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Memory for object locations: Priority effect and sex differences in associative spatial learning

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Abstract

This paper reports two experiments conducted to examine priority effects and sex differences in object location memory. A new task of paired position-learning was designed, based on the A–B A–C paradigm, which was used in paired word learning. There were three different paired position-learning conditions: (1) positions of several different objects (B-objects and C-objects) around referent objects (A-objects) were learned in the A–B A–C position-learning condition, (2) positions of several different objects with no referent objects were learned in the 0–B 0–C position-learning condition, and (3) positions of identical objects (stars) with no referent objects were learned in the 0-star 0-star position-only condition. The results revealed a significant priority effect on performance in the A–B A–C and the 0–B 0–C position-learning conditions but not in the 0-star 0-star position-only condition. Contradictory results were obtained with respect to the sex variable: a female superiority effect on paired position learning was significant in Experiment 1, but this effect was not replicated in Experiment 2. In addition, an articulatory suppression task used in Experiment 2 had a significant effect on recall of different object positions but no effect on recall of identical object positions. This suggested that verbal encoding was not necessary for learning of positions of identical objects.

Keywords: Priority effect; Interference; Sex difference; Paired associate learning; Object location memory

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Interference has been one of the long-standing topics of interest in the study of memory and has been extensively studied by using lists of word pairs during the classical interference era of 1900–1970 (Anderson, 2003). Different types of interference phenomena were observed as a result of variations in the experimental procedures used: proactive interference, retroactive interference, and the priority effect. These interference phenomena are often established in the so-called A–B A–C paradigm using control conditions. In an A–B A–C procedure, after two lists of word pairs (A–B and A–C lists) are learned in succession, participants in an experimental group are given stimulus words (A-words) as cues and asked to produce C response words. A basic finding is that the experimental group recalls fewer C response words than a control group who either learned only the A–C list or learned two lists with different stimulus words (a D–B list, instead of the A–B list, and then the A–C list). This type of interference is known as proactive interference. In the retroactive interference condition, the experimental group's memory for B response words is compared to that of a control group who either learned only the A–B list or learned two lists with different stimulus words. The experimental group shows worse memory for B words than the control participants. On the other hand, a variation of the recall test, known as the modified–modified free recall (MMFR) test, was also used in the A–B A–C paradigm. This recall procedure requires participants to recall both of the lists learned in succession, and recall of the A–B list is compared to that of the A–C list rather than comparing the two A–C lists learned in two different conditions (A–B A–C versus D–B A–C conditions). Tulving and Watkins (1974) demonstrated that when an A–B list was not tested prior to the presentation of an A–C list, higher recall of the B than the C was observed in the MMFR test. This observation of higher recall of B than C was termed the priority effect.

Although interference phenomena are well established, mechanisms responsible for interference have not as yet been discovered (Eysenck, 1994). Two major theories dominated research during the classical interference era: unlearning (Barnes & Underwood, 1959) and McGeoch's response competition (McGeoch & Irion, 1952). In essence the theory of unlearning stated that new associations (the A–C stimulus–response) or well-practiced associations caused extinction of the previous associations (A–B) or less-practiced associations. In contrast, the response competition view posited that multiple responses (B and C) were elicited by a stimulus (A) and competed with each other during retrieval, resulting in one response dominating the other. In the classical two factor theory of interference, however, Melton and Irwin (1940) argued that both response competition and unlearning contributed to interference. Although paired associative learning became unattractive to many researchers after the classical interference era, some proposals to explain the interference phenomena have continued to be put forward and discussed.

A mediational explanation of the priority effect, proposed by Arkes and Lyons (1979), has received little attention from thinkers interested in the A–B A–C paradigm. According to the mediational theory, when an immediate test of B items does not take place, the B items are retained during the A–C list learning. This is an encoding strategy adopted by participants who know that they are to be tested on the B items and do not want to forget them while learning the C items. It follows that the B items are studied twice in relation to the A items, first at A–B learning and then at A–C learning; for this reason, the B items are recalled better than the C items (priority effect). In a study done by Cinan (2003), an interesting dual task design was used to test the mediational theory. The participants in a dual-task A–C only group learned an A–B list in a single task condition followed by a dual task condition in which an A–C list was learned. It was thought that if B was retained during A–C learning, then the concurrent task at A–C encoding should affect the recall of B, although the A–B list was learned free from the concurrent task. The performance of the dual-task A–C only group was compared with a control group, who learned both the A–B and the A–C lists in a single task condition. The results showed that the recall of B learned in the single task condition was affected by the concurrent task performed at A–C encoding. This finding supported Arkes and Lyons' view that B is retained at A–C learning.

Two other concepts emerge from current views and studies on interference: contextual information, and executive control of retrieval, specifically inhibitory control. The effect of contextual information on response competition was emphasized in two separate attempts to explain findings of paired associate studies: the contextual fluctuation view of Mensink and Raaijmakers (1988), Bower, Thompson-Schill, and Tulving's (1994) expanded view of competition. The basic idea underlying these contextual-dependent positions is that the memory trace consists of stimulus, response and contextual information and, as a result, retrieval is determined by much more than the nature of simple association between a stimulus (A) and two responses (B and C); contextual elements active at retrieval can be detrimental or beneficial mediators for the resolution of response competition. On the other hand, Anderson (2003) reconsidered the theories of interference and proposed an executive control mechanism, which resolves response competition by inhibiting inappropriate responses. Anderson argued that inhibition processes would impair later recall of the responses suppressed.

The A–B A–C paradigm was applied in a novel context of spatial memory in the present study with two main objectives: (1) to provide further insights into interference phenomena, and (2) to provide new insights into categorical processing of spatial relations. Spatial memory is essential for humans to store and recall locations of objects in the environment and to learn layouts that can be used for navigation. Recent views maintain that spatial memory is not a unitary system. A variety of spatial memory tests were used to study sex differences in spatial abilities. While numerous studies have demonstrated a male advantage in spatial learning (Devlin & Bernstein, 1995; Sanders, Soares, & D'Aquila, 1982), some studies have shown a female advantage (Silverman & Eals, 1992; Tottenham, Saucier, Elias, & Gutwin, 2003), and others found no differences between males and females (Golledge, Ruggles, Pellegrino, & Gale, 1993). It has also been shown that males and females use different strategies in spatial learning (Dabbs, Chang, Strong, & Milun, 1998; Voyer & Saunders, 2004). The nature of the spatial tasks used in these studies should be considered with respect to the concept of a multi-component spatial system, it is thought that females could be better at the tasks that are sensitive to some specific subcomponents of object location memory. Kosslyn (1987) distinguished between two different aspects of object location memory: categorical spatial relations and coordinate spatial relations. Postma, Izendoorn, and De Haan (1998), on the other hand, argued that object location memory requires processing of three types of information: what information, where information (metric information), and an integration of both types of information.

Males were found to outperform females in the tasks that require encoding and retrieval of Euclidian distances between objects (Postma et al., 1998). Iachini, Sergi, Ruggiero, and Gnisci (2005) assessed object location memory in a different 3-D environmental setting, and in line with the previous studies (Postma et al., 1998), they also found that metric information about the relationship between objects was preserved better by males than females. In contrast, Silverman and Eals (1992) and Eals and Silverman (1994) found that females were better than males at the tasks that required recall of positions of objects that had changed places. The researchers argued that females are better at this type of spatial memory task, which is thought to involve encoding of categorical relations between objects (object A is to the left of object B). However, Postma, Jager, Kessels, Koppeschaar, and van Honk (2004) found no sex difference in a Silverman Object Location Task. There are other studies that failed to find a female advantage in object location memory (Choi & L'Hirondelle, 2005; Iachini et al., 2005). Thus, the research results obtained so far are controversial, and a clear pattern of sex differences in different spatial tasks has yet to be established (Iachini et al., 2005).

Experiment 1

The application of the A–B A–C paradigm used in verbal memory to object location memory provides a platform for addressing two different issues regarding the two different types of memory: priority effects in verbal memory and categorical processing of spatial relations. In the present study, the first question asked is whether the priority effect can be observed in object location memory and if so how this effect can be explained by the theories of interference put forward in the field of verbal memory. In addition, it is thought that the A–B A–C design is more appropriate than the tasks used in the object location learning literature to assess categorical spatial relations (above, below, to the left, to the right of the referent position of an A-object) in which a female advantage would be expected based on the views of some authors (Eals & Silverman, 1994; Silverman & Eals, 1992).

In the present study, the A–B A–C paired word learning task was modified into an A–B A–C position-learning task, and three different position-learning conditions were designed (see Fig. 1): The A–B A–C position-learning condition, the 0–B 0–C position-learning condition, and the 0-star 0-star position-only condition. In the A–B A–C position-learning condition, three groups of objects, called A-objects, B-objects, and C-objects, were used to form the A–B object pairs and the A–C object pairs. Seven A–B object pairs and seven A–C object pairs were shown on a computer screen in two successive presentations of 8×10 matrices. Thus, participants learned the positions of seven different target objects (B) paired with seven other objects (A) that served as points of reference. Subsequently, they learned the positions of seven different target objects (C) paired with the same seven referent objects (A). After learning the 14 target objects (B and C) in two successive learning sessions, the participants were given a cued-recall session in which the A objects as cues were presented in their previously studied locations on the matrix, and the participants were asked to reproduce the positions of the B and the C-objects on the matrix containing the A-objects. In the 0–B 0–C position-learning condition, on the other hand, no A-objects were used. The B-objects and the C-objects in this condition were presented in the same positions (the same cells of the matrix) as they were in the A–B A–C condition, but each was positioned around an empty cell, instead of an A-object. In the 0-star 0-star position-only condition, all the objects presented were the same (stars), each situated around an empty square in a similar way to the 0–B 0–C condition. The positions of the stars in the two successive presentations were the same as the positions of the B and C-objects used in the A–B A–C and the 0–B 0–C conditions. This last condition required participants to reproduce only the positions without needing to know what was where. Thus, object identity information (B and C as two alternative objects and A-objects as landmark cues) was

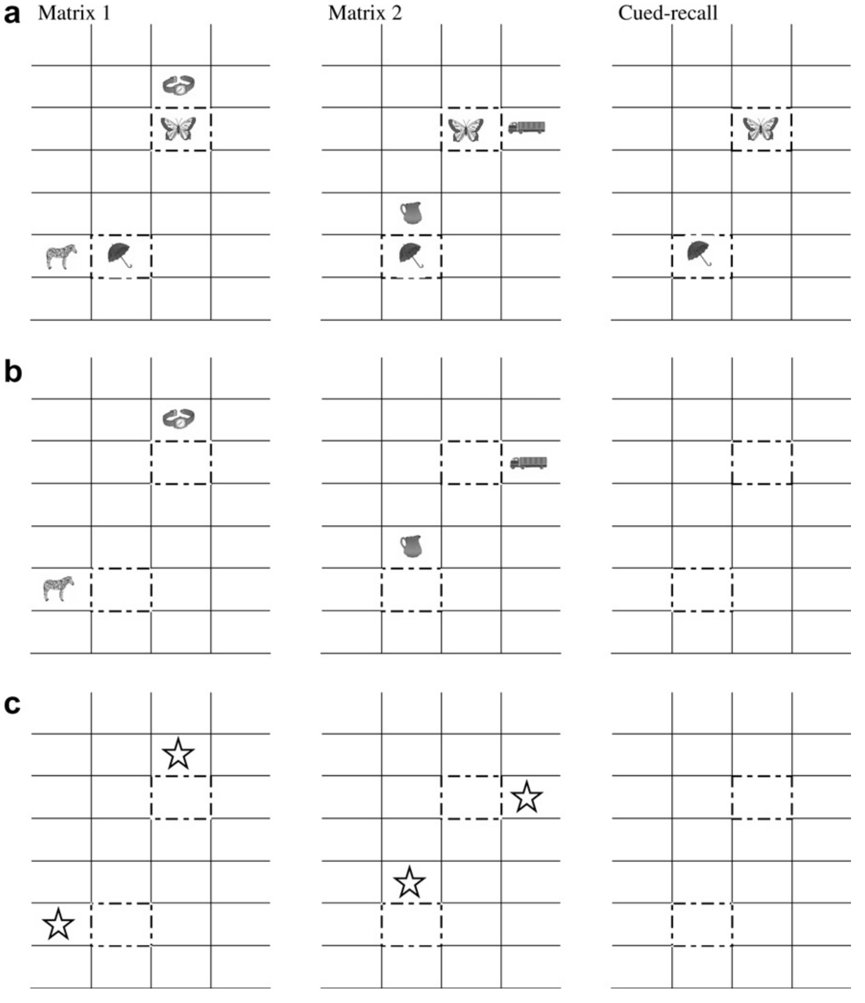

Fig. 1. An illustration of subsections of two matrices as a function of the three position learning conditions and corresponding matrices in the cued-recall sessions. The examples only show two of seven object-pairs observed for each matrix. (a) A–B A–C condition, (b) 0–B 0–C condition, (c) 0-star 0-star condition.

manipulated across the three conditions, and the effect of this manipulation on learning of categorical spatial relations and paired-positions was examined.

Method

Participants

A total of 146 students from Istanbul University volunteered to take part in this study. They were assigned to one of three experimental conditions. There were 25 females and 24 males (mean age = 21.96, $SD = 2.54$) in the A–B A–C position-learning condition, 25 females and 24 males (mean age = 22.27, $SD = 2.23$) in the 0–B 0–C position-learning condition, and 24 females and 24 males (mean age = 22.35, $SD = 2.55$) in the 0-star 0-star position-only condition. Most participants were right handed, (right handed, 137; left handed, 9) as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971).

Materials and procedure

The three different position-learning conditions (the A–B A–C position-learning condition, the 0–B 0–C position-learning condition, and the 0-star 0-star position-only condition) were designed by the first author (see Fig. 1 for an illustration of subsections of the three tasks).

The participants were tested individually. They were first given a practice session, which involved recall of only four positions. Although a few differences existed (see below), the three position learning conditions were mainly similar: In all the conditions, there were three trials, and, in each trial, there were two study sessions followed by two cued-position recall sessions. In the two study sessions of a trial, there were two successive presentations of 8×10 matrices on a 15-in. computer screen, and the participants had to study seven object positions in each matrix, presented for 30 s. At the beginning of each matrix, the phrase 'presentation 1' or 'presentation 2' appeared on the screen for 1 s. Immediately after the presentation of the second matrix, a sequence of 15 random numbers (two digit numbers between 10 and 99) appeared on the screen at a rate of 1 s per number, and the participants read each number aloud. The number repetition was required in order to diminish the influence of the recall of primary memory representations on the recall-performance of the participants. After a total of 14 positions (seven in the first and seven in the second study session) were learned in the two recall sessions, the first learned object positions were recalled first and the second learned object positions were recalled second for half of the participants; the recall order was reversed for the other half of the participants.

Six objects for the practice task and 63 objects for the main task were selected from grayscale-shaded images provided courtesy of Michael J. Tarr (Brown University, Providence, RI). The objects were chosen so that they were not predominantly male or female-oriented objects and that the A–B and the A–C pairs were unrelated. The 63 grayscale objects were divided into three sets of 21 objects. In each set, there were seven A-objects, seven B-objects, and seven C-objects, which formed the A–B object pairs and the A–C object pairs.

The A–B, A–C object pairs were used in the A–B A–C position-learning condition. Seven locations (cells) in a matrix were identified. These cells were fixed for the two matrices used in the two successive study sessions of each trial, and one A-object was placed in each of the cells. The B-objects in the first matrix and the C-objects in the second were paired with the A-objects in such a way that each object (B or C) was placed in one of four positions (above, below, to the left, or to the right of the A-object cell) randomly under the constraints that not more than three objects were placed in the same direction around the A-object cells and that there was at least one object placed in one of the four positions. As the positions of the B or the C-objects, not the A-objects, had to be studied, it was important to prevent confusion about which object in a pair was A or B/C. For this reason, two preventive measures were used: (1) the frame of each A-object cell was made distinct by using bold broken lines, and (2) before a study session, the matrix with only the A-objects placed in their cells was shown to the participants for

5 s, followed by another 5-s presentation of the 14 objects (the B and the C-objects), placed randomly in a 2-line × 7-column table. In this way, the participants were also familiarized with the objects, the positions of which they were to recall. The participants were told that each A-object was to be paired with a different object (B or C) in the two matrices, which were to be presented in succession. As described above, this study session of two matrices was followed by a number repetition task. Then, in the cued-recall session, the participants were given the matrix with the A-objects, printed on an A4 paper, and the 14 objects (B and C) were presented on the screen in a random order. Each of the 14 objects presented in the recall session had a number ranging from 1 to 14. The participants were asked to place the number of an object, rather than the name of the object, in the cell in which they thought the object had appeared in the previously studied matrices. The recall order of the B-objects versus C-objects was counterbalanced: half of the participants were first asked to recall the positions of the objects in the first matrix (the B-objects) and then those in the second matrix (the C-objects) on a different sheet of paper. The other half did the reverse. The same procedure was repeated with new objects (A, B, and C) placed in new locations in the second trial, and this procedure was repeated again with new objects in the third trial.

The materials and the procedure were similar for the 0–B 0–C position-learning condition, except for one key difference, which was that there were no A-objects on the matrices. The cells occupied by the A-objects in the A–B A–C condition were still made distinct with the bold broken lined frame, but in the 0–B 0–C condition they were empty. Before a study session, the participants in the 0–B 0–C condition were also shown these marked empty cells in a matrix for 5 s, similar to the presentation of the matrix with the A-objects in the first condition. In the two successive recall sessions, the pre-marked cells were presented to the participants who had to recall the positions of the B objects and the C objects. Similar to the 0–B 0–C position-learning condition, the third condition did not have A-objects. In addition, the B-objects and the C-objects employed in the first and the second position learning conditions were not used in the 0-star 0-star position only condition. Instead, all the objects occupying the positions of the B and the C-objects on the matrices were identical stars. For this reason, there was no need for the presentation of a star for 5 s to familiarize the participants with this object before a study session, as was done with the B and the C-objects in the other conditions. The rest of the materials and the procedure were similar to the ones used in the 0–B 0–C position-learning condition.

Results and discussion

The present data on the three position-learning tasks were examined for the number of positions recalled correctly. The data were also scored for several different types of errors with the consideration that different types of error might give some indications about the strategies used by the two sexes. Examples of such error types included: (1) correct object that was placed in wrong cell (right, left, above, or below) around the correct A-object (the A–B A–C position learning condition) or the correct marked cell (the 0–B 0–C position learning condition). This type of error might be related to “what information”. (2) Incorrect object placed in the correct cell around the correct A-object or the correct marked cell. This measure might be related to “where information". However, very few errors of each type were found and, therefore, the error data were not reported in this paper.

Table 1 shows mean correct positions recalled per matrix (the first matrix versus the second matrix) in the three position-learning conditions for females and males. The data were first analyzed in an analysis of variance with Sex (female versus male) and Task Type (the A–B A–C position-learning task, the 0–B 0–C position-learning task, and the 0-star 0-star position-only task) as between-subjects variables, and Learning-order (the B versus the C-objects, or the stars in the first matrix versus those in the second matrix) as a within-subjects variable. The results showed a significant sex effect, $F(1,140) = 6.24$, $p < .02$, indicating a female advantage in the paired position-learning. There was also a significant learning order effect on recall performance, $F(1,140) = 8.93$, $p < .01$, but no significant main effect of Task Type was found, $F(2,140) = 1.51$, $p > .05$. There was no significant Sex by Task-type interaction; therefore the effect of Sex for each position-learning task was not examined. The only significant interaction obtained was between Task Type and Learning-order, $F(2,140) = 5.32$, $p < .01$. Thus, the differential effect of the learning order for each task was analyzed further.

The data obtained in the A–B A–C position-learning condition showed a significant learning order effect (priority effect), indicating that the positions of the B-objects were recalled better than those of the C-objects, $t(48) = 3.6$, $p < .01$. Similarly, the data in the 0–B 0–C position-learning condition revealed a significant learning order effect on recall, $t(48) = 2.72$, $p < .01$. In contrast to the findings obtained both in the A–B A–C and the 0–B 0–C position-learning conditions, no learning order effect was found on the recall of the positions of identical stars in the 0-star 0-star position-only task, $t(47) = -0.84$, $p > .05$.

The present finding that, overall, the female participants were better than the males at retention of relative positional information (above, below, to the right, and to the left) appears to be in line with the results of the studies done by Silverman and Eals (1992) and Eals and Silverman (1994) who also showed a female advantage in object location memory. However, the gender performance was not affected by the variation in object identity information across the position-learning conditions. This was not expected

Table 1
Mean number of correct positions recalled in the three position learning conditions for females and males

Position learning conditions (Means over three trials and out of seven positions on a matrix)	Male		Female	
	M	*SD*	*M*	*SD*
A–B A–C position-learning				
B-objects	4.21	1.58	4.92	1.66
C-objects	3.56	2.00	3.87	1.88
Total (B + C)	7.76	3.15	8.79	3.17
0–B 0–C position-learning				
B-objects	3.64	1.55	4.51	1.44
C-objects	2.99	1.42	3.92	1.64
Total (B + C)	6.63	2.51	8.43	2.61
0-star 0-star position-only				
First matrix	3.96	1.64	4.18	1.03
Second matrix	4.19	1.21	4.38	1.31
Total	8.15	2.02	8.56	1.81

because the A–B A–C position-learning condition required all the spatial skills that females are thought to be good at, such as the use of landmarks (A-objects), left-right terms and information about objects' identities.

With respect to the priority effect, an interesting pattern of results appears to have emerged across the three position-learning conditions. A significant priority effect was found in the A–B A–C and the 0–B 0–C position-learning conditions where different objects (the B and the C-objects) were used, but there was no priority effect in the 0-star 0-star position-only condition involving identical objects. This suggests that the position-only condition involves different spatial memory processes than the other two conditions. The third condition did not require information about objects' identities and therefore it would involve the processing of "where" information, rather than "what" information. On the other hand, the A–B A–C and the 0–B 0–C position-learning conditions would involve "what is where" information about the two alternative objects (B versus C) around an A-object location or empty marked cell, which would result in B–C relational position-learning. In the verbal memory literature, the B–C relational encoding was thought to lead to a priority effect in recall of paired-associate lists. Arkes and Lyons (1979) argued that B items are strengthened by the A–B–C relational learning at the presentation of the A–C list. Based on this mediational theory, the priority effect found in the A–B A–C and the 0–B 0–C position-learning conditions of the present study indicates that the positions of B-objects were retained during the study of the C-object locations. The present data in the 0–B 0–C position-learning condition suggest that in a paired position-learning paradigm, A-objects are not needed for participants to use the B–C relational position-learning strategy. In contrast, when the identical objects were used in the third condition, the participants did not need to distinguish two alternative object identities (B versus C), and it appears that they did not use the strategy of relational learning of two alternative positions around a pre-marked cell, presented in two matrices. Perhaps, under such conditions the more appropriate strategy to use is to learn relative positions of seven identical objects in one matrix, separately from the other matrix. No priority effect was found in the 0-star 0-star position-only condition, but it seems that neither the different strategy nor the identical objects used in this condition made it an easier condition than the other two conditions, because the results showed no significant performance difference among the three position learning conditions.

The mediational explanation of the priority effect cannot be seen as an alternative view to the response competition theory; it simply explains why the B responses dominate the C responses in the retrieval competition under the MMFR conditions. In the present study, the participants in all the three positional-learning conditions were asked to discriminate between the object positions with respect to the matrix membership. In a counterbalanced experimental design, they were asked to reproduce the positions from one of the two alternative matrices first and then those from the other. Thus, simple response competition cannot account for the contrast found between the different position-learning conditions.

The unlearning theory is out of the question here, as it would predict unlearning of A–B positional relations due to the learning of the new A–C associations (retroactive interference). On the other hand, it should be noted that no extra study practice or retrieval practice was given to any one of the two alternative matrices to be remembered in the present study. The participants were given one study session of 30 s for each matrix, and the retrieval order of the two matrices was counterbalanced. Under these circumstances, inhibitory control of retrieval cannot explain why C, and not B, would be inhibited, as Anderson

(2003) believes that inhibition was driven by the act of selective retrieval of target items due to the need to override interference from competing items.

One assertion made by Arkes and Lyons (1979) was that C-items were learned in relation to B-items during A–C presentation. William A. Roberts (personal communication) suggested that B–C relational learning could be analyzed in the present data by computing conditional probabilities. He hypothesized that if the B–C relational position learning hypothesis is correct, then the probability of C response being correct should be higher when B is correct than when it is not correct. In order to test this hypothesis, p(C correct|B correct) versus p(C correct|B incorrect) was calculated across the three position-learning conditions. The results indicated that recall of C positions was higher when the B positions recalled were correct than when they were incorrect in the A–B A–C position learning condition (p(C correct|B correct) = .58; p(C correct|B incorrect) = .39), and in that 0–B 0–C position-learning condition (p(C correct|B correct) = .59; p(C correct|B incorrect) = .39). In the 0-star 0-star position learning condition, on the other hand, conditional probabilities were close to each other (p(the stars in the second matrix correct|the stars in the first matrix correct) = .64; p(the stars in the second matrix correct|the stars in the first matrix incorrect) = .62). This finding of memory for C positions conditional on memory for B positions provided converging evidence for the mediational hypothesis.

Experiment 2

This experiment had two aims. The first aim was to replicate Experiment 1 with some modifications. The number of object positions to be remembered per trial was increased. Second, an articulatory suppression task condition was used to examine the role of verbal encoding in the paired position-learning tasks and to test the verbal memory hypothesis (Chipman & Kimura, 1998; Choi & L'Hirondelle, 2005). This hypothesis maintains that the use of a verbal strategy gives an advantage to females in object location memory. In addition, unlike the recall procedure used in Experiment 1, in Experiment 2 all the object positions from the two matrices learned successively were reproduced on the same answer sheet containing the matrix. Thus the recall procedure did not require the participants to discriminate between object positions with respect to first/second matrix membership, and therefore there would be no need for competition between the responses.

Method

Participants

A total of 127 students from Istanbul University participated in this experiment. They were assigned to one of the three position-learning tasks. Twenty three females and 21 males (mean age = 21.77, $SD = 2.96$) performed the A–B A–C position-learning task, 20 females and 20 males (mean age = 21.30, $SD = 2.31$) performed the 0–B 0–C position-learning task, and 22 females and 21 males (mean age = 21.00, $SD = 2.62$) performed the 0-star 0-star position-only task. Most participants were right handed, (right handed, 115; left handed, 12).

Materials and procedure

With some exceptions, the materials and the procedure were almost the same as those in Experiment 1. The number of object positions to be learned was increased from 7 to 8 on a matrix or from 14 to 16 on a study session of two consecutive matrices. Thus, in a study session, eight object positions were presented on a 9×11 matrix, followed by another set of eight on a second matrix. In addition, the number of trials was increased from three to six trials (each with a study session and a recall session), and an articulatory suppression task was imposed halfway through the trials. That is, in three out of six trials, the participants learned the paired-object positions under the articulatory suppression task condition, in which they uttered out loud the same sequence of digits '1, 2, 3, 1, 2, 3,...' while being presented with the paired-object positions in the computer display. The order of the articulatory suppression task condition and the single task condition was counterbalanced across participants. Half of the participants performed the articulatory suppression task in the first three trials; the other half performed the task in the last three trials. A change in the recall procedure was also made. In the cued-recall procedure used in Experiment 1, the positions of the objects in the first matrix (the B-objects) and those in the second matrix (the C-objects) were recalled on two different sheets of paper in two separate successive sessions. In Experiment 2, all the positions were reproduced on the same sheet of paper containing the matrix with the marked cells (in the 0–B 0–C position-learning condition, and the 0-star 0-star position-only condition) or the A-objects (in the A–B A–C position-learning condition).

Results and discussion

Fig. 2 presents mean number of correct object positions recalled for the first matrix and the second matrix as a function of Task Type and the articulatory suppression/single task

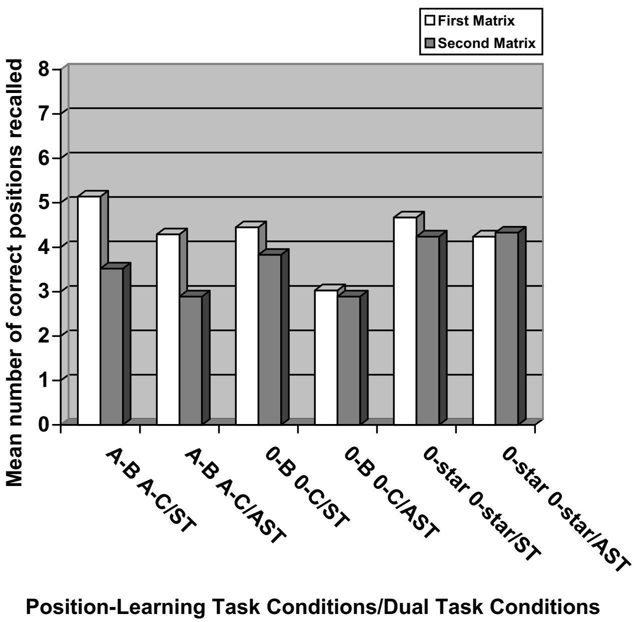

Fig. 2. Mean scores for the first matrix and the second matrix as a function of Task Type (A–B A–C position-learning, 0–B 0–C position-learning, and 0-star 0-star position only tasks) and the articulatory suppression task/single task conditions (AST/ST).

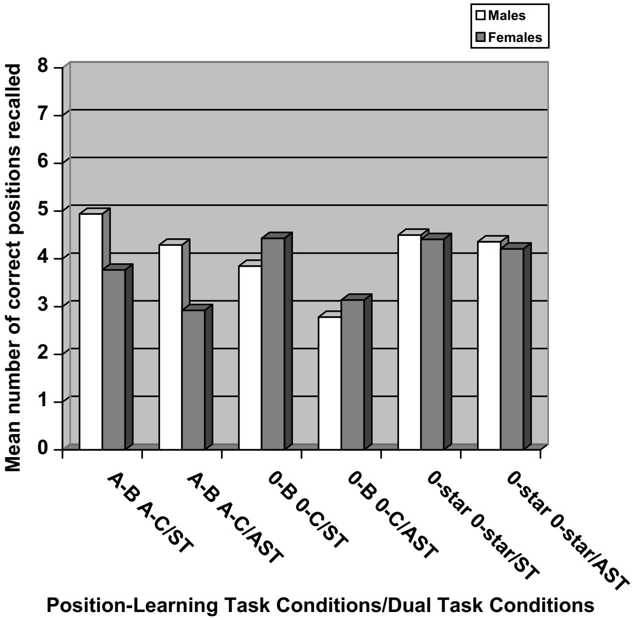

Fig. 3. Mean scores for males and females as a function of Task Type (A–B A–C position-learning, 0–B 0–C position-learning, and 0-star 0-star position only tasks) and the articulatory suppression/single task conditions (AST/ST).

condition. Mean correct scores for males and females as a function of Task Type and the articulatory suppression/single task condition are given in Fig. 3.

The data were first analyzed in an analysis of variance with Task Type and Sex (female versus male) as between-subjects variables, and Learning-order (the B versus the C-objects, or the stars in the first matrix versus those in the second matrix) and the articulatory suppression/single task condition as within-subjects variables. The results showed that the main effects of Learning-order, $F(1, 121) = 44.41$, $p < .001$, and the articulatory suppression task, $F(1, 121) = 57.31$, $p < .001$, were significant but that no significant main effect of Sex was found, $F(1, 121) = 2.42$, $p > .05$. The result concerning the sex difference is not consistent with Experiment 1. The results of Experiment 2 showed a significant interaction between the articulatory suppression condition and Learning-order, $F(1, 121) = 5.03$, $p < .03$, and between the articulatory suppression condition and Task Type, $F(1, 121) = 9.84$, $p < .001$. The interaction between Learning-order and Task Type was also significant, $F(1, 121) = 16.77$, $p < .001$. No interaction was found between Sex and the articulatory suppression condition, $F(1, 121) = .75$, $p > .05$, or between Sex and Learning-order, $F(1, 121) = .33$, $p > .05$, but there was a significant interaction between Sex and Task Type, $F(1, 121) = 6.75$, $p < .01$. The main effect of Task Type on recall was also significant, $F(2, 121) = 5.64$, $p < .01$. Further, post hoc tests (Scheffe) showed that the task type effect was due to the articulatory suppression condition; performance on the 0-star 0-star position-only task was better than that on the other two position learning tasks in the dual task condition. There was no significant difference between the three position-learning tasks in the single task condition, which is consistent with the findings of Experiment 1.

The data obtained for each type of position-learning task were analyzed by using an analysis of variance with Learning-order and the articulatory suppression task as the within-subjects variables and Sex as a between-subjects variable. In the A–B A–C position-learning condition, the effects of Learning-order, $F(1,42) = 59.28$, $p < .001$, and the articulatory suppression task, $F(1,42) = 20.22$, $p < .001$, were both significant. Thus, a significant priority effect was observed despite the fact that the recall procedure of Experiment 2 did not require the participants to discriminate between the B and the C object positions with respect to the first/second matrix membership. This finding is in line with the view that response competition alone is not capable of explaining interference phenomena (Melton & Irwin, 1940; Mensink & Raaijmakers, 1988). The results showed a significant effect of sex, $F(1,42) = 12.02$, $p < .01$, but contrary to what was expected, the male participants performed the task better than the females. No interaction was found between the variables. Thus, contrary to what would be predicted based on the verbal memory hypothesis, the non-significant interaction result indicated that the articulatory suppression task did not impair memory of the females more than the males; both sexes were affected equally by the presence of the secondary task, which inhibits the use of verbal coding in memory tasks (Baddeley, 1986). This present result is consistent with the findings of Postma et al. (1998), who demonstrated that gender performance on their object location memory tasks was not differentially affected by a concurrent articulatory suppression task.

In the 0–B 0–C position-learning condition, the effects of Learning-order, $F(1,38) = 6.54$, $p < .02$, and the articulatory suppression task, $F(1,38) = 61.23$, $p < .001$, were significant. In this condition, although mean scores of the female participants were slightly higher than those of the males, there was no significant effect of sex on recall, $F(1,38) = 1.55$, $p > .05$, and no significant interaction was found between the variables. In contrast to the findings obtained both in the A–B A–C and the 0–B 0–C position-learning conditions, there was no significant effect of learning order, $F(1,41) = .87$, $p > .05$, articulatory suppression $F(1,41) = 1.15$, $p > .05$, or gender, $F(1,41) = .19$, $p > .05$, on the 0-star 0-star position only task. No interaction between variables was found either.

Thus, Experiment 2 replicated the pattern of the results found in Experiment 1 with respect to the priority effect but not with respect to the sex difference. The priority effect was observed on the A–B A–C and the 0–B 0–C position-learning tasks while there was no effect on the 0-star 0-star position-only task. The overall effect of sex was not significant in Experiment 2, and the sex difference found in the A–B A–C position-learning condition was contradictory to the observation in Experiment 1. With respect to a sex difference, only the mean scores obtained in the 0-star 0-star position-only condition seemed to be consistent with those in Experiment 1. A possible cause for these contradictory results might be the change made in the recall procedure. In the procedure of Experiment 1, recall order of the first matrix and the second matrix previously studied in succession was counterbalanced; the participants recalled either the positions on the first matrix first and then the ones on the second matrix on two separate answer sheets or they did this in reverse order. In contrast, the participants in Experiment 2 reproduced all the positions from the two matrices on the same answer sheet containing the matrix. Therefore, in Experiment 2 there was no need to make responses with regard to matrix membership. This might have had a greater impact on A–B A–C and 0–B 0–C position-learning than on 0-star 0-star position learning because under the matrix-discrimination conditions involving different objects, for successful recall, forming of the associations between object identity information and matrix membership would be necessary. This type of detailed object-location information might have given a slight advantage to the female participants in Experiment 1. This explanation is in line with the observation that no inconsistency was seen between Experiment 1 and Experiment 2 with regard to the gender performances on the 0-star 0-star position only condition involving identical objects. Nevertheless, overall the gender factor yielded no reliable sex difference, nor interaction with the concurrent articulatory suppression task or with Task Type. The present study, therefore, failed to find strong support for Silverman and Eals's (1992) view that females would outperform males on memory tasks for object location.

Finally, an important observation in the present study was that no priority effect and no articulatory suppression effect was observed on the 0-star 0-star position only task, while both effects were present on the other two position learning tasks involving several different objects. This pattern of results suggests that it would be useful to make the distinction that verbal encoding is necessary for object location memory involving different object identity information, but is not essential for learning spatial positions involving just where information. The findings also suggest that the priority effect is a result of verbal encoding.

General discussion

The present study examined object location memory by using a paired-position learning paradigm in which positions of several different target objects or identical target objects were learned in relation to several referent objects or premarked positions. The paired-position learning paradigm was based on the A–B A–C paradigm used to study verbal memory. This allowed the opportunity to detect similarities between the two types of memory. The present results indicated that object location memory is affected by priority effects, similar to verbal memory. In addition, when a referent-object (A-object) was absent (the 0–B 0–C position learning condition), the priority effect remained, suggesting that the priority effect is not dependent on the presence of referent objects. Furthermore, the articulatory suppression task affected performance in the A–B A–C position learning condition and the 0–B 0–C position learning condition. In contrast, no priority effect or articulatory suppression effect was observed on performance for identical objects. Together, these results indicated that the priority effect and verbal processing are associated with the paired-position learning of several different objects only, but not identical objects.

Postma's dual task studies on object location memory yielded contradictory results with respect to articulatory suppression effects on performance in the condition in which positions of identical stimuli had to be reconstructed (position-only condition). Similar to the present results, Postma and De Haan's (1996) study demonstrated that an articulatory suppression task selectively interfered with learning the positions of different objects, whereas no suppression effect was found on performance in the position-only condition where all the objects used were the same (Experiment 3). However, Postma et al. (1998) failed to repeat this finding of selective interference. Performance of their participants in all the conditions including the position-only condition was affected by the articulatory suppression task. They concluded that the secondary task did not just obstruct ongoing verbal processing, but also exerted its influence by means of some form of general capacity reduction. The position-only task used by Postma and his colleagues and the position only task used in the present study both did not require use of information about different object identities, but they were very different tasks. Postma's position only task evaluated the processing of ”where” information in terms of measurable distances, metric distances between identical objects. The 0-star 0-star position only task tested the processing of “where” information about relative position (right, left, above, below) of each of several identical objects to a reference point. Thus, the position-only task used by Postma et al. might involve more general resources and therefore be more sensitive to interference from the secondary task than the 0-star 0-star position only task.

With respect to the effect of sex, while Experiment 1 demonstrated a female advantage in object location memory, Experiment 2 failed to replicate this finding. More interesting, as indicated by the absence of a sex by dual task condition (with or without the articulatory suppression task) interaction, the articulatory suppression task did not selectively impair performance of females in the present study. This finding is in line with the dual task studies by Postma and De Haan (1996) and Postma et al. (1998), who also failed to provide support for the verbal hypothesis, which maintains that a verbally mediated strategy is utilized by females in object location memory tasks.

The application of the A–B A–C paradigm to spatial memory also allowed us to evaluate the applicability of theoretical ideas put forward about priority effects in verbal learning to object-location learning. The pattern of results found across the three position learning conditions was best explained by using the mediational view of Arkes and Lyons (1979) for the priority effect. The learning of identical object positions did not produce priority effects, whereas the effects were observed in the two position-learning conditions in which positions of different objects had to be reconstructed. In these two conditions “what is where” information was necessary for successful recall, and the need for this information would cause the participants to adopt the mediational encoding strategy. That is, the B object identities and positions would be retained at the learning of the C object positions. Correct recall of the C-positions would then become dependent upon recall of B, and this would in turn result in inferior recall of the C-object positions compared to B. In line with this explanation, the calculations of conditional probabilities across the three position-learning conditions in Experiment 1 presented substantial evidence for the B–C dependence hypothesis by showing that the probability of the C positions being correctly recalled was higher when the B positions recalled were correct than when they were incorrect in the A–B A–C and the 0–B 0–C conditions. Thus, in accordance with Arkes and Lyons’s (1979) mediational view, the present study revealed a processing of B–C relations in paired position learning of different objects.

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