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Sex differences for selective forms of spatial memory

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Abstract

In the present study, a systematic comparison of sex differences for several tests of spatial memory was conducted. Clear evidence for more accurate male performance was obtained for precise metric positional information in a wayfinding task and in an object location memory task. In contrast, no sex difference characterized topological information processing (object-to-position assignment). Together, these findings provide further insight in the specificity of sex differences in spatial memory and in the functional architecture of spatial memory. Implications for the relevant evolutionary basis are discussed.

Keywords: Spatial memory; Sex differences; Evolution

1. Introduction

Spatial memory concerns the ability to store knowledge about spatial features of our environment, and to retrieve it at a later moment in time, typically allowing purposeful behavior. Spatial memory is vital for many everyday tasks, as well as for an organism's well-being in general. It allows us to remember where important objects in our surroundings are, so we can find them when needed. Moreover, it provides a general overview or map of space that can be used for navigation. Because of this eminent relevance, special neural circuitry for encoding and storing spatial information has evolved in birds and mammals. O'Keefe and Nadel (1978) argued that the hippocampal formation inside the medial temporal lobe forms the neural substrate for a cognitive map of space. Interestingly, damage to the hippocampus in both animals and humans is typically associated with highly defective spatial learning and orientation (cf. Kessels, de Haan, Kappelle, & Postma, 2001). Sherry, Jacobs, and Gaulin (1992) point out that interspecies as well as intraspecies differences exist in hippocampal volume. The latter suggest that males and females might differ in spatial memory ability. The question we intend to address in the present study is in how far this also applies for humans.

The number of studies on human sex differences which include a test of spatial memory has substantially increased over the years. Intriguingly, they have yielded several seemingly conflicting results and conclusions. Some argue that men outperform women, in line with the generally supposed male superiority for spatial abilities, whereas others take the opposite view (Eals & Silverman, 1994; Silverman & Eals, 1992). Two major reasons can be conceived for these controversies. First, spatial memory is a rather complex function, crossing the hypothesized main dimensions of spatial ability, and depending on multiple functional requirements (e.g., attention, general memory capacity, the handling of spatial information). Second, similar to spatial ability in general, spatial memory clearly is not a single unitary function, but instead forms a multidimensional concept (Kessels et al., 2001; Postma, 2000; Schacter & Nadel, 1991). Consequently, spatial memory can be operationalized in multiple ways. In turn, these different forms of spatial memory might show a distinct pattern of sex differences.

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Regarding the first reason, studies contrasting general (nonspatial) memory differences between men and women with differences in spatial memory are relevant. Lewin, Wolgers, and Herlitz (2001) report that women have a higher verbal and nonverbal episodic memory score, whereas men tended to be better on visuospatial episodic memory tests. Similarly Herlitz, Nilson, and Backman (1997) found superior female scores on tests of nonspatial episodic memory. McGivern et al. (1997) demonstrated that both young and adult females outmatched males on visual recognition memory. The difference was mediated by the type of objects which had to be recognized. That is, it disappeared when more male-oriented objects were used. Summarizing, women seem to have a better general (episodic) memory capacity, This advantage can disappear or reverse if the information to be memorized includes a high degree of spatial processing.

As mentioned above, a central question is how to precisely measure spatial memory. A tentative taxonomy of spatial memory distinguishes between spatial working memory, memory for routes and sequential spatial information, and knowledge about spatial layouts, such as involved in memory for object locations (cf. Kessels et al., 2001, 2002; Postma, 2000; Schacter & Nadel, 1991). To what extent do sex differences vary for the distinct forms of spatial memory? A widely used test of spatial working memory is the Corsi Block-Tapping Task. The examiner taps sequences of increasing length over nine cubes mounted on a board. Subjects have to replicate this sequence. By increasing the length of the sequences, spatial working memory span can be estimated (Kessels, Postma, Kappelle, & De Haan, 2000a; Kessels, Van Zandvoort, Postma, & De Haan, 2000b). Orsini et al. (1986), Orsini et al. (1987), and Capitani, Laiacona, and Ciceri (1991) demonstrated a significantly larger spatial memory span in men than in women. These studies tested huge numbers of subjects (>400). Kessels et al. did not obtain a sex difference on the Corsi Block-Tapping Test, however, in a study of 70 healthy controls and 70 brain damaged patients. Possibly, these effects are rather small and hence are only found in very large sample sizes. It may be noticed that this spatial working memory test critically relies upon spatiotemporal integration (Ferreira, Verin, Levy, Dubois, & Agid, 1998) and the ability to keep these space–time links active for a limited period of time.

Route learning can be achieved both by studying a map and by actual navigation through an environment. In either case, one needs to store a sequence of spatial decisions in order to remember the route. Galea and Kimura (1993) observed that men performed superiorly in learning a route on a map. Men also remembered general metric properties better. Women, however, tended to recall more of the landmarks visible on the map. Dabbs, Chang, Strong, and Milun (1998) and Miller and Santoni (1986) also supported the notion that women and men rely on different strategies (landmark vs metric) when learning a route on a map. Gron, Wunderlich, Spitzer, Tomczak, and Riepe (2000) reported that men were faster than women in finding their way out of a virtual maze. Interestingly, this was accompanied by partly different patterns of brain activation. When route knowledge is acquired and tested by actual navigation in the real world, not only visual signals are important, but information on whole-body movements through space is assembled as well. The latter includes both motor programs and vestibular signals (Berthoz, 1999; Worsley et al., 2001). Lewin et al. (2001) did not find a significant difference between men and women in recalling a route between various objects within a room. Similarly, Lawton and Charleston (1996) did not observe men and women to differ in an incidental wayfinding task in an indoor environment. At the end of the route men were better, however, in locating the direction of the starting point. More recently, Silverman et al. (2000) demonstrated men to perform better than women on several measures of wayfinding on a circuitous route through a wooded area. Subjects in this study did not have to reproduce the actual route, but rather had to find the shortest way to the starting point. Thus, there is a clear advantage to continously mentally update one's position with respect to point of depart. Interestingly, the wayfinding measures correlated significantly with mental rotation ability, which according to the authors reflects a selectively evolved, shared underlying spatial mechanism (i.e., space constancy).

The original inputs in route learning and wayfinding situations are dynamic, engaging a 'from within the environment' perspective. In contrast, object location memory taps a more static view of environmental space, with the original input yielding a 'from above' perspective.[1] Typically, it is tested by presenting a number of objects within a frame—such as on a tabletop or on a computer screen—for some time. Subsequently, one has to reproduce the original positions of the studied objects or recognize in a new display which objects occupy their original locations and which do not. Most of the discrepancies regarding sex differences in spatial memory stem from studies testing object location memory. Silverman and Eals (1992; Eals & Silverman, 1994) showed female superiority in a paper and pencil test, in which subjects had to mark those objects in an array that had changed places from a previously studied display. James and Kimura (1997) further precised this difference by noting that women were only better for object exchanges,

[1] We presume that object location memory relies on an allocentric (absolute, viewer independent) appreciation of space. Note, however, that small-scale displays usually include an alignment of test and presentation displays. Thus, items are perceived from the same perspective, and performance might party rely on viewer-centered, egocentric coding as well (Postma, Kessels, & van Asselen, 2003).