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No sex differences in spatial location memory for abstract designs

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ABSTRACT

Previous research has demonstrated a female advantage, albeit imperfectly, on tests of object location memory where object identity information is readily available. However, spatial and visual elements are often confounded in the experimental tasks used. Here spatial and visual memory performance was compared in 30 men and 30 women by presenting 12 abstract designs in a spatial array for recall and recognition (visual memory) and spatial location ("object" location memory). Object location memory was measured via a sensitive absolute displacement score defined as the distance in mms between the position assigned to the object during recall and the actual position it originally occupied. There were no sex differences in either the visual or spatial location tests. Controlling for age and estimated IQ scores made no impact on the results. These data suggest an absence of a sex difference in purely visual and spatial aspects of object location memory.

1. Introduction

Several decades of research on sex differences in spatial cognition have found selective male-favoring and female-favoring performance biases, contrary to the popular stereotype of men performing better on "all things spatial" (Hamilton, 2008; Kimura, 1999). The robust male advantage on tests of mental rotation, judgement of line orientation, and spatial navigation is well documented with effect sizes ranging from 0.7 to 1.2 (Astur, Ortiz, & Sutherland, 1998; Driscoll, Hamilton, Yeo, Brooks, & Sutherland, 2005; Moffat, Hampson, & Hatzipantelis, 1998; Rahman & Koerting, 2008; Saucier, Green, Leason, MacFadden, & Elias, 2002; Voyer, Voyer, & Bryden, 1995).

In the early 1990s researchers began to show that women also outperformed men, on average, on what was ostensibly considered a "spatial task" involving remembering the locations of previously seen objects on an array (Eals & Silverman, 1994; Silverman & Eals, 1992). This work cast further doubt on the claim that men excelled at all spatial abilities and has paved the way for a task-specific view of human cognitive sex differences. In a meta-analytic review of the extant literature (comprising 123 effect sizes from 36 studies), women have been shown to perform better than men on most tests of object location memory, particularly those involving objects whose identities are readily available (Voyer, Postma, Brake, & McGinley, 2007). The mean weighted effect size for the female bias reported in that meta-analysis was 0.269, but this was influenced by age and object type (the sex difference is found after 13 years of age with the exception of objects classed as feminine, uncommon or gender-neutral). Recent research also appears to confirm that women outperform men in location recall of objects under conditions where the objects have exchanged places, shifted position, or when new objects are added to a previously seen array. This occurs across a range of presentation formats, in addition to the standard paper-and-pencil tests, and includes computerized object arrays, virtual reality environments, actual "table-top" displays, and internet-based test batteries (Hassan & Rahman, 2007; Levy, Astur, & Frick, 2005; Rahman, Wilson, & Abrahams, 2003; Silverman, Choi, & Peters, 2007; Spiers, Sakamoto, Elliot, & Baumann, 2008).

One of the important findings from Voyer et al. (2007) was the number of studies reporting no sex differences in object location arrays across presentation formats (e.g., Dabbs, Chang, Strong, & Milun, 1998; Epting & Overman, 1998; Janzen & Van Turennout, 2004; Jones & Healy, 2006; Kessels, Nys, Brands, van den Berg, & Van Zandvoort, 2006; Postma, Jager, Kessels, Koppeschaar, & Van Honk, 2004). Still others report sex differences only in sub-conditions of the tests used; for objects presented close to the body (Saucier, Lisoway, Green, & Elias, 2007) or for object exchanges but not object shifts (James & Kimura, 1997 cf. Hassan & Rahman, 2007; Levy et al., 2005 although these latter studies applied object exchange and shift arrays in sequence which may cause interference effects which was not the case in James and Kimura). Another study reported better performance by women on location exchanges for objects presented in the right side of the array compared to objects presented in the left side, and compared to the performance of men (Alexander, Packard, & Peterson, 2002). These,

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and other inconsistencies, have led some authors to suggest that a strong version of the claim that women are better than men on object location memory is unwarranted (Postma et al., 2004). In support, a series of studies using computerized tests have shown that men outperformed women on a "distance" measure of object location memory (where object identities are removed). However, these studies report no sex differences on two other components called "object-to-position assignment" (in which different objects are relocated using pre-marked positions) and "object-to-location binding" (in which different objects are relocated without marks; Postma, Izendoorn, & De Haan, 1998; Postma et al., 2004). The latter two components are comparable to the exchange, shifts, and novel objects conditions in the paper-and-pencil arrays used often in previous studies. One study using an actual room environment also confirms these findings (Iachini, Sergi, Ruggiero, & Gnisci, 2005). The distance measure on which men excelled (referred to as metric positional encoding) appears to be a more "purer" test of the spatial component of object location memory tasks. These findings take us back somewhat to the common viewpoint that perhaps men are indeed better at purely spatial elements of cognitive tasks, even those which on first sight appear to be female favoring.

The current state of research suggests that further work is needed to dissociate and empirically test different cognitive task characteristics that may be responsible for the inconsistent findings. Indeed, Voyer et al. (2007) and Postma et al. (2004) suggest work is needed to separate "purely spatial" from relatively nonspatial components of object location memory (see also Gallagher, Neave, Hamilton, & Gray, 2006). Here we propose to test this by examining sex differences in spatial location memory for abstract designs which cannot be easily verbalised (although a recent study indicated that the female advantage is robust irrespective of how easy it is to verbalize the object stimuli; Lejbak, Vrbancic, & Crossley, 2009). Moreover, the use of such a task allows us to separate spatial and visual memory which may have been confounded in previous tests. This is important as several studies (conducted in parallel but separately from research on object location memory) have reported a female advantage in verbal episodic memory, and some visual episodic memory tasks which cannot be fully explained by higher verbal ability in women (Herlitz, Airaksinen, & Nordström, 1999; Hertilz, Nilson, & Bäckman, 1997; McGivern et al., 1997 cf. Lewin, Wolgers, & Herlitz, 2001).

The distinction between spatial and visual memory is also of relevance to understanding the neuroanatomical correlates of putative sex differences. A puzzling aspect of the extant research is the absence of sex differences in hippocampal neural activation during performance on spatial memory tasks or in hippocampal anatomical structure (e.g., Blanch, Brennan, Condon, Santosh, & Hadley, 2004; Janzen & Van Turennout, 2004). Yet, within classical neuropsychological research the link between hippocampal structure and function and spatial location memory is robust (e.g., Kessels, De Haan, Kappelle, & Postma, 2001). Part of the puzzle arises from the observation that the sexes appear to differ in two aspects of spatial memory – object location memory which appears female-favoring and spatial navigation which appears male-favoring – both of which depend on hippocampal integrity. This makes sex differences in hippocampal structure and function difficult to isolate.

A somewhat specific spatial deficit in patients with hippocampal lesions appears to support the notion that this structure plays a large, if not exclusive role, in spatial location memory (Kessels et al., 2001). However, early work demonstrating a deficit in location memory among patients with right temporal lobectomy (RTL; and thus including damage to large parts of the hippocampal formation) confounded spatial and visual memory components (Abrahams et al., 1999; Feigenbaum, Polkey, & Morris, 1996; Piggott & Milner, 1993; Smith & Milner, 1981, 1989). Independent reports have also shown that patients with RTLs have deficits in tasks requiring purely visual memory including object, faces and "door" recognition as well as learning and recalling complex designs (Abrahams, Pickering, Polkey, & Morris, 1997; Jones-Gotman, 1986a, 1986b; Morris, Abrahams, Baddeley, & Polkey, 1995; Morris, Abrahams, & Polkey, 1995). Subsequent work in which experimental tasks were created so as to separate spatial and visual memory indicate that spatial, but not visual, memory is the primary deficit seen in RTL patients (thus implicating hippocampal formation). Nunn, Polkey, and Morris (1998) matched healthy controls, RTL and LTL patients on the recall and recognition of abstract designs (visual memory). RTL patients showed a significant deficit in the ability to accurately relocate the designs to previously seen locations (location memory) compared to healthy controls and LTL patients. In addition, the extent of hippocampal resection was significantly correlated with spatial location memory deficits in the RTL group only. These lines of evidence suggest that separating visual from spatial memory may help illuminate the cognitive components in which sex differences might also be found. These components may then be subject to further study using methods to isolate the relevant neural correlates in both sexes (e.g., in neurological patient populations and neuroimaging investigations). Note that one often cited study did report greater activation in the left hippocampus in men compared to women during a maze navigation task (Gron, Wunderlich, Spitzer, Tomczak, & Riepe, 2000). However, this isolated finding is inconsistent with the documented role of the right hippocampus in spatial memory (the left hippocampus on the other hand is strongly implicated in verbal but not spatial memories) and has never been replicated.

To address some of the inconsistencies in previous work, we used a version of the "design location memory" task developed by Nunn et al. (1998) to test for sex differences in the recall and recognition (visual memory) and location (location memory) of 12 abstract designs presented on a spatial array. The task permits us to dissociate "visual memory" from "object location memory" by asking participants to explicitly recall the designs, identify them from a set of foils, and recall their locations separately. The task also reduces the use of verbal strategies due to the abstract nature of the designs. We used 12 abstract designs, compared to the 8 used by Nunn et al. (1998), in order to increase task difficulty for our sample of healthy adults. Based on the evidence for the task-specificity of cognitive sex differences and the apparent male-advantage during memory for object locations when object identities are removed (producing a more "purer" spatial task; Postma et al., 2004; Voyer et al., 2007), we predicted that men would perform significantly better than women on the "object" location memory component of the task. We made no directional predictions regarding sex differences in visual recall and recognition due to the ambiguity of the current literature on these aspects.

2. Method

2.1. Participants

Sixty participants (18–43 years) took part (30 men and 30 women) who were recruited via advertisements from the student population of Queen Mary University of London and the local community (East London region). Participants were screened for general physical and neuropsychiatric health via a check-box questionnaire. The range of conditions included severe anxiety, recurrent depression, schizophrenia, manic depression, speech and language disorders, panic attacks, severe alcohol and drug dependence, severe oppositional behavior as a child, dissociation, any head injury, epilepsy, learning disability, any other developmental delay, and any other neurological disorder. No participants