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Walking in the Corsi test: Which type of memory do you need?

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Abstract

Sex differences are often reported in spatial abilities. However, some studies show conflicting results, which can be ascribed to the complexity of the variables involved in the visuo-spatial domain. Until a few years ago, it was widely accepted that men outperformed women on almost all spatial tasks. However, recently some studies [A. Postma, G. Jager, R.P.C. Kessels, H.P.F. Koppeschaar, J. van Honk, Sex differences for selective forms of spatial memory, Brain Cogn. 54 (2004) 24–34; D.H. McBurney, S.J.C. Gaulin, T. Devineni, C. Adams, Superior spatial memory of women: stronger evidence for the gathering hypothesis, Evol. Hum. Behav. 18 (1997) 165–174; Q. Rahman, G.D. Wilson, S. Abrahams, Sexual orientation related differences in spatial memory, J. Int. Neuropsychol. Soc. 9 (2003) 376–383] found sex differences for selective forms of spatial memory and described a female advantage in specific spatial abilities. In this paper, we studied sex differences by testing object locations and route memories with the Corsi Block-Tapping test (CBT), one of the non-verbal tasks most used in clinical settings, and its modified, large-scale version. Our results showed a performance advantage for males in both tests and a more homogeneous pattern of memory in females.

Keywords: Sex differences; Memory for route; Memory for object locations; Corsi Block-Tapping test (CBT); Visuo-spatial memory

A common problem in everyday life is retrieving the location of one or more objects from memory. People spend a lot of time reminding themselves where they have put their keys or an important document.

Another common, everyday life situation involving memory systems is recalling a route or a shortcut a friend showed us some weeks ago to avoid a traffic jam. The question is: do we need the same type of memory to remember the location of an object and a shortcut? To answer this question, we first have to clarify that in the above examples an object is not only an object but also an object in a scene. Hollingworth [11] provides unequivocal evidence that objects in scenes are bound episodically to scene context in memory, forming a scene-level representation. This is also true for visual short- and long-term memories: both are stored as part of a larger contextual representation of the scene. Different brain regions are involved in discrete visual objects and in spatial scenes representations. The former are likely maintained in infero-temporal brain regions, and the latter in medial temporal ones [7,16].

To recall a pathway from memory requires different strategies and different memory systems. Recent reports [17,10] show that humans and animals do not acquire information about routes and object locations in the same way. Memorizing routes is a very complex task, which can be accomplished by two different systems. In one system, depending on striatum [12], reliable sequences of responses to given situations (i.e., repeating a fixed route) are learned gradually. In the other system, depending on hippocampus [36,10], flexible representations permitting novel responses (e.g., finding new shortcuts) are processed.

Sex difference studies also report differences in memory systems involved in route learning [31]. According to Grön et al. [8], women and men activate different brain regions during navigation. In fact, they found that women managed a path-finding test by engaging the right parietal and prefrontal areas, whereas men relied on the left hippocampal region.

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These differences could reflect the use of different strategies, rather than different competences, by the two sexes. When navigating, women typically pay more attention to landmarks in the environment than to Euclidean properties. On the contrary, men favour an Euclidean strategy (i.e., encoding metric distances from one place to another). In navigation both strategies are more or less useful depending on the environmental situation. If an examiner requires participants to follow either landmark- or Euclidean-based descriptions, the emergence of different navigational styles is induced by different task instructions and is not due to real sex differences [31]. Saucier et al. [31] found that males perform better when they use Euclidean information, and that females perform better when they use landmark-based navigation, suggesting that it is possible to identify different behavioral patterns in navigation only when the experimental instructions do not allow participants to use personally selected strategies. In light of these results, it is evident that the type of instructions and not different experiences, skills, or capabilities may elicit differences.

Indeed, one controversial question in literature concerns the task used to measure sex differences. Sometimes, when we read about males' and females' differences in spatial ability, we are put off course by the vagueness and amplitude of the “spatial ability” concept.

Linn and Petersen [15] identified three major spatial categories (spatial perception, mental rotation, and spatial visualization) underling that visuo-spatial ability should not be considered as a unitary concept. Meta-analyses in the literatures suggest that clear sex differences appear in mental rotation and manipulation of mental images [15,37,35].

A further unsolved problem is linked to the presence of both passive and active components in memory tasks [27,4]. According to several studies (i.e., [4,5]), an important distinction should be made between passive storage and active processing components since female disadvantage appears only when the spatial memory task implies an overload of active components.

Given the several factors that may affect performances on visuo-spatial tasks, studies using similar tests in similar populations may obtain apparently contrasting results due to subtle differences in procedures or samples.

For example, in the Corsi Block-Tapping test (CBT), one of the most important, widely used non-verbal tasks, sex differences do not always emerge and seem to be present only at specific ages [25]. Several studies [23,24,3] described a significantly larger spatial short-term memory span in men than in women. In other studies [25,13,21,33] no differences between males and females were found on the CBT. There could be different reasons for this, including differences in sample size and age of subjects. Indeed, Pagulayan et al. [25] suggested a span increase in early adolescence. In support of this statement, some studies found no differences between males and females until 14 years of age [33,21]; however, opposite results showed that males outperformed females even in early childhood [29,24,23]. The magnitude and consistency of sex differences in spatial memory have been questioned widely and it seems to be task procedure-dependent. Indeed, Mammarella et al. [18] demonstrated the existence of a double dissociation between spatial-simultaneous and spatial-sequential working memory in children with visuo-spatial learning disabilities.

These discrepancies seem very similar to those found for gender differences in the above-mentioned navigational studies. Indeed, learning or just remembering a sequence of blocks to be tapped could be very similar to recalling a sequence of places to be reached during a trip. However, the likeness of CBT with path memory has never been demonstrated. It is possible therefore that remembering a sequence of block-tapping in CBT is somehow similar to remember a sequence of steps in a route, but it is also possible that the two types of memories differ, relying on different processing. Were this case the ability to recall block-tapping sequences would not completely correspond to recall sequences of steps.

In order to test this hypothesis, we developed a new version of the CBT that specifically requires repeating a sequence of places by following a path.

In a large version of the CBT, walking allowed us to evaluate route-memory capability by measuring a pathway span, as well as learning and delayed recall of a supra-span pathway. Short- and long-term memory performances in the Walking Corsi test (WalCT) and the CBT were compared. We expected that if the two tests measured the same memory system we would find no differences; vice versa, if the two tests assessed different types of spatial memory, we would find differences between the two tests. Moreover, considering the controversy over the presence or absence of gender differences, we also investigated this question in our college student sample.

Seventy-five undergraduates (35 females and 40 males) from “La Sapienza” University of Rome were recruited. Mean age was 23.26 years (S.D. = 1.40) for women and 23.1 years (S.D. = 2.86) for men; all had 13 years of education.

Sixty-three subjects were right-handed, 11 left-handed, and 1 ambidextrous [22,30]. All subjects had normal or corrected-to-normal vision. In accordance with the local ethical committee (and the Declaration of Helsinki), all participants gave their informed consent before volunteering for this study.

The CBT [6] is a well-known test extensively used in experimental investigations and it is probably the most important neuropsychological non-verbal test, currently used to assess spatial memory in brain-damaged patients. It is suitable for studying short- or long-term memory, depending on the length of the sequence and the interval between stimulus presentation and response [34]. In this test, nine wooden blocks (3 cm × 3 cm) are affixed to a 25 cm × 30 cm baseboard in a standard random configuration [34]. On the experimenter's side of the baseboard, the blocks are numbered for easy identification (see Fig. 1a).

Three different conditions were performed: short-term memory (VSTM), learning (VSL) and delayed recall (VLTM).

In the first condition (VSTM), the examiner tapped a sequence of blocks at the rate of one block per second, and subjects attempted to reproduce the same sequence in the same presentation order. Sequences of increasing length (starting from 2-block sequences) were presented until the subject failed to reproduce three out of five trials of a given length. A span score was calculated corresponding to the larger sequence the subject is able to correctly reproduce.

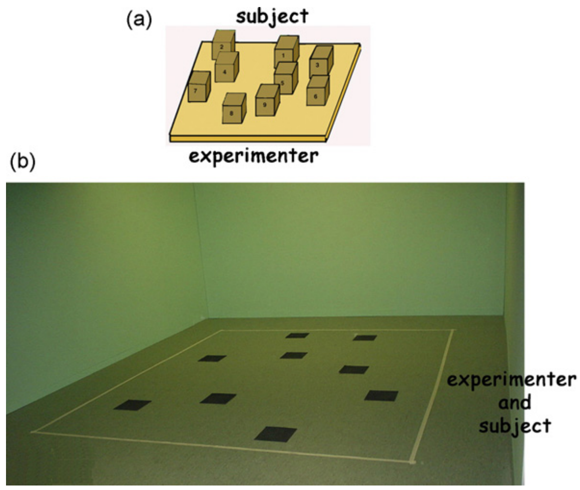

Fig. 1. (a) Apparatus used for administering the stimuli in the CBT. Numbers are only on the examiner's side. (b) Modified version of the CBT on a large scale. The scale was 10:1 and measured 2.50 m × 3 m; black squares were 30 cm × 30 cm.

In the VSL, the subject had to learn an 8-block sequence shown by the examiner [34]. The learning criterion corresponded to three consecutive correct reproduction of the sequence (maximum number of trials: 18). The score was calculated as follows: one point was given for each cube correctly tapped until the criterion was reached; then it was added to the score corresponding to correct performances on the remaining trials (up to the 18th). For example, if a subject reached the learning criterion within the 3rd presentation, he would obtain a score of 8cubes × 3 = 24 plus 8cubes × 15 = 120 for the remaining trials. Thus, the subject obtained a total score of 144, which is the maximum possible score.

Five minutes later (VLTM), the examiner asked the subject to reproduce the previously learned sequence. The score was the number of cubes the subject correctly recalled.

Subjects were tested individually in a quiet room with artificial lighting. They were seated on a height-adjustable chair in front of the CBT, face to face with the examiner.

We created a large-scale version of the CBT (scale 10:1) in an empty room (5 m × 6 m) in which walls were completely covered with curtains hiding all external landmarks (i.e., doors, heaters, etc.).

Nine black squares (30 cm × 30 cm) were placed on a 2.50 m × 3.00 m light-grey carpet (see Fig. 1b). The scaled position and the relative spatial layout of the squares were the same as in CBT.

In WalCT the experimental conditions, administration, and scoring procedures are identical to the CBT ones, except for the starting position. In fact, in order to facilitate the replication of the test, even in rooms slightly larger than the carpet, we decided that examiner and subject would use the same starting point, after controlling, in a pilot study, that different points of view do not influence performance on the WalCT [26].

In the three tasks (VLSTM, VSL and VLTM) the examiner presented each sequence by walking on the carpet and stopping on each square for 2 s.

The administration order of the CBT and the WalCT was counterbalanced across subjects, whereas the order of the three experimental conditions was unchanged in both tests.

After the testing session, an informal debriefing was carried out during which the subjects were asked to report their difficulties on both tests and the strategies they used during the experimental tasks.

Separate statistics were performed for the three experimental conditions (short-term memory—VSTM, learning—VSL, and delayed recall—VLTM). A 2 (group: M vs. F) × 2 (type of test: CBT vs. WalCT) mixed ANOVA on span scores revealed significant main effects of group ($F_{(1,73)} = 14.366$; $p < .000$) and tests ($F_{(1,73)} = 15.141$; $p < .000$), as well as a significant interaction group × tests ($F_{(1,73)} = 5.451$; $p < .02$). A Duncan post hoc analysis revealed that on both tests males had a statistically larger span than females, $p < .001$. Further, males showed a larger span on the WalCT than on the CBT ($p < .001$), while females' spans did not differ on the WalCT and the CBT. To investigate the independence of the two tests, performances on the CBT and the WalCT were submitted to a 1-way ANOVA, which showed that the span on the WalCT was significantly larger than that on the CBT ($F_{(1,74)} = 15.52$; $p < .000$).

A 2 × 2 (groups × tests) analysis of variance on learning performances revealed main effects for sex and test, $F_{(1,73)} = 3.857$; $p < .05$ and $F_{(1,73)} = 56.684$; $p < .000$, respectively. There was no significant interaction for group × test (p = n.s.). Overall, males reached the learning criterion faster than females on both tests. A 1-way (repeated measures) ANOVA showed that learning was significantly faster on the WalCT ($F_{(1,74)} = 57.74$; $p < 000$).

A 2 × 2 (group × test) ANOVA on the number of cubes/squares the subjects were able to recall after a delay yielded no significant main effect for group (p = n.s.). Males and females did not differ in recalling what they have learned, and both recalled almost the same number of cubes or squares. The sequence in WalCT was recalled better than that in the CBT ($F_{(1,73)} = 97.560$; $p < 002$). No significant interaction effects on test and group were present (p = n.s.). The 1-way ANOVA assessing the independence of the two tests revealed a significant difference between the WalCT and the CBT($F_{(1,74)} = 9.58$; $p < .01$) (Table 1).

The present study investigated the relationships among sex, memory for object location and memory for routes by using a standard, well-known test (CBT) to evaluate the first type of memory and a modified version of this test (WalCT) to assess memory for routes.

The CBT [6] is a simple, but powerful, test widely adopted in the last quarter of a century by clinical neuropsychologists to study large clinical population [14] as well as by researchers to investigate memory processes in healthy subjects [3,23].

In the last decade, more attention has been paid to the wholeness or the fragmentation of spatial memory. There is evidence that non-verbal, short-term memory has distinct visual and spatial-sequential components. For instance, Grossi et al. [9] found two Alzheimer patients presenting contrasting patterns of impairment. One patient had a normal score on the CBT but a deficit on the visual matrix task [VMT: 14]; the second patient presented the opposite pattern. These results suggest that even

Table 1
Reports of the means and standard deviations (S.D.) of the span, the learning criterion, and the delayed recall obtained in the CBT and the WalCT

Group	CBT span	WalCT span	CBT learning (no. of cubes)	WalCT learning (no. of squares)	CBT LTM	WalCT LTM
Males ($n = 40$)	5.28 (0.88)	6.08 (1.25)	118.55 (22.42)	142.68 (15.11)	7.53 (1.09)	7.93 (0.35)
Females ($n = 35$)	4.83 (0.82)	5.03 (1.04)	115.91 (20.11)	133.06 (11.82)	7.11 (1.84)	7.74 (0.89)

Means and standard deviations of the number of cubes/squares: subjects were able to repeat immediately (span); necessary to reach the learning criterion plus the overall cubes/squares of the remaining trials (learning); of previously learned cubes/squares subjects were able to recall after 5 min.

though CBT and VMT appear to test the same spatial memory processing, actually they may assess different functions. Indeed, differences in spatial memory tasks might be explained by the procedure. In fact, Mammarella et al. [18] demonstrated a double dissociation between spatial-simultaneous and spatial-sequential working memory in visuo-spatial learning-disabled children. The existence of this double dissociation suggests the importance of investigating the modality of stimulus presentation in sex differences. In this study, we used spatial-sequential tasks and the comparison between CBT and WalCT to contrast two tasks that use the same procedure.

More recently, several studies (i.e., [28,2]) have focused on how precisely tests measure spatial memory. Attempts to list different spatial memories distinguish at least between memory for object locations and two different types of memory for routes and spatial working memory [10,13]. This question is crucial for understanding the connection between spatial memory and memory for routes and it is a fundamental issue in clinical setting, since a clearer distinction would enable to identify most suitable tests for assessing memory deficits. Indeed, in clinical observations patients suffering from topographical disorientation are not affected by memory deficits on CBT, thus leaving open the question about which type of memory is compromised in topographical disorders.

This distinction might also explain the conflicting results reported in literature. It is well known that males outperform females on a wide range of tasks involving spatial abilities. However, Postma et al. [28] found the opposite pattern for selective forms of spatial memory. Moreover, a distinction between active processing and passive storage has been recently suggested in theories of visuo-spatial memory [35,5]. This distinction seems to be crucial since the amount of active processing should be a critical variable in determining sex differences [35].

In light of these data, it seems important to identify specific tasks to test different competences. We believe that, even though CBT is a gold-standard for testing spatial memory, it is ill-suited for measuring memory for routes. This kind of memory that is measured by WalCT, differs from that measured on CBT in several respects. First, it also involves memory for idiothetic information, so that learning or recalling sequences is easier on WalCT because visuo-spatial and idiothetic information is summed as occurs when we move in a real environment. Second, in WalCT the subjects' point of view of the display continuously changes depending on their movements on the carpet while repeating the sequence. This requires continuous updating of the mental representation of the display and the subject's position in the environment, making this test more complex than CBT. Furthermore, we should take in consideration that the rate of stimuli presentation differs in the two tests and could be responsible for the observed differences. However, WalCT seems to be easier than CBT despite its longer inter-stimulus rate. Furthermore, in literature the inter-stimulus interval has little or no effect on performances in not elderly population [32,20]. Therefore, the possible effect of the presentation rate, even deserving further investigation, does not seem to be very relevant. The presence of significant differences in the tests *per se* suggests that CBT and WalCT measure different components of memory.

Generally, subjects had a larger span, learned faster, and recalled better the squares of WalCT than the blocks of CBT. Moreover, they reported visualizing a pathway on the carpet, i.e., an ideal line joining the squares covered by the examiner, which helped them reproducing the sequences. They did not report having similar experiences on the CBT. It is also true that, as already stressed, when subjects walk in the environment to reproduce the sequence they do not use only spatial memory but also idiothetic memory based on vestibular and proprioceptive information relative to their whole body movements. It is very likely that this type of memory is linked to a more basic function in everyday life, such as remembering a pathway in the environment. Subjects also reported that in the delayed recall of WalCT they consulted a sort of map stored in their mind. Once again, they had no similar experience on CBT. These subjective reports suggest that the WalCT and the CBT actually involve different types of processing. WalCT seems requiring more active processing, above all regarding subjects' ability to re-organize information during the reproduction of the pathway. In their debriefing subjects described being confused when they were in the middle of the carpet, reproducing the sequence they had just seen, and that they got lost in the aerial view of the scene. In any case, regardless of their reports, subjects performed better on WalCT than on CBT. This suggests the presence of a more active component; however, in this case, we should have observed a simultaneous disadvantage in females' performances, since females are generally disadvantaged when active processing loading increases (i.e., [4]). Instead, we found that females had the same span when they walked on the squares and when they tapped the cubes, while males not only had a larger span than females on both tests, but also performed better on WalCT than on CBT. Males were faster than females in learning the supra-span sequence. Sex differences, however, completely disappeared once the sequence had been learned. The smaller span in females and their slower learning were unrelated to the possibility of storing and recalling previously learned spatial information from long-term memory.

To explain gender differences in navigation, some researchers [1,19] refer to evolutionist theories suggesting females have an advantage on tasks requiring what is at the same location and differentiating this from other locations, and that males have an advantage on tasks such as way finding, judgment of metric properties, and heading direction. Based on these assumptions, since present results suggest that CBT and WalCT measure different memory processing, if we hypothesize that CBT is more similar to an object location task and WalCT to a route-memory task, we should expect that women will outperform men on the CBT and that men will outperform women on the WalCT. Although we did not observe this trend, we found that females performed worse on both tests and that, although males had a larger span on the WalCT than on the CBT, females did not show any difference between tests.

At this point, we wondered which are the actual differences between CBT and WalCT and what might be the reason for the absence of a female advantage in CBT. Future studies should investigate which neural correlates are involved in the CBT and the WalCT to explore more thoroughly which type of spatial memory they actually measure.

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