobs, L. F., & Gaulin, S. J. (1992). Spatial memory and adaptive specialization of the hippocampus. *Trends in Neurosciences, 15*(8), 298–303.

Vandenberg, S. G., & Kuse, A. R. (1978). Mental rotations: A group test of three-dimensional spatial visualization. *Perceptual and Motor Skills, 47*, 599–604.