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Sex Differences in Remembering the Locations of Objects in an Array: Location-Shifts Versus Location-Exchanges

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Women outperformed men on Silverman and Eals' Location Memory task when the locations of pairs of objects were exchanged, as in their original study, but not when the locations of objects were shifted to sites previously unoccupied by another object. Alternative explanations to Silverman and Eals' claim that women's superior performance was due to better location memory are discussed.

KEY WORDS: Spatial; Cognitive; Memory; Sex differences.

Tests of spatial ability are generally performed better by males across most species, including humans (Beatty 1979; Gaulin and Fitzgerald 1986; Halpern 1992; Maccoby and Jacklin 1974; McGee 1979). Therefore, it was surprising when Silverman and Eals (1992) suggested that, although natural selection for hunting abilities would have given men an advantage on certain standard spatial tests, the foraging lifestyle of prehistoric women would also have selected for certain abilities that could be termed spatial. To gather edible plants effectively, it would be useful to have an accurate memory for the spatial configuration of local flora and other landmarks. Silverman and Eals (1992) developed a Location Memory task intended to measure the ability to process the locations of

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objects within a complex array. Subjects were presented with an array of 27 objects, which was then replaced with another array in which 14 of the objects were in different positions. Subjects were asked to indicate both objects that had moved and those that had not moved. They found that women outscored men on this task (Eals and Silverman 1994; Silverman and Eals 1992).

Silverman and Eals (1992) created their response array by exchanging the locations of pairs of objects. In this way, the pattern of filled and unfilled space did not differ between the two arrays. Shifting the locations of the objects to locations previously unoccupied by another object would change this pattern. It is of interest that location memory tasks involving shifting the locations of objects as opposed to exchanging them have been suggested to involve different brain areas. Pigott and Milner (1993) found that an intact right-temporal lobe was important for detecting location-shift, but only an intact hippocampus was important for detecting location-exchange. Their sample size was too small to report any sex differences on these tasks. The purpose of the present study was to determine if shifting the locations of the objects instead of exchanging them would affect the sex difference found on Silverman and Eals' task. If women do have better location memory for objects in an array, then this manipulation should not have an effect.

METHODS

Subjects

Subjects were undergraduate volunteers recruited through the Introductory Psychology subject pool at the University of Western Ontario. Subjects were 86 men and 88 women. Ages ranged from 18 to 27 years. All were right-handed and spoke English as their first language.

Procedure

Subjects were administered either the Location-Exchange task or the Location-Shift task. Both tasks used a presentation array identical to the one used for Silverman and Eals' (1992) original task (Figure 1). The Location-Exchange task also used the same response array as Silverman and Eals (Figure 2), but the Location-Shift task used a new response array (Figures 3 and 4). As in Silverman and Eals' original task, subjects were asked to indicate with an "X" those objects that had moved, and with a circle those objects that had not moved. Scores were calculated as the number of objects correctly marked.

Location-Exchange task. Forty-three men and 41 women were administered this task. Subjects were shown the presentation array (Figure 1) on either an 11 × 17 in. (0.28 × 0.43 m) sheet of paper, or on a 17-in. Sony computer monitor. The subject was given 1 min to study the array, which was then replaced with the response array (Figure 2). The response array was shown either on an 11 × 17 in. (0.28 × 0.43 m)

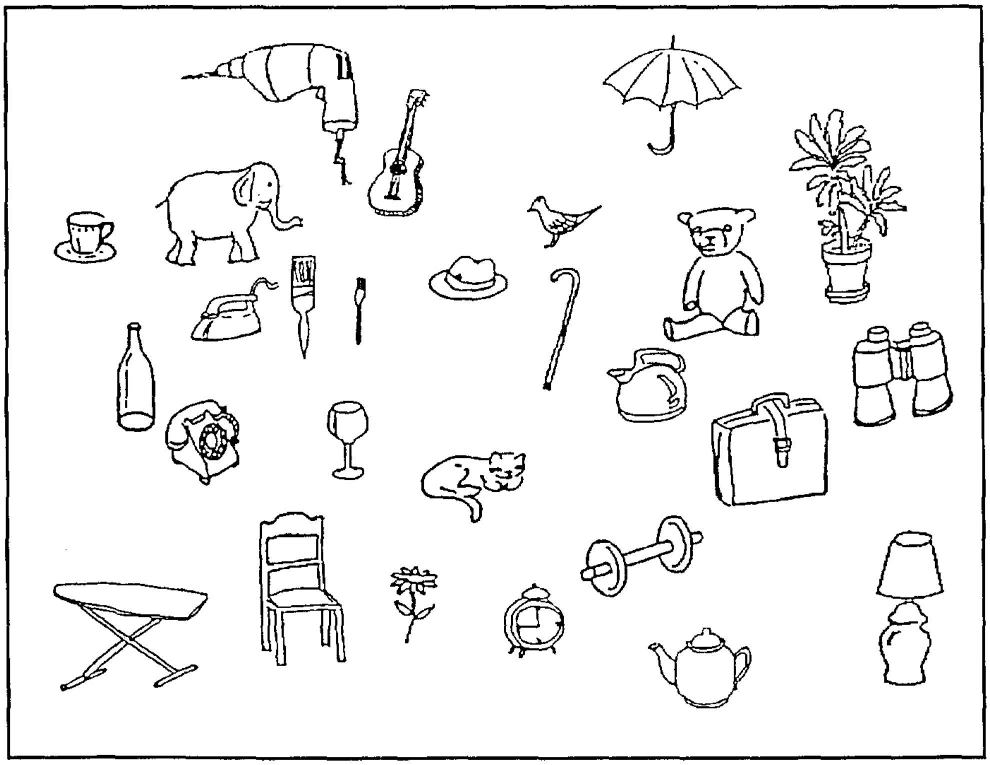

FIGURE 1. The presentation array from Silverman and Eals' (1992) original study. Used in the present study as the presentation array for the Location-Exchange and Location-Shift tasks.

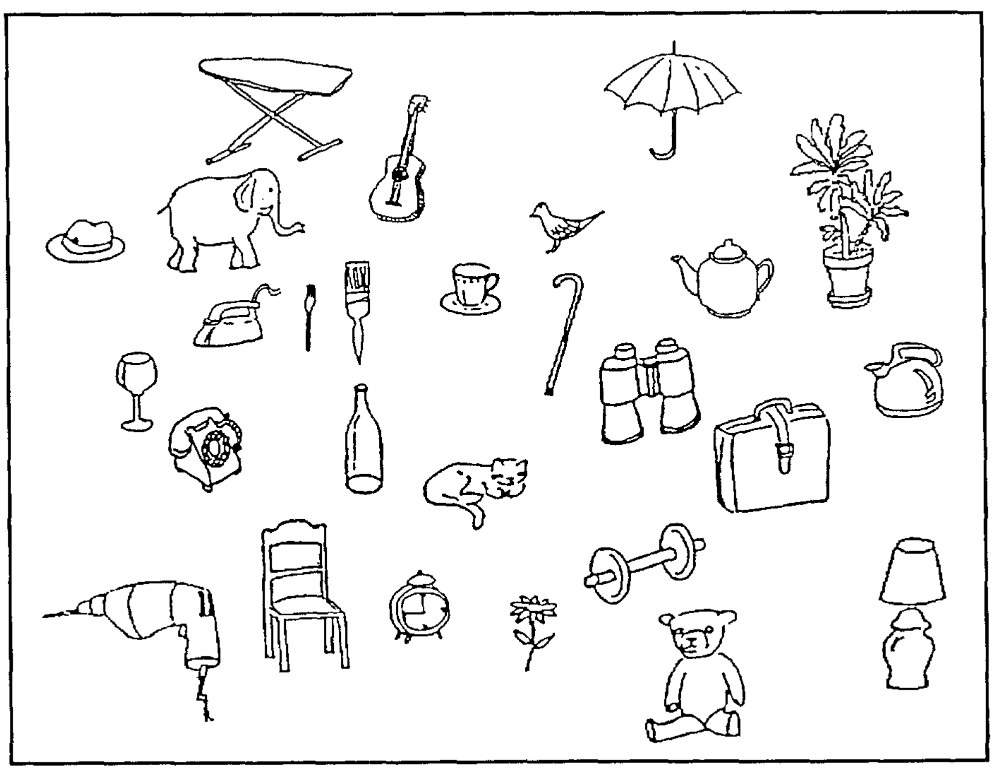

FIGURE 2. The response array from Silverman and Eals' (1992) original Location Memory task. Used in the present study as the response array for the Location-Exchange task.

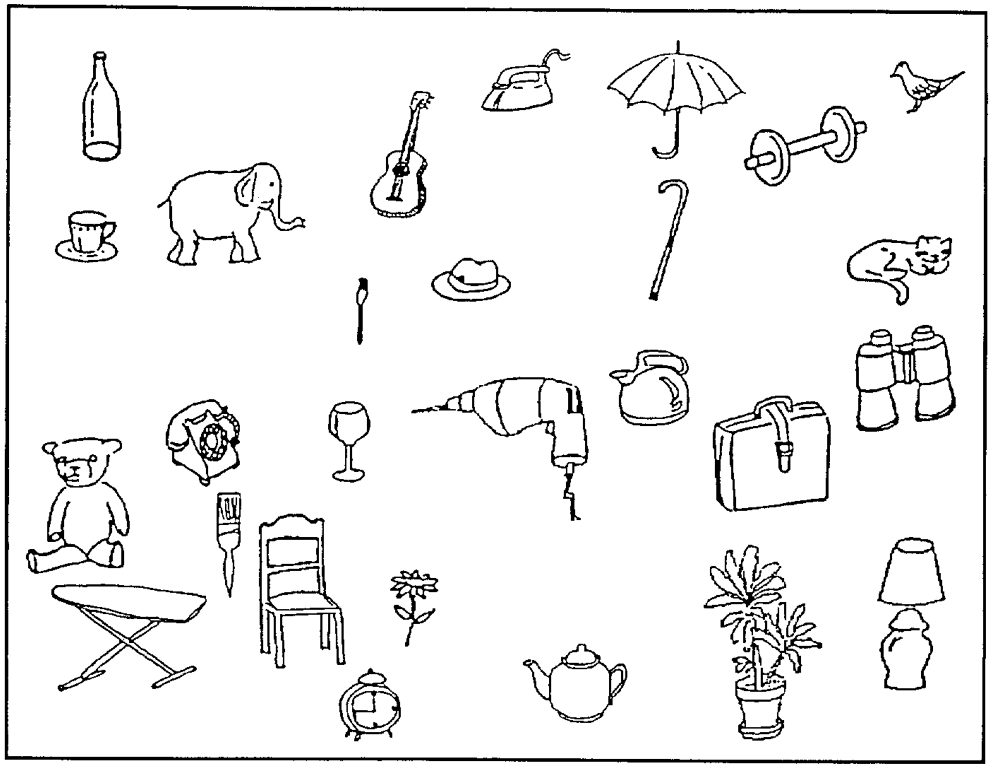

FIGURE 3. Response Array 1 for the Location-Shift task. The locations of 12 objects from the presentation array (see Figure 1) were shifted to locations previously unoccupied by another object.

sheet of paper, or on the computer monitor with a transparency covering the screen. These manipulations led to three presentation/response conditions: paper presentation with paper response (paper/paper), computer presentation with paper response (computer/paper), and computer presentation with computer response (computer/computer).

Location-Shift task. Forty-four men and 46 women were administered this task. Following Silverman and Eals' (1992) original procedure, an 11 × 17 in. (0.28 × 0.43 m) sheet of paper displaying their presentation array (Figure 1) was placed in front of the subject. The subject was given 1 min to study the array, which was then replaced with an 11 × 17 in. (0.28 × 0.43 m) sheet of paper displaying the new response array.

Two different response arrays were used to test the effect of shifting the locations of the objects, but any one subject was given only one of them. Response Array 1 (Figure 3) was created by shifting the locations of 12 of 27 objects to locations previously unoccupied by an object on the presentation array. Response Array 2 (Figure 4) was created to replicate the findings from Response Array 1 by shifting the locations of a different set of 14 objects to locations unoccupied by an object on the presentation array.

For both of these response arrays, an attempt was made to place objects in spaces completely unoccupied by objects on the presentation array, but due to the

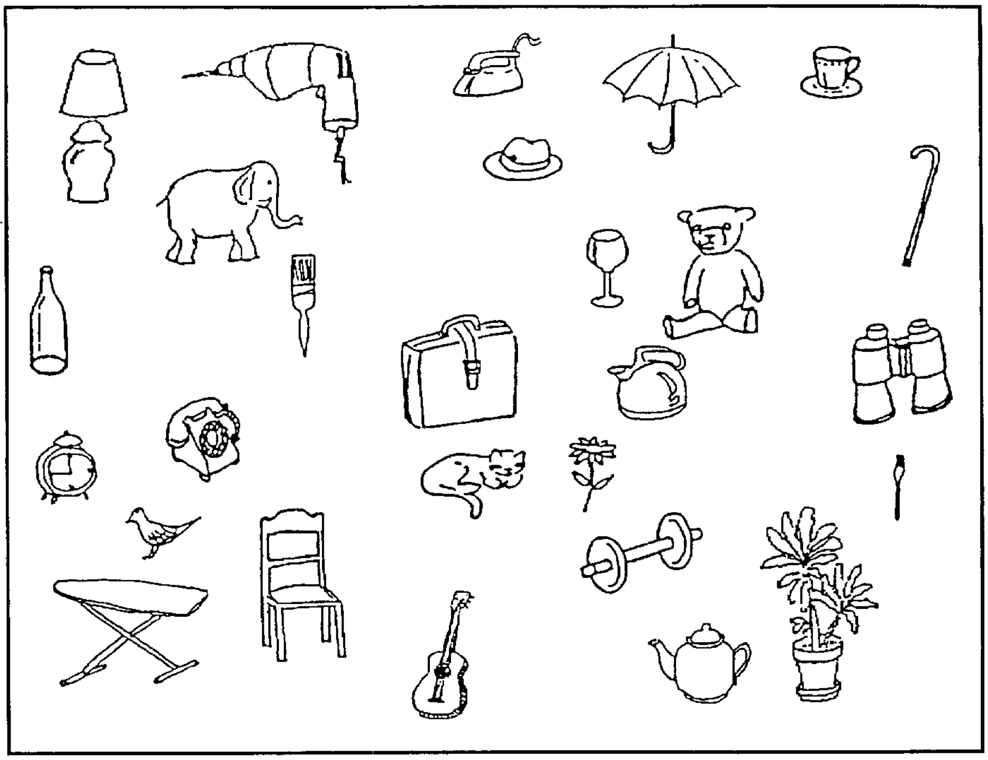

FIGURE 4. Response Array 2 for the Location-Shift task. The locations of 14 objects from the presentation array (see Figure 1) were shifted to locations previously unoccupied by another object.

limited amount of blank space in the array, a small degree of overlap occurred. Also, an attempt was made to equate the distance that objects were moved on the Location-Shift task with that of the Location-Exchange task.

RESULTS

The results of the Location-Exchange task (Table 1) were analyzed with a 2 × 3 analysis of variance with sex and condition (paper/paper, computer/paper, computer/computer) as between-subjects factors. Women outscored men on the Location-Exchange task ($F_{(1,78)} = 9.10, p < .005$), regardless of the condition, replicating the Silverman and Eals (1992) effect.

Table 1. Mean Number Correct and Standard Deviations for the Location-Exchange Task as a Function of Sex and Condition

	Men			Women		
	Mean	*SD*	*N*	Mean	*SD*	*N*
Paper/Paper	19.7	3.20	20	21.7	2.82	20
Computer/Paper	19.4	2.02	12	21.2	2.17	12
Computer/Computer	18.8	3.06	11	20.2	1.72	9

Maximum number correct for all conditions was 27.

Table 2. Mean Number Correct and Standard Deviations for the Location-Shift Task as a Function of Sex and Response Array

	Men			Women		
	Mean	*SD*	*N*	Mean	*SD*	*N*
Response Array 1	22.0	2.20	24	21.9	3.10	25
Response Array 2	22.1	2.63	20	22.2	2.21	21

Maximum number correct for all conditions was 27.

The results of the Location-Shift task (Table 2) were analyzed with a 2 × 2 analysis of variance with sex and response (Array 1 or 2) as between-subjects factors. There were no significant differences found between the two response arrays and no Sex × Response Array interaction. No sex difference was found on the Location-Shift task.

Since no significant interaction effects were found in these two analyses, data from the Location-Exchange task were collapsed across presentation/response condition and data from the Location-Shift task were collapsed across response array, for the final analysis. A 2 × 2 analysis of variance with sex and task (Location-Exchange/Location-Shift) as between-subjects factors revealed a significant Sex × Task interaction ($F_{(1,188)} = 5.87, p < .05$, Figure 5). Men scored higher on the Location-Shift task than they did on the Location-Exchange task ($t_{(90)} = 4.48, p < .001$), but women's scores did not differ on these two tasks.

DISCUSSION

Silverman and Eals (1992) claimed that women's scores were higher on their task (Location-Exchange) due to better location memory for objects embedded in a complex array. If so, women should outperform men not only on one specific Location Memory task, but on a variety of tasks involving memory for locations of objects in an array. The data from the present study showed that women had better location memory for objects in an array only on the Location-Exchange task, which replicated Silverman and Eals' (1992) finding, but not on the Location-Shift task.

The Location-Exchange task, which was the same as Silverman and Eals' (1992) original task, did not introduce new locations into the response array. Subjects were given all of the possible locations and were essentially asked to recognize whether each location was occupied by the same object, making object identity information an important cue. In the Location-Shift task, objects were relocated by shifting their locations into a position that had been previously unoccupied by another object. In this way, new locations were included in the response array and, since subjects could use information about the arrangement of filled and unfilled space in the array to solve the task, the importance of object identity information was de-emphasized. Therefore, it appears that women may outperform men on object location memory tasks only when object identity information is a necessary cue for solving the task.

The question arises whether the female advantage on the Location-Exchange task could be accounted for by simple object memory instead of location memory,

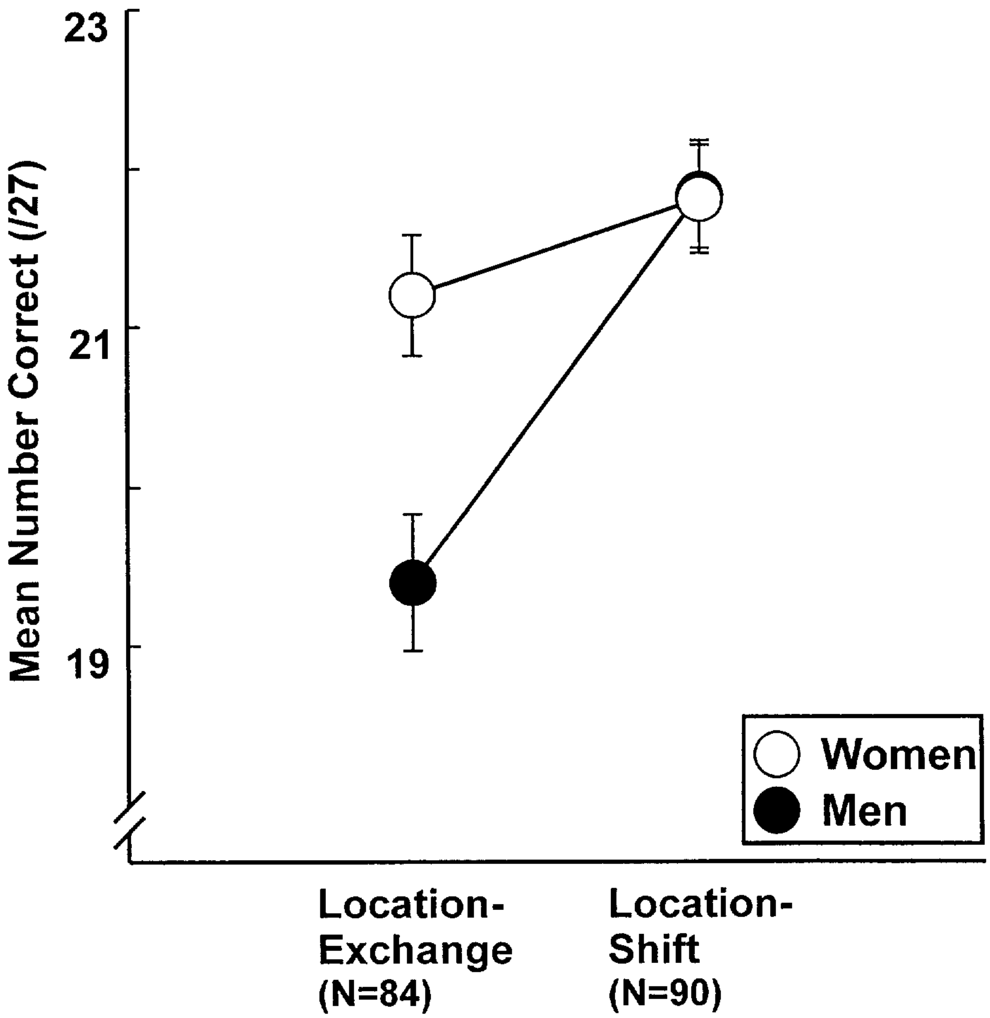

FIGURE 5. Mean number correct on the Location-Exchange and Location-Shift tasks as a function of sex and task.

since it has been shown that women outperform men on tests of item memory (Galea and Kimura 1993; Harshman et al. 1983; Maccoby and Jacklin 1974; Stumpf and Jackson 1994). Silverman and Eals (1992) claimed that object memory did not account for the sex difference found on their Location Memory score, but their test for object memory was not ideal. It consisted of a response array created by adding 20 new objects (foils) to the presentation array by placing them in the spaces between probe objects. Subjects were asked to circle those objects that had been on the presentation array (probes) and put an "X" through the objects that had not (foils).

There are two problems with this method of measuring item memory. First, since objects were in the same locations for the presentation and response arrays, subjects could have used both object identity and location information to solve the Object Memory task. It appears, therefore, that Object Memory and Location Memory scores were confounded. Second, Object Memory was controlled for in the analysis by calculating a ratio of Location Memory score to Object Memory score, whereas a more appropriate procedure when comparing measures of this sort would have been an analysis of covariance (Packard and Boardman 1987). It seems necessary to address these problems before it can be claimed that item memory does not influence the sex difference found on the Location-Exchange task.

There is some evidence that women and men may process object identity and location information differently. Hoesing et al. (1994) showed subjects arrays of letters and then measured reaction times for letter identification (whether a particular letter was part of the array) or location identification (whether a particular location was occupied in the array). They found that women's reaction times for letter and location identification were equal, but men were faster at identifying locations. They concluded that women might use a common system to process object identity and location information, whereas men may use different systems.

On the Location-Exchange task, object identity had to be used in conjunction with location information to determine if an object had moved. A system that integrated object identity and location information (perhaps used by women) would likely show an advantage on this type of task. On the Location-Shift task, a change in the location of an object could be determined by the change in the pattern of filled and unfilled space in the array, making object identity information less important. This would give less advantage to an integrated system, since location information could be used alone to solve the task.

Although the specifics of Silverman and Eals' (1992) argument may have to be modified, their general evolutionary scheme may be valid. They argued that the evolutionary pressures placed on prehistoric women due to a gathering lifestyle would have selected for superior location memory for objects in a complex array, but to elaborate on this position, men and women may have evolved different cognitive systems for processing information about the environment in general.

Prehistoric women are assumed to have predominantly gathered small, immobile food items and would usually have navigated through familiar territory. Successful foraging would require the ability to remember the locations of specific (i.e., edible) plants and efficient navigation would likely favor a strategy that involved recognition of familiar landmarks. These types of selection pressures might have led to the development of a memory system in women that is highly capable of associating an object with a particular location.

Prehistoric men predominantly tracked and hunted big game, would have had larger home ranges than women, and would often have been led into unfamiliar territory. These conditions would have made navigation by landmarks unreliable. A more effective navigational strategy would be to remember locations in terms of more global coordinates and to learn a route in terms of distance and direction cues. This might have led to the development of a memory system different from that of women. Men would benefit from a higher capacity for location information relative to object information, and the ability to remember the association between an object and a particular location might be less well developed.

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