Selective Sexual Orientation–Related Differences in Object Location Memory

Bano Hassan

University of East London

Qazi Rahman

University of East London and Institute of Psychiatry at King’s College

The present study examined sexual orientation–related differences in object location memory by using 3 object arrays (testing object exchange, object shift, and novel objects conditions) and 1 metric positional memory array. Heterosexual women and homosexual males significantly outperformed heterosexual men in all 3 object arrays. However, there were no group differences in metric positional memory. Heterosexual males expectedly outperformed the other groups in spatial perception (Judgment of Line Orientation; A. L. Benton, K. D. Hamsher, N. R. Varney, & O. Spreen, 1983). Regression modeling revealed that sexual orientation and spatial perception predicted object exchange performance, whereas recalled childhood gender nonconformity, a robust developmental marker of adult sexual orientation, predicted object shift and novel object performance alone. A measure ascribed to the actions of prenatal androgens, the 2nd to 4th finger length ratio, did not predict object location memory. These data may limit possible developmental pathways for sexual variation in selective forms of spatial memory.

Keywords: sexual orientation, object location memory, metric positional memory, childhood gender nonconformity, prenatal androgens

Sexual dimorphisms in certain forms of human spatial memory are known to be among the largest (in terms of effect size) and most robust individual differences documented (e.g., Astur, Tropp, Sava, Constable, & Markus, 2004; Kimura, 1999). These take the shape of male advantages in tests of egocentric (viewer-dependent) place learning across several presentation formats (in paper-and-pencil tests: Choi and Silverman, 1996; Dabbs, Chang, Strong, & Milun, 1998; Galea & Kimura, 1993; tasks using photographs: Holding and Holding, 1989; real-life terrain level routes: Saucier, Green, MacFadden, & Elias, 2002; Silverman et al., 2000; and computer simulations using “mazes”: Moffat, Hampson, & Hatzipantelis, 1998) as well as on virtual reality human analogues of classic allocentric (viewer-independent) paradigms derived from rodent models of hippocampal functioning (e.g., the Morris water maze). Here, men show shorter latencies to locate hidden platforms and spend more time in the training quadrant of the tasks compared with women (Astur, Ortiz, & Sutherland, 1998; Astur et al., 2004; Driscoll, Hamilton, Yeo, Brooks, & Sutherland, 2005; Jonasson, 2005; Sandstrom, Kaufman, & Huettel, 1998). Sex differences are not found on human analogues of another commonly used spatial navigation test in rodents, the radial-arm maze (Astur et al., 2004; Levy, Astur, & Frick, 2005). The preceding studies have also noted sex differences in spatial strategies such that men use primarily Euclidean (geometric) cues (and descriptors about distances and cardinal directions), whereas women use primarily landmark (using environmental information and descriptors) cues to aid navigation (e.g., Dabbs et al., 1998; Rahman, Andersson, & Govier, 2005; Sandstrom et al., 1998; Saucier et al., 2002).

The observation that women rely primarily on landmark cues suggests that they encode and manipulate information about object identities and object locations better than men do. Intriguingly, studies on human sex differences in object location memory have yielded conflicting results (Voyer, Postma, Brake, & McGinley, in press). Several studies have demonstrated that women are better than men in object location recall for objects that have exchanged places or when new objects are added to a previously studied display (Eals & Silverman, 1994; McBurney, Gaulin, Devineni, & Adams, 1997; Silverman & Eals, 1992). However, some studies have shown that women were better only for object exchanges and not for objects displaced from their original locations (James & Kimura, 1997, cf. Duff & Hampson, 2001); others reported no sex differences in paper-and-pencil object array tests (Dabbs et al., 1998; Eping & Overman, 1998; Postma, Jager, Kessels, Koppe-schaar, & Van Honk, 2004); one study reported better performance by women on exchanges for objects presented in the right hemisphere (indicating left hemisphere advantage; Alexander, Packard, & Peterson, 2002); and one further study showed that women produce smaller absolute displacement scores than men (but no sex differences in verbal object recall or object recognition) when placing real-world objects back in their original locations following a delay on a “table top” task (Rahman, Wilson, & Abrahams, 2003).

It is important to note that a series of investigations that fractionated object location memory into three subcomponents—object-to-position assignment (in which different objects are relo-
cated with the aid of premarked positions), metric positional memory (in which all objects were identical, thus requiring recall of precise positions only), and object-to-location binding (in which different objects had to be relocated without marks)—showed that men outperform women on metric positional memory only, with no sex differences in the remaining conditions (Postma, Izendoorn, & De Haan, 1998; Postma et al., 2004; Postma, Winkel, Tuiten, & Van Honk, 1999). These authors argue that their object-to-location assignment condition (in which they report no sex differences) is comparable to exchange, displacement, and novel object conditions in the arrays used in previous studies, whereas the positional memory condition (in which they report a male advantage), requiring recall of metric information, is novel and should be factored into further studies. Because of this, these authors argue that female superiority in object location memory remains highly circumspect. It is unclear whether such disparate findings are due to the nature of sex differences in specific subcomponents of object location memory or to methodological differences (Voyer et al., in press). Nonetheless, the array of manipulations detailed above (object exchange, object shift, novel objects, and metric positional memory) had not been tested in a comparative design, and this was a central goal of the present study. Recently, Levy et al. (2005) have shown that women outperform men in two-dimensional arrays tapping exchange, shift, and novelty conditions, but they did not examine metric positional memory.

It is important to note that the above studies on object location memory are unclear as to the frame of spatial reference examined. They have assumed that it relies on allocentric processing (Postma et al., 2004), yet all studies use small-scale displays and comprise an egocentric frame of spatial encoding because participants are seated in front of the object arrays and do not switch position.

Sex differences in spatial memory are further confused by reports of within-sex variation attributable to sexual orientation. Heterosexual men consistently outperform homosexual men on basic spatial ability tests known to favor males, such as Mental Rotation, the Water Level test, and Judgment of Line Orientation (Glade, Beatty, Larson, & Staton, 1990; McCormick & Witelson, 1991; Neave, Menaged, & Weightman, 1999; Rahman & Wilson, 2003; Sanders & Ross-Fielde, 1986; Wegesin, 1998). However, homosexual men also display significantly smaller absolute displacement scores (female-typical) than heterosexual men in the “table top” task of Rahman, Wilson, and Abrahams, (2003), and homosexual men use a significantly greater landmark-based navigation strategy (female-favoring) than do heterosexual men (Rahman et al., 2005). The effect sizes for the men’s contrasts in both these studies were large, suggesting they were nontrivial group differences. Heterosexual and homosexual women do not differ in any measure of spatial cognition and memory thus far examined. Because of this, the present study opted not to include homosexual women in the design.

The neurodevelopment of sex and sexual orientation–related differences in spatial memory functions has been proposed to depend upon prenatal androgen levels (Jonasson, 2005; Rahman, 2005). The prenatal androgen theory proposes that neurobehavioral differences between the sexes are controlled by organizational gonadal androgens. Homosexuals are predicted to show sex-atypical neurocognitive patterns, consistent with the atypical shift in their sexual partner preference, under the actions of these androgens (Ellis & Ames, 1987; Rahman, 2005). Thus far, the pattern of cross-sex shifts in spatial cognition among homosexual men is supportive.

Interestingly, there are few investigations concerning the role of prenatal or developmental factors in sexual orientation–related cognitive differences. Because invasive measurements of prenatal androgens are impractical for comparative studies in adults, researchers have used somatic markers assumed to develop under the actions of these sex steroids, such as 2nd to 4th finger length ratios (or 2D:4D; Manning, 2002). Low 2D:4D ratios (male-typical; Manning, 2002) are known to be robustly associated with greater testosterone exposure in utero (Brown, Hines, Fane, & Breedlove, 2002; Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, & Manning, 2004) and relate to homosexuality in men and women (McFadden et al., 2005; Rahman, 2005). Moreover, 2D:4D among women (sexual orientation not specified) is correlated with volumetric asymmetry of the hippocampus and improved place learning scores (Csatho et al., 2003; Kallai et al., 2005). However, Rahman, Wilson, and Abrahams (2004) found that 2D:4D did not independently predict variance in sexually dimorphic cognitive performance above that predicted by sexual orientation. One final developmental consideration in sexual orientation studies is extensive evidence for an association between childhood sex atypicality in play behavior, interests, and activity, or “childhood gender nonconformity” (CGN), and homosexuality in men and women (examined prospectively and retrospectively; Bailey & Zucker, 1995). It has been suggested that CGN is an endophenotype (that is, “closer” to genetic and/or prenatal influences on a trait) for sexual orientation, being substantially more heritable than sexual orientation per se (Bailey, Dunne, & Martin, 2000). Thus, CGN may be a better predictor of cognitive and behavioral differences associated with sexual orientation than sexual orientation per se.

In the present study, we sought to examine sexual orientation–related differences in object location memory under three conditions (object exchange, object shift, and novel object), using object arrays and one condition of metric positional memory. We predicted that heterosexual women and homosexual men would perform significantly better than heterosexual men on object exchange, object shift, and novel object conditions. Heterosexual men were predicted to perform significantly better than heterosexual women and homosexual men on metric positional memory. For comparative purposes, we also predicted that heterosexual men would score significantly better on a measure of spatial perception, the Judgment of Line Orientation test, than the other two groups. This study also investigated the novel nondirectional hypothesis that two developmental markers previously associated with human sexual orientation (CGN and 2D:4D) would predict cognitive differences.

Method

Participants

Sixty participants (ages 18–45 years) were recruited (20 heterosexual men, 20 heterosexual women, 20 homosexual men). Participants were screened via semistructured interview to exclude any history of psychiatric or neurological morbidity, head injury, learning disability, or drug abuse in self or in first-degree relatives. Heterosexuals and homosexuals were recruited from similar sources (university student organizations, including gay and les-
bian societies), and all came from the southeast and London regions of the United Kingdom. Sexual orientation was assessed using self-identification (gay, heterosexual, straight, or bisexual) and a single-item question about sexual feelings (attractions and fantasies) on a 7-point scale (0 = exclusively heterosexual, 6 = exclusively homosexual). Only participants who responded either 0 and 1 (heterosexual) or 5 and 6 (homosexual) and checked either “gay” or “heterosexual/straight” on self-identification took part (bisexual respondents were excluded). Thirty-five of the 60 participants were White, and the remaining were of non-White ethnicity (2 Black, 19 South Asian, 1 Hispanic; 3 “other”). The groups did not differ in ethnic makeup, $\chi^2(2, N = 60) = 4.25, p > .10$. They also did not differ in age, years spent in education since the age of 5, or handedness scores (evaluated using the Edinburgh, Scotland, Handedness Inventory [EHI]; Oldfield, 1971; all ps for one-way analysis of variance [ANOVA] > .10; see Table 1).

Among heterosexual women, 7 were taking oral contraceptives, 2 were classified as in the menstrual phase of their cycles during cognitive testing (2–5 days from the onset of the last menstrual period), 5 were considered as in the midluteal phase (5–10 days counting backward from the onset of the next menstrual period), and 12 were classified as “other” (all other days).

**Procedure**

Written informed consent was obtained from all participants, and the University of East London Ethical Committee for Research Studies approved all procedures. The cognitive battery was administered in a fixed order similar to that for Levy et al. (2005). Participants completed the first two object arrays (object exchange and object shift), followed by the IQ and Judgment of Line Orientation tests (lasting approximately 10 min), then the third object array (novel objects), and finally the metric positional memory task. A CGN questionnaire was then completed and finger measurements taken. The entire testing session lasted approximately 40 min.

**Object Location Memory Task**

Using the tasks designed by Levy et al. (2005), we presented participants with a stimulus array of black-and-white drawings of 31 familiar objects on a $21 \times 29.7$ cm card. Participants were asked to study the objects for 1 min (with no explicit instruction that they had to remember object locations). Participants were then shown the object exchange condition, in which seven pairs of objects exchanged positions, and were given 1 min to circle any objects that moved from their original locations as seen on the stimulus array. Participants were then presented with the object shift condition, in which 14 objects had moved to previously unoccupied positions relative to the stimulus array, and were given 1 min to circle the displaced objects. After participants had completed the IQ and Judgment of Line Orientation tests, they were asked to visualize the stimulus array and were then shown the novel object condition, containing 14 new objects in the same positions as 14 old objects. They were given 1 min to circle the novel objects. Correct scores for the three response arrays were calculated as the number of correctly circled objects minus the number of incorrectly circled objects (omissions were ignored). The maximum score obtainable for each array was 14 (scorers were independent and blind to group).

Metric positional memory was tested using a task adapted from a computerized version developed by Postma et al. (1998). Fifteen objects were shown on a stimulus card (same size as previously), and all were identical (a bucket). Participants studied the stimulus for 1 min and were then asked to mark crosses on a blank response sheet of paper (of the same size as the stimulus card) corresponding as closely as they could recall to the location of each object. Absolute distances were measured (in millimeters by an independent scorer blind to group) between the original location of the object and the nearest cross marked by superimposing the transparent response sheet over the stimulus card in the same orientation and drawing straight line distances between the centers of the objects and the nearest crosses. In almost all cases, crosses were placed near an object location as judged by visual inspection by the scorer. Where a cross was deemed to be placed equidistant between two object locations, a second independent scorer (blind to group) also measured the distances. Measurements were then averaged across all objects, providing a mean absolute displacement score, reflecting metric positional memory, for each participant. Note that for each participant we calculated a “best fit” measure that yielded the smallest absolute displacement score for

<table>
<thead>
<tr>
<th>Variable</th>
<th>Heterosexual men</th>
<th>Heterosexual women</th>
<th>Homosexual men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>$M = 32.40, SD = 7.50$</td>
<td>$M = 33.15, SD = 8.70$</td>
<td>$M = 29.60, SD = 7.05$</td>
</tr>
<tr>
<td>Years of education</td>
<td>$M = 17.35, SD = 3.06$</td>
<td>$M = 16.17, SD = 2.68$</td>
<td>$M = 15.05, SD = 4.07$</td>
</tr>
<tr>
<td>Handedness$^a$</td>
<td>$M = 79.83, SD = 15.86$</td>
<td>$M = 86.03, SD = 21.11$</td>
<td>$M = 90.56, SD = 13.89$</td>
</tr>
<tr>
<td>Estimated WAIS FSIQ</td>
<td>$M = 112.10, SD = 4.12$</td>
<td>$M = 110.50, SD = 4.45$</td>
<td>$M = 110.60, SD = 6.39$</td>
</tr>
<tr>
<td>Judgment of Line Orientation</td>
<td>$M = 27.30, SD = 1.78$</td>
<td>$M = 19.50, SD = 4.23$</td>
<td>$M = 21.95, SD = 1.70$</td>
</tr>
<tr>
<td>CGN</td>
<td>$M = 1.54, SD = 0.32$</td>
<td>$M = 3.41, SD = 0.69$</td>
<td>$M = 3.13, SD = 0.69$</td>
</tr>
<tr>
<td>Right-hand 2D:4D</td>
<td>$M = 0.96, SD = 0.01$</td>
<td>$M = 0.99, SD = 0.02$</td>
<td>$M = 0.98, SD = 0.02$</td>
</tr>
<tr>
<td>Left-hand 2D:4D</td>
<td>$M = 0.97, SD = 0.01$</td>
<td>$M = 1.00, SD = 0.02$</td>
<td>$M = 0.99, SD = 0.02$</td>
</tr>
</tbody>
</table>

*Note. WAIS FSIQ = Wechsler Adult Intelligence Scale Full-Scale IQ (estimated using the National Adult Reading Test—Revised; Nelson, 1982). CGN = childhood gender nonconformity scores. 2D:4D = 2nd to 4th finger length ratio. $^a$ Handedness was measured with the Edinburgh Handedness Inventory (Oldfield, 1971).
the stimulus as a whole. That is, the first scorer had to combine each original object location with a reconstructed location identified by the cross, using visual inspection as described, and then calculate the absolute displacement score for this combination. If a second scorer was required, as detailed above, he or she repeated this procedure and the smaller of the two absolute displacement scores was adopted.

**General Intelligence**

Wechsler Adult Intelligence Scale (WAIS) Full-Scale IQ (FSIQ; Wechsler, 1955) scores were estimated using the National Adult Reading Test—Revised (NART–R; Nelson, 1982).

**Judgment of Line Orientation**

This task consisted of 30 items (Benton, Hamsher, Varney, & Spreen, 1983). For each item, participants were required to judge which lines in a complex array were in the same spatial orientation as two line fragments appearing above the array. Participants scored 1 point for the two correct choices (0 points for any other response). The maximum possible score was 30. Participants completed a series of five practice trials on which they were corrected if an incorrect answer was given.

**Predictor Variables**

CGN. Recalled childhood gender nonconformity was measured using a 10-item scale that asked participants to rate their sex-typed behavior and interests (e.g., same-sex and opposite-sex peer play preference, interest in rough-and-tumble play, fantasy role play, and gender identity) from as early as they could remember up to 12 years of age on a 5-point scale (4 items were reversed scored). The wording of the scale depended on the particular item. For items regarding toy and play preferences wording ranged from always boy-like (for 1) to always girl-like (for 5); for items concerning activity levels it ranged from very high (for 1) to very low (for 5); and for items concerning gender identity it ranged from very masculine (for 1) to very feminine (for 5). The scale had high internal consistency (Cronbach’s α = .93). High average scores reflect feminine childhood sex-typed behavior and interests.

2D:4D. All participants had their right and left 2nd and 4th finger lengths measured, following Manning (2002). Finger lengths were measured from the tip of the finger to the basal crease on the palmar face of each hand using a pair of digital calipers measuring to .01 mm. This was done twice. Where there was a band of creases at the base of the finger, the most proximal of these was measured. The repeatability of the measurements was high (all Cronbach’s αs = .98), and thus the measurements were averaged and 2D:4D for each hand was computed by dividing the length of the 2nd finger by the length of the 4th finger.

**Statistical Analyses**

Group differences in cognitive and predictor variables were analyzed with one-way ANOVA using SPSS, Version 11.0. Following this, group differences in Judgment of Line Orientation and the object location memory measures were analyzed with general linear model analysis of covariance with age and general intelligence as covariates. Decomposition of significant group effects involved three t tests, with a Bonferroni correction (p < .01). All other alphas were set at .05. The effect size for these comparisons is also reported according to standard criteria (Cohen’s d), where 0.2 is regarded as a small effect, 0.5 a medium effect, and ≥ 0.8 a large effect (Cohen, 1988). Intercorrelations between covariates and the cognitive measures and among the cognitive measures themselves were calculated using Pearson’s r. Finally, a series of stepwise multiple regression equations were performed between performance on each object location measure and the predictor variables (sexual orientation, Judgment of Line Orientation, CGN scores, right-hand 2D:4D, and left-hand 2D:4D). The assumptions of regression were found to have been met on visual inspection of the residual plots for each regression that confirmed homoscedasticity, whereas inspection of the correlation matrix showed no evidence of multicollinearity (all rs < .8).

**Results**

**Estimated Intelligence and Judgment of Line Orientation Scores**

One-way ANOVA revealed no significant group differences in estimated WAIS FSIQ scores, F(2, 59) = 0.62, p > .10. However, there were significant group differences in Judgment of Line Orientation scores, F(2, 59) = 39.76, p < .001 (see Table 1). Post hoc comparisons revealed that heterosexual men scored significantly higher than heterosexual women, t(38) = 7.59, p < .001, d = 2.40, and homosexual men, t(38) = 9.71, p < .001, d = 3.07. Heterosexual women and homosexual men did not differ significantly in Judgment of Line Orientation scores at the conservative alpha value, t(38) = -2.40, p = .021, d = 0.76. Table 2 shows that estimated WAIS FSIQ scores correlated significantly with Judgment of Line Orientation scores. A significant main effect of group upon Judgment of Line Orientation scores remained after the addition of age and estimated WAIS FSIQ as covariates in ANCOVA, F(2, 59) = 40.76, p < .001 (see Table 3 for estimated marginal means). Age and estimated WAIS FSIQ were significant as covariates, F(2, 59) = 6.85, p = .01 and F(2, 59) = 5.61, p = .02, respectively.

**Object Location Memory**

There was a significant group difference on object exchange scores, F(2, 59) = 13.23, p < .001 (see Table 3), with post hoc

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2. Estimated WAIS FSIQ</td>
<td>.28*</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3. Judgment of Line Orientation</td>
<td>–.13</td>
<td>.26*</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>4. Object exchange</td>
<td>.08</td>
<td>-.01</td>
<td>-.47**</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>5. Object shift</td>
<td>-.04</td>
<td>-.03</td>
<td>-.45**</td>
<td>.66**</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>6. Novel object</td>
<td>.07</td>
<td>-.04</td>
<td>-.42**</td>
<td>.68**</td>
<td>.63**</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>7. Metric positional memory</td>
<td>.07</td>
<td>-.08</td>
<td>.21</td>
<td>-.04</td>
<td>.01</td>
<td>-.31**</td>
<td>–</td>
</tr>
</tbody>
</table>

Note. WAIS FSIQ = Wechsler Adult Intelligence Scale Full-Scale IQ (estimated using the National Adult Reading Test—Revised; Nelson, 1982).

*p < .05. ** p < .01.
comparisons showing that heterosexual women scored significantly higher than heterosexual men, \( t(38) = -3.96, p < .001, d = 1.25 \), homosexual men scored significantly higher than heterosexual men, \( t(38) = -4.14, p < .001, d = 1.31 \), and there was no significant difference between heterosexual women and homosexual men, \( t(38) = -0.22, p > .10, d = 0.07 \). The significant group difference in object exchange scores remained following the application of ANCOVA, \( F(2, 59) = 102.08, p < .001 \), but no significant group by object manipulation interaction remained nonsignificant, \( F(2, 110) = 0.008, p > .10 \). The addition of age and estimated WAIS FSIQ in a repeated measures ANCOVA eliminated the significant main effect of object manipulation, \( F(2, 110) = 0.87, p > .10 \), but the significant main effect of group remained, \( F(2, 55) = 19.08, p < .001 \), and the group by object manipulation interaction remained nonsignificant, \( F(4, 114) = 0.31, p > .10 \). In this model, no covariate was significant, with \( p_s > .10 \). Note that the pattern of correlations in Table 2 shows that object exchange, object shift, and novel object scores were positively correlated with each other.

Analysis of absolute displacement scores for metric positional memory with one-way ANOVA revealed a significant effect of group, \( F(2, 59) = 3.19, p = .048 \). However, post hoc tests revealed no significant differences at the conservative alpha value between heterosexual men and heterosexual women, \( t(38) = 2.48, p = .018, d = 0.78 \), and no significant differences between heterosexual men and homosexual men, \( t(38) = 1.93, p = .066, d = 0.59 \), or between heterosexual women and homosexual men, \( t(38) = -0.55, p = .585, d = 0.17 \) (see Table 3). The significant group difference also remained following the application of ANCOVA, \( F(2, 59) = 3.56, p = .035 \) (see Table 4 for estimated marginal means). In this model, no covariate was significant, with \( p_s > .10 \). Metric positional memory was not included in the repeated measures ANOVA or ANCOVA above, because the dependent variable here is measured in different values relative to the other three conditions.

### Predictors of Object Location Memory

Between-groups analysis of the developmental predictors (CGN scores and right- and left-hand 2D:4D) was conducted first (see Table 1). For CGN, there was a significant effect of group, \( F(2, 59) = 56.33, p < .001 \), with heterosexual women and homosexual men scoring significantly higher (feminine) than heterosexual men, \( t(38) = -10.87, p < .001 \) and, \( t(38) = -9.19, p < .001, d = 2.95 \), respectively. There was no significant difference

#### Table 3

**Means and Standard Deviations for Object Location Memory Scores by Group**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Heterosexual men</th>
<th>Heterosexual women</th>
<th>Homosexual men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( M )</td>
<td>( SD )</td>
<td>( M )</td>
</tr>
<tr>
<td>Object exchange</td>
<td>4.80</td>
<td>3.76</td>
<td>8.65</td>
</tr>
<tr>
<td>Object shift</td>
<td>2.75</td>
<td>3.83</td>
<td>6.70</td>
</tr>
<tr>
<td>Novel object</td>
<td>8.25</td>
<td>3.12</td>
<td>11.85</td>
</tr>
<tr>
<td>Metric positional memory</td>
<td>22.42</td>
<td>3.19</td>
<td>19.67</td>
</tr>
</tbody>
</table>

*aAbsolute displacement scores in millimeters.

#### Table 4

**Estimated Marginal Means and Standard Error of Measurement for Judgment of Line Orientation and Object Location Memory Scores by Group**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Heterosexual men</th>
<th>Heterosexual women</th>
<th>Homosexual men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( M )</td>
<td>( SEM )</td>
<td>( M )</td>
</tr>
<tr>
<td>Judgment of Line Orientation</td>
<td>27.18</td>
<td>0.59</td>
<td>19.76</td>
</tr>
<tr>
<td>Object exchange</td>
<td>4.74</td>
<td>0.63</td>
<td>8.59</td>
</tr>
<tr>
<td>Object shift</td>
<td>2.72</td>
<td>0.72</td>
<td>6.73</td>
</tr>
<tr>
<td>Novel object</td>
<td>8.17</td>
<td>0.51</td>
<td>11.84</td>
</tr>
<tr>
<td>Metric positional memory*a</td>
<td>22.06</td>
<td>0.80</td>
<td>19.52</td>
</tr>
</tbody>
</table>

*aAbsolute displacement scores in millimeters.
between heterosexual women and homosexual men, \( t(38) = 1.27 \), \( p > .10 \), \( d = 0.40 \).

There was a significant group difference for right-hand 2D:4D, \( F(2, 59) = 5.75, p < .01 \). Heterosexual men had significantly lower (masculine) ratios than did heterosexual women, \( t(38) = -3.24, p < .01 \), \( d = 1.89 \), and the comparison with homosexual men just failed to reach significance at the conservative threshold, \( t(38) = -2.70, p = .010 \), \( d = 1.26 \). There were no significant differences between heterosexual women and homosexual men, \( t(38) = .83, p > .10 \), \( d = 0.50 \). There was also a significant group difference for left-hand 2D:4D, \( F(2, 59) = 9.05, p < .001 \), with heterosexual men having significantly lower ratios than heterosexual women, \( t(38) = -4.25, p < .001 \), \( d = 1.89 \), and homosexual men, \( t(38) = -2.92, p < .01 \), \( d = 1.26 \). Heterosexual women and homosexual men did not significantly differ, \( t(38) = 1.45, p = .15 \), \( d = 0.50 \).

Regression analysis revealed that sexual orientation and Judgment of Line Orientation scores were significant predictors (\( \beta = .34, t = 2.67, p = .010 \), and \( \beta = -.30, t = -2.38, p = .021 \), respectively) of object exchange scores (CGN scores, right-hand 2D:4D, and left-hand 2D:4D being rejected by the model), \( F(2, 59) = 13.10, p < .001 \) (\( R^2 = .31 \), adjusted \( R^2 = .29 \)). CGN was a significant predictor of both object shift scores (\( \beta = .52, t = 4.75, p < .001 \)), \( F(1,59) = 22.56, p < .001 \) (\( R^2 = .28 \), adjusted \( R^2 = .26 \)) and novel object scores (\( \beta = .54, t = 4.99, p < .001 \)), \( F(1, 59) = 24.90, p < .001 \) (\( R^2 = .30 \), adjusted \( R^2 = .28 \)).

Excluded variables for both models were sexual orientation, Judgment of Line Orientation scores, right-hand 2D:4D, and left-hand 2D:4D. The stepwise model for metric positional memory did not run, indicating that none of the entered predictors contributed significant variance. By way of clarity, force-entering sexual orientation onto the first step of a new model for metric positional memory scores (because a between-group effect was found for this measure as detailed above), followed by the stepwise entry of the predictor variables, still produced a nonsignificant model, \( F(1, 59) = 3.28, p = .075 \) (\( R^2 = .05 \), adjusted \( R^2 = .03 \)).

Discussion

As predicted, heterosexual women and homosexual men were superior to heterosexual men in three conditions of object location memory. Contrary to our predictions, heterosexual men were not superior in their metric positional memory. The present data also suggest that sexual orientation per se and basic spatial perception ability were the only significant predictors of object exchange scores, whereas a psychosexual developmental variable, CGN, was the only significant predictor of object shift and novel object performance. A developmental marker ascribed to the prenatal androgenic action, namely 2D:4D, did not significantly predict any object location memory measure.

The pattern of findings replicate those of Levy et al. (2005), who used similar tasks and drew conclusions that are consistent with several studies involving two-dimensional arrays that show female advantages in recalling the identities and locations of objects (e.g., Alexander et al., 2002; Eals & Silverman, 1994; James & Kimura, 1997; McBurney et al., 1997; Rahman, Wilson, & Abrahams, 2003; Silverman & Eals, 1992). As with Levy et al. (2005), our novel objects condition involved the substitution of new objects (that could be easily verbalized) rather than the addition of new and uncommon objects (those without easy verbal labels), as was done in Eals and Silverman (1994), who reported no sex differences in this condition. In line with Levy et al. (2005), we argue that men may perform poorer on object change detection when substitution of new objects takes place, compared with the addition of new objects to previously studied arrays. The fact that our new objects could be verbalized may tap into superior female verbal memory and thus maximize sex differences. Our object shift data are inconsistent with James and Kimura’s (1997) finding that shifted objects did not elicit a female advantage (but object exchanges did, which was also demonstrated here). However, now two reports (the present study and Levy et al., 2005) are demonstrative of a general female advantage on object location memory irrespective of whether location changes are detected by using object identity alone (the object exchange conditions used here and in Levy et al., 2005) or by using both identity and location information. As suggested by Levy et al. (2005), it is possible that some interference from our object exchange array affected performance on object shifts that followed immediately after (as indicated by reduced accuracy across all our groups in object shift scores compared with the other conditions). Our participants also viewed both object exchange and shift arrays in sequence, which was not the case in James and Kimura (1997). Nonetheless, the consistency of effect sizes for group differences across all three conditions mitigates any influence of interference. Furthermore, it is unlikely that spatial interference from the Judgment of Line Orientation task affected performance on the novel objects condition, considering that scores were higher here than for any other array. Note that in our data the effect of object manipulation disappeared after addition of the covariates, suggesting an effect of age and general cognitive function upon the differential levels of accuracy across object memory scores irrespective of group (the between-group effect remained).

The absence of a male advantage on metric positional memory here is inconsistent with three other studies (Postma et al., 1998, 1999; 2004). If anything, heterosexual men here performed marginally worse than heterosexual women, judging by the pattern of effect sizes and considering the alpha values at conventional levels of significance. Such a discrepancy may be attributable to the different presentation formats used across studies. The present study used a novel two-dimensional array, whereas the three Postma et al. studies used a computerized one, which may have permitted them greater experimental control over task presentation and more accurate scoring. However, our task was designed to follow Postma et al.’s as closely as possible. Our scoring was aided by the ease of our task (which resulted in crosses being marked close to original locations) and the fact that we used more objects than Postma et al. did (e.g., 15 here versus 10 in Postma et al., 2004), thus permitting more fine grained metric recall information to be obtained here (scored by independent raters blind to group status). Nonetheless, it is also possible that the greater number of objects used here may, in fact, have made our task more difficult, thus reducing the sensitivity to a sex difference. Differences in object numbers across our conditions (fewer in metric positional memory than in the previous arrays) is an unlikely explanation for the inconsistent results, because heterosexual women still held a nonsignificant advantage here, judging by the absolute displacement scores (Table 2). Our data are also consistent with Rahman, Wilson, and Abrahams (2003), who reported a large female ad-
vantage in absolute displacement scores. Nonetheless, their task required participants to relocate actual objects to their original locations rather than to mark crosses, thus tapping object-to-location binding processes that may be mediated by greater verbal processing among women, thus maximizing the sex difference. All this suggests that use of the more sensitive absolute displacement score produces discrepancies across studies and indicates the need for consistent task formats and several methods of scoring.

The sexual orientation findings here are the first of their kind examining several components of object location memory. They support the cross-sex shift shown by homosexual men in absolute displacement scores on object-to-location reassignment in one previous study (Rahman, Abrahams, & Wilson, 2003) and are supportive of femaleypical performance in this group on forms of spatial cognition such as mental rotation and spatial perception (e.g., Gladue et al., 1990; Neave et al., 1999; Rahman & Wilson, 2003). The similarity in object exchange, object shift, and novel objects scores between heterosexual women and homosexual men indicate that the latter also show generalized advantage in recalling the identities and locations of objects. Greater verbal and semantic fluency skills in both heterosexual women and homosexual men (Rahman, Abrahams, & Wilson, 2003) may mediate such performance patterns and should be investigated in the future. However, for metric positional memory (noting trend effects found here only) the pattern of effect sizes suggests that homosexual men scored somewhat in between heterosexual men and women. If replicated in the future, this would support the mosaic-like neurocognitive profile (i.e., comprising maleotypical and femaleotypical components) found in domains such as spatial navigation strategy, where homosexual men evidence greater use of femaleotypical landmark cues but maleotypical use of Euclidean information (Rahman et al., 2005).

The current findings also suggest that the origins of sexual variation in object location memory are complex. There was no predictive value of 2D:4D, suggesting a limited role for the factor assumed to underlie the development of this somatic marker, prenatal androgen exposure, upon object location memory. This is inconsistent with one other study, which examined place learning rather than object location memory and tested only women (Csatho et al., 2003). The data are consistent with Rahman et al. (2004), who reported no effect of 2D:4D upon several sexually dimorphic spatial cognitive functions, including object location memory. Animal models indicate that sexual dimorphism in spatial memory tasks such as the Morris water maze and radial arm maze may be modulated by prenatal androgen manipulation (e.g., Williams, Barnett, & Meck, 1990), but no studies have examined analogs of object location memory used in humans. Moreover, 2D:4D is an imperfect measure of prenatal androgen levels, because sex difference is reported to be less than half a standard deviation (whereas sex differences in levels of prenatal androgen levels is very large; Lutchmaya et al., 2004) and ethnic differences are often larger than sex differences (Manning, 2002). Ethnicity could not be examined here, because there were too few cases for meaningful analysis. Finally, the relationship between 2D:4D and human sexual orientation is unclear, because several studies with small samples report masculinized ratios among homosexual men, although one large scale study is supportive of the feminization of 2D:4D among homosexual men as found here (putatively indicative of lower exposure to prenatal androgens; Lippa, 2003, cf. McFadden et al., 2005). At this stage the relationship between somatic measures of prenatal androgens and object location memory remains elusive.

The finding that group status (sexual orientation) and Judgment of Line Orientation predicted object exchange scores suggests that detection of spatial location using object identity alone is dependent on one’s sex and sexual orientation and that better spatial perception skills impair performance here. This latter finding is consistent with the observation that femaleotypical spatial navigation performance and strategy usage may derive from other facets of basic spatial skills (Astur et al., 2004; Choi & Silverman, 2003). It is important to note that our findings show for the first time that CGN, a robust developmental correlate of sexual orientation, predicted object shift and novel object scores alone. This tentatively suggests that the recall of spatial changes that requires both object identity and location information derives from the level of early postnatal childhood sex-atypicality. This is wholly consistent with the growing notion that CGN is a biological endophenotype for adult sexual orientation and its correlates because of genetic involvement (Bailey et al., 2000). Nonetheless, it has yet to be determined whether the pathways leading to differential CGN involve genetic, prenatal, and/or postnatal factors acting on the development of the neural substrates underlying sexual orientation and its particular profile of neurobehavioral correlates, such as spatial memory skills. Because neural regions were not examined here, the morphological and functional neurobiological basis of our observed sexual differences is unclear. The hippocampus has long been proposed to have central involvement in spatial memory, including object location memory (Kessels, De Haan, Kappelle, & Postma, 2001), but structural and functional sex differences here have not been robustly found in humans (e.g., Blanch, Brennan, Condon, Santosh, & Hadley, 2004; Janzen & Van Turennout, 2004). Similarly, the perirhinal cortex is strongly involved in object memory in rodents, monkeys, and humans, yet sexual dimorphism in this region is not known (Winters & Bussey, 2005).

In conclusion, the study has demonstrated, for the first time, robust cross-sex shifts among homosexual men in recalling the identities and locations of objects but not in the metric positions of objects, although here a heterosexual sex difference was not statistically significant at a corrected alpha threshold. The sex and sexual orientation-related differences were large in terms of effect size, suggesting they are nontrivial differences. The significant predictive value of CGN but not 2D:4D tentatively narrows down the number of putative developmental pathways responsible for spatial memory for objects and their locations to the postnatal period, thus necessitating future work to consider both sexuality and its developmental correlates in spatial memory and its subcomponents.

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