Large Sexual-Orientation-Related Differences in Performance on Mental Rotation and Judgment of Line Orientation Tasks

Qazi Rahman and Glenn D. Wilson
Institute of Psychiatry at King’s College London

This study examined the performance of heterosexual and homosexual men and women on 2 tests of spatial processing, mental rotation (MR) and Benton Judgment of Line Orientation (JLO). The sample comprised 60 heterosexual men, 60 heterosexual women, 60 homosexual men, and 60 homosexual women. There were significant main effects of gender (men achieving higher scores overall) and Gender × Sexual Orientation interactions. Decomposing these interactions revealed large differences between the male groups in favor of heterosexual men on JLO and MR performance. There was a modest difference between the female groups on MR total correct scores in favor of homosexual women but no differences in MR percentage correct. The evidence suggests possible variations in the parietal cortex between homosexual and heterosexual persons.

Sex differences in certain cognitive abilities are well established. Men are typically found to excel on certain tests of mathematical reasoning and visuo-spatial processing, in particular on tests of mental rotation (MR), whereas women excel on tests of verbal fluency, perceptual speed, and facial emotion processing (e.g., Halpern, 1992; Kimura, 1999; McClure, 2000; Voyer, Voyer, & Bryden, 1995). However, these differences are also task specific. For example, although men achieve higher scores on tests of mathematical aptitude, women do better on tests involving computation (Kimura, 1999). Additionally, women excel at one type of spatial memory task (i.e., the encoding and retrieval of object locations), whereas the oft-cited female superiority in “verbal abilities” is limited to tests of verbal fluency (i.e., the generation of words or categories to phonetic or semantic exemplars), for which this superiority is considered small in any case (Eals & Silverman, 1994; Hyde & Linn, 1988; Kimura, 1999).

Less well documented has been the growing yet variable evidence for within-gender differences in sexually dimorphic cognitive abilities attributable to a key human individual difference: sexual orientation. Early reports demonstrated female-typical cognitive performance in homosexual men, that is, poorer on spatial processing and better on verbal fluency (Gladue, Beatty, Larson, & Staton, 1990; McCormick & Witelson, 1991; Sanders & Ross-Field, 1987), though others failed to replicate them (Gladue & Bailey, 1995; Tuttle & Pillard, 1991). Recent reports have confirmed the gender-atypical pattern for gay men (Neave, Menaged, & Weightman, 1999; Wegesin, 1998a). In all cases, these studies have suffered from small samples (ranging anywhere from 13 to 32 subjects per gender and orientation group), which may be less sensitive to finding theoretically small differences. Although prior studies have tested homosexual women, they have been poorly sampled (common in sexual-orientation studies; Bancroft, 1997) and have not appeared to show a gender-atypical neuropsychological profile. One study did report that homosexual women showed trends toward male-typical performance in MR, although these were not significant (Wegesin, 1998a). However, Gladue et al. (1990) reported that homosexual women performed more poorly than heterosexual women on a spatial perception task (the Water Level Test). Further work is needed using larger samples of lesbians. In addition, prior studies have also failed to examine important variables, such as age and general intellectual ability, which may relate to sexual-orientation-related differences in cognitive performance.

It is unknown whether the differences reported above stem from biological or psychosocial determinants, although recent interest has focused on the role of organizational and activational effects of gonadal hormones and variation in neural substrates underlying performance on these tasks (Collaer & Hines, 1995; Frederiske, Lu, Aylward, Barta, & Pearlson, 1999; Grimshaw, Sitarenios, & Finegan, 1995; Gur et al., 2000; Hines, 2000). The corpus of evidence has arisen from the theory of neurohormonal sexual differentiation, that is, the neurodevelopment of physiological and behavioral differences between the two sexes under the control of sex hormones. Thus, homosexuals are considered to follow sex-atypical patterns (in the direction of the opposite sex) of development in neurobehavioral domains comparable with, or as a by-product of, the “atyp-
ical” shift in their partner preferences (Ellis & Ames, 1987; LeVay, 1993). An array of evidence has been provided to suggest that physically and behaviorally, homosexuals follow gender-atypical patterns and that prenatal or genetic factors are implicated in the ontogenesis of these differences and for homosexual partner preferences (Bailey & Zucker, 1995; Lippa, 2000; Hu et al., 1995; McFadden & Pasanen, 1998; Reite, Sheeder, Richardson, & Teale, 1995; Williams et al., 2000). However, evidence from domains of behavior other than cognition suggests that homosexual men and women may show strong gender-typical partner preferences, such as preference for younger partners by heterosexual and homosexual men and less interest in casual sexual encounters by heterosexual and homosexual women (Bailey, Gaulin, Agyei, & Gladue, 1994). Thus, homosexuals appear to show composite patterns of gender-atypical and gender-typical behavior.

The current study aimed to explore whether there were differences in performance between homosexual and heterosexual men and women on spatial tasks known to be dependent on a network of brain regions involving the parietal cortex: the MR test (Vandenberg & Kuse, 1978, adapted from that described by Shepard & Metzler, 1971) and, for the first time, the Benton Judgment of Line Orientation (JLO; Benton, Hamsher, Varney, & Spreen, 1983) test. These tasks were chosen because of their established efficacy in eliciting gender differences. As suggested by Sanders & Ross-Field (1987), tasks that show large normative gender effects may be more sensitive to eliciting sexual-orientation-related differences. Additionally, these tasks have been shown to be sensitive to parietal lesions. Benton’s classic studies using the JLO demonstrated that patients with right parietal lobe damage performed worse than those with left-sided damage (Benton, Varney, & Hamsher, 1978; Hamsher, Capruso, & Benton, 1992). Recent work using functional magnetic resonance imaging has shown that both MR and JLO activate the superior parietal cortex bilaterally, with the right lobe “kick starting” early processing of the tasks (Barnes et al., 2000; Ng et al., 2000). It is important to note that activation of the dorsolateral prefrontal cortex has also been found during MR (M. S. Cohen et al., 1996). This region may be engaged during tracking and encoding of relations between objects in spatial working memory and the execution of strategies to solve the task. Such studies suggest the intriguing possibility of differences in those neural substrates underlying behavioral differences between homosexual and heterosexual men and women. This is important because differences in neuroanatomy may provide clues to better understanding the neurodevelopment of sexual orientation (Allen & Gorski, 1992; Byne et al., 2001; LeVay, 1991).

On the basis of the extant literature, we predicted an overall gender difference between men and women in MR and JLO performance: Men would perform better than women. Moreover, we expected heterosexual men to achieve higher scores than homosexual men on both tasks. No differences in performance on either task were expected between heterosexual and homosexual women.

**Method**

**Subjects**

Two hundred forty healthy subjects were recruited (ages between 18 and 40 years and screened to ensure no history of head injury, psychiatric or neurological illness, psychoactive medication use, or drug use): 60 heterosexual men, 60 homosexual men, 60 heterosexual women, and 60 homosexual women. Heterosexual subjects were recruited from university sources, the local community (through newspaper advertisements), and social networks. Homosexual subjects were recruited from university gay and lesbian organizations, the local community, gay–lesbian press, and social networks. Recruitment advertisements for both heterosexual and homosexual subjects stated that volunteers were needed to take part in a study of “gender, sexuality, individual differences and cognition” and that they would be remunerated for their time. All subjects came from within the London, Greater London, and Southeast regions of England. The possibility of some volunteer biases operating in the present sample cannot be excluded. For example, it is likely that our homosexual sample reflected those who were more open about their sexual orientation compared with one that could be acquired by probability sampling (typically requiring very large samples because of the minority prevalence of homosexuality and thus not feasible in the present study). Additionally, heterosexual subjects may have been oversampled from university sources. Sexual orientation was assessed using a modified Kinsey scale, derived from Coleman (1987). This involved responding to a question about self-identification, sexual–romantic attraction, sexual–romantic fantasies, and sexual behavior on a 7-point scale ranging from 0 (exclusively heterosexual) to 6 (exclusively homosexual). Those scoring 5 or 6 were classified as homosexual, and those scoring 0 and 1 were classified as heterosexual. Subjects with intermediate (bisexual) scores were not included in the study. Demographic information was acquired regarding age, number of years in full-time education since the age of 5, and ethnicity (White, Black, South Asian, East Asian, Hispanic, or Other). Subjects were classified by parental socioeconomic status (SES) into the following categories according to the Standard Occupational Classification of the Office of Population Census and Surveys (Office of Population Census and Surveys, 1991): (a) professional, (b) managerial and technical occupations, (c) skilled occupations—nonmanual, (d) skilled occupations—manual, (e) partly skilled occupations, and (f) unskilled occupations.

**Measures**

**Intelligence.** Intellectual ability was assessed using Raven’s Standard Progressive Matrices test (SPM; Raven, 1958). The SPM contains 60 items of increasing difficulty. Subjects are required to select one among six or eight alternatives to complete a matrix problem. Raw scores were used in analysis (maximum score was 60). The SPM is among the best available measures of general intelligence and complex, abstract reasoning and is reasonably gender neutral (Lezak, 1994).

**Handedness.** This was assessed using the Edinburgh Handedness Inventory (EHI; Oldfield, 1971). The EHI requires subjects to demonstrate 10 unimanual tasks and to state the degree of preference for the hand used as either strong (2 points) or weak (1 point). Assessments were completed only once for each subject, and a handedness laterality quotient was calculated by subtracting the score for the left hand from the score for the right hand, dividing by the sum of both, and multiplying by 100. Only predominantly
right-handed subjects (those scoring +31 to +100) were included (Oldfield, 1971). Subjects scoring +30 and below were excluded from the study.

**MR test.** This 20-item test (Vandenbarg & Kuse, 1978, adapted from that described by Shepard & Metzler, 1971) required subjects to view a test item (a two-dimensional representation of a three-dimensional cuboid made up of 10 cubes) and then decide whether four other items were the same. Each test item had two correct and two incorrect choices. Subjects were also instructed that two were correct and two incorrect. On each of the items, subjects received 2 points if they marked both correct choices and 1 point if they marked only one correct choice. All other responses received a score of 0. The maximum possible score was 40. This was the total correct measure for speed and accuracy (MR-total correct). Percentage correct was scored for accuracy per se and was the total number correct divided by the total number of trials attempted multiplied by 100 and divided by 2 (MR-percent-age correct). Subjects completed three practice trials on which they were corrected if an incorrect answer was given.

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

**Procedure**

Subjects were tested individually on all tasks. Subjects completed the battery of tests in a random fashion (different for each subject) and provided demographic information at the end of the session (approximately 30 min long). Each subject was remunerated £20 for his or her time. The Ethical (Research) Committee of the Institute of Psychiatry and Maudsley Hospital, London, approved all procedures.

**Statistical Analyses**

To determine whether the data were normally distributed, box plots were compared for each variable. SES and ethnicity were analyzed by chi-square. Group differences in age, years of education, handedness scores, and IQ were analyzed by the general linear model (GLM) factorial (Gender × Sexual Orientation) analyses of variance (ANOVAs) using the Statistical Package for the Social Sciences (Version 8.0). Group differences in spatial performance were also examined using GLM factorial analysis of covariance (ANCOVA) with covariates. Possible covariates under consideration were age, IQ, years of education, and handedness scores. Qualification as a covariate was determined if group differences were present in any of these listed variables. Post hoc comparisons used the GLM ANCOVA method separately for men and women. This method reduces error variance and adjusts the means for the dependent measures as though all subjects scored equally on the covariates. Alpha levels for these comparisons were adjusted and set at 0.025; all other alphas were set at 0.050. Effect size for ANOVAs (ν²) were also calculated in which 0.010 is a small effect, 0.050 a medium effect, and 0.100 a large effect by standard criteria (J. Cohen, 1988).

**Results**

**Subject Characteristics**

Two-way ANOVAs (Gender × Sexual Orientation) revealed no group differences in years of education or handedness scores (all ps > .10). However, there were main effects on age of gender, F(1, 239) = 13.460, p < .01, and sexual orientation, F(1, 239) = 10.722, p = .001. In the present sample, men were older than women, and homosexuals were older than heterosexuals (Table 1). A main effect of sexual orientation on Raven’s SPM scores also reached significance, F(1, 239) = 4.012, p = .046, with homosexuals achieving lower scores than heterosexuals. Age and IQ were entered as covariates in subsequent analyses. There were no group differences in ethnicity; ethnicity was collapsed into White versus non-White because there were too few cases in the latter’s subcategories, χ²(3, N = 240) = 3.127, p = .373. There were also no group differences in SES; partly skilled and unskilled were collapsed into White versus non-White because there were too few cases for analysis, χ²(15, N = 240) = 21.430, p = .124.

**Spatial Tests**

**Benton JLO.** Visual inspection of the box plots revealed substantial negative skewness for JLO scores (computed skewness value = −0.928, SE = 0.157). We transformed the scores using a “reflect and transform” technique (Tabachnick & Fidell, 1996). The largest score in the distribution was determined and 1 added to it to form a constant. A new variable was computed by subtracting each score from the constant, allowing the variable to become one with positive instead of negative skewness. A log transformation was then applied to this variable. Analysis of the

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Education (years)</th>
<th>Handedness (EHI scores)</th>
<th>IQ (Raven’s SPM score)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heterosexual men M</td>
<td>29.91</td>
<td>15.96</td>
<td>82.67</td>
<td>47.05</td>
</tr>
<tr>
<td>SD</td>
<td>6.60</td>
<td>3.29</td>
<td>19.42</td>
<td>7.41</td>
</tr>
<tr>
<td>Homosexual men M</td>
<td>32.08</td>
<td>16.51</td>
<td>83.02</td>
<td>44.83</td>
</tr>
<tr>
<td>SD</td>
<td>5.66</td>
<td>3.86</td>
<td>20.19</td>
<td>6.68</td>
</tr>
<tr>
<td>Heterosexual women M</td>
<td>26.80</td>
<td>16.65</td>
<td>87.33</td>
<td>46.86</td>
</tr>
<tr>
<td>SD</td>
<td>5.87</td>
<td>3.29</td>
<td>16.96</td>
<td>6.73</td>
</tr>
<tr>
<td>Homosexual women M</td>
<td>29.61</td>
<td>15.95</td>
<td>85.31</td>
<td>45.55</td>
</tr>
<tr>
<td>SD</td>
<td>5.35</td>
<td>3.71</td>
<td>18.46</td>
<td>6.46</td>
</tr>
</tbody>
</table>

*Note.* EHI = Edinburgh Handedness Inventory; SPM = Standard Progressive Matrices test.
transformed scores (Table 2 lists unadjusted–transformed raw scores, unadjusted–transformed scores, and adjusted–transformed scores) revealed a significant main effect of gender, $F(1, 239) = 16.068, p < .0001$, with men scoring better than women overall, and a significant interaction between gender and sexual orientation, $F(1, 239) = 45.450, p < .0001$. In this model there was also a significant effect of IQ as a covariate, $F(1, 239) = 25.506, p < .0001$, but not age, $F(1, 239) = 0.087, p = .769$. Decomposing the interaction revealed that heterosexual men scored significantly higher than homosexual men, $F(1, 119) = 51.724, p < .0001$, whereas the scores of heterosexual and homosexual women did not differ, $F(1, 119) = 3.890, p = .051$, $\eta^2 = 0.032$. Table 2 also shows that homosexual men did not differ in their scores from heterosexual women. The difference between the two male groups constituted a very large effect by standard criteria ($\eta^2 = 0.307$).

**MR.** Inspection of the box-plot profiles revealed that all MR data were normally distributed. The analysis of MR-total correct scores revealed a significant main effect of gender, $F(1, 239) = 21.950, p < .0001$, with men achieving higher scores than women overall, and a significant Gender × Sexual Orientation interaction, $F(1, 239) = 21.214, p < .0001$. Age and IQ were both significant covariates in this model, $F(1, 239) = 5.682, p = .018$, and $F(1, 239) = 9.040, p = .003$, respectively. Table 2 shows that heterosexual men scored significantly higher than homosexual men, $F(1, 119) = 13.440, p < .0001$, but also that homosexual women achieved higher scores than heterosexual women, $F(1, 119) = 6.672, p = .01$. Again, the size of the difference between the male groups was large ($\eta^2 = 0.104$), whereas it was moderate between the female groups ($\eta^2 = 0.054$).

To examine possible differences in accuracy scores per se, we conducted an analysis of MR-percentage correct scores, which revealed a main effect of gender, $F(1, 239) = 8.867, p = .003$, with men solving a greater percentage of attempted items than women, and a significant interaction between gender and sexual orientation, $F(1, 239) = 6.444, p = .012$. Only IQ remained a significant covariate, $F(1, 239) = 32.493, p < .0001$. Comparisons revealed a large difference in favor of heterosexual compared with homosexual men, $F(1, 119) = 14.628, p < .0001$, $\eta^2 = 0.111$, and no difference between heterosexual and homosexual women, $F(1, 119) = 0.005, p = .946$. This result suggests that although possible differences in speed (computing percentage measures removes the influence of speed) may not affect the overall gender differences in MR performance (or the difference between heterosexual and homosexual men), in the present sample the differences between heterosexual and homosexual women may be attributable to homosexual females compromising accuracy for speed.

**Discussion**

The current study aimed to provide new information on the controversial and variable evidence concerning differences in spatial cognition between heterosexual and homosexual individuals using a larger sample, and for the first time, a comparable group of homosexual women. The present study confirms the established gender differences in performance on tests of spatial rotation and line judgment (Halpern, 1992; Kimura, 1999; Voyer et al., 1995). The levels of performance by heterosexual men in the present study are comparable with those obtained from larger samples of college-educated men as are the overall gender differences (Halpern, 1992; Silverman, Phillips, & Silverman, 1996). However, this study is the first to reveal striking differences between heterosexual and homosexual men in a

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**Table 2**

**Spatial Scores: Unadjusted and Adjusted Means by Group**

<table>
<thead>
<tr>
<th>Group</th>
<th>Benton JLO&lt;sup&gt;a&lt;/sup&gt;</th>
<th>MR total correct</th>
<th>MR % correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unadjusted–untransformed</td>
<td>Unadjusted–transformed</td>
<td>Adjusted–transformed</td>
</tr>
<tr>
<td>Heterosexual men</td>
<td>28.40</td>
<td>0.322</td>
<td>0.335&lt;sup&gt;***&lt;/sup&gt;</td>
</tr>
<tr>
<td>M</td>
<td>1.84</td>
<td>0.282</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homosexual men</td>
<td>24.18</td>
<td>0.738</td>
<td>0.724</td>
</tr>
<tr>
<td>M</td>
<td>3.75</td>
<td>0.328</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterosexual women</td>
<td>24.81</td>
<td>0.721</td>
<td>0.730</td>
</tr>
<tr>
<td>M</td>
<td>3.43</td>
<td>0.259</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homosexual women</td>
<td>25.56</td>
<td>0.637</td>
<td>0.630</td>
</tr>
<tr>
<td>M</td>
<td>3.74</td>
<td>0.298</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note.** Scores are adjusted for covariates’ age and IQ (Raven’s Standard Progressive Matrices test score). JLO = Judgment of Line Orientation test; MR = Mental Rotation test. 
<sup>a</sup> Transformed scores are in reverse direction. 
<sup>b</sup> Heterosexual men scored higher than homosexual men. 
<sup>c</sup> Homosexual women scored higher than heterosexual women. 
<sup>**</sup> $p < .05$. 
<sup>***</sup> $p < .001$. 

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benchmark test of spatial processing, the Benton JLO. Homosexual men performed substantially worse than heterosexual men, the size of this difference being large by standard criteria. The present findings also confirm previously reported “deficits” in MR ability in homosexual men compared with heterosexual men (Gladee et al., 1990; McCormick & Witelson, 1991; Neave et al., 1999; Wegesin, 1998a). The picture is less clear for women, our results showing that although there were differences between heterosexual and homosexual women in total correct scores (speed plus accuracy) on MR, this moderate difference disappeared when examining percentage-correct scores (accuracy only). Overall, the profile of results reinforces the notion that homosexual men score in female-typical directions on certain aspects of cognitive functioning, whereas any differences between homosexual and heterosexual women may be due to differences in the speed at which the tasks are solved (e.g., Sanders & Ross-Field, 1987; Wegesin, 1998a). Otherwise, homosexual women perform in female-typical directions, confirming earlier reports (Gladee & Bailey, 1995; Gladee et al., 1990; Tuttle & Pillard, 1991).

A dominant role for the parietal cortex in MR and JLO has been revealed by a number of lesion and functional neuroimaging studies (Benton et al., 1978; Hamsher et al., 1992; Ng et al., 2000). Although in men the parietal regions are strongly activated bilaterally during JLO performance, in women they fail to activate bilaterally (Gur et al., 2000). Given the well-established gender differences in spatial task performance and concurrent gender differences in functional activation of the parietal cortex, the present results suggest differences in the functioning of parietal cortex regions between heterosexual and homosexual men. Neuroimaging studies could elucidate this possibility in the future, but there is already support for this notion from a number of studies. Reite et al. (1995) found more symmetric auditory source locations using magnetoencephalography in gay men compared with heterosexual men, a pattern more typical of women. Note that this study examined auditory processing and found a bilateral activity. A possible expectation for visuospatial processing could be that homosexual men activate the parietal cortex asymmetrically, similar to heterosexual women. Thus, the brain activity patterns of homosexual men and heterosexual women may be similar depending on the type of function investigated: lateralized for visuospatial function but bilaterally represented for auditory processing (Reite et al., 1995).

Wegesin (1998b) found no differences in asymmetry of event-related potentials between heterosexual and homosexual individuals, but slow-wave activity during an MR task was similar for homosexual men and heterosexual women. There was also a nonsignificant trend toward male-typical slow-wave activity in lesbians, but they did not otherwise seem to differ electrophysiologically from heterosexual women. At the very least, these studies seem to confirm a neurophysiological basis to the similarity in heterosexual women’s and gay men’s spatial performance. However, these statements need to be considered in the context of the often elusive sex differences reported in lateralization of a number of functions in heterosexuals (Voyer, 1996).

Although there may be a neural basis for the differences reported, whether these arise from biological or psychosocial factors remains uncertain. There is some evidence that they may stem from variations in gonadal steroids, in particular testosterone. Recently, Neave et al. (1999) showed that the deficit by gay men on MRs could be accounted for by a trend for higher circulating testosterone (T) levels in this group. This is in line with a proposed curvilinear relationship between T and spatial ability in men, such that either high or low levels may produce decrements in performance (Moffat & Hampson, 1996). However, the literature is scattered with positive, negative, and null relationships between T and spatial ability (Silverman, Kastuk, Choi, & Phillips, 1999), and only one robust study has confirmed the curvilinearity hypothesis (O’Connor, Archer, Hair, & Wu, 2001). In homosexual men, higher levels of T may represent an activation effect due to task difficulty or they may reflect different patterns of prenatal testosterone exposure on brain organization in utero (Williams et al., 2000). However, the influence of factors such as differences in spatial test anxiety, life history of spatial experiences, and sex-typed occupational choice cannot be excluded.

The need to consider additional variables (such as age and IQ) that contribute to performance was highlighted by the current study, although strong group differences remained after these factors were statistically controlled for. Previous work may have overemphasized the “matching” of groups on variables such as IQ, thus avoiding an examination of the contribution of variation within these populations. An exploration of the effects of individual differences on sexual-orientation-related cognitive functioning with even larger samples would be useful. Investigation of additional spatial abilities, some of which show gender effects, such as spatial memory for routes, paths, and layouts, and spatial working memory, could elucidate whether sexual-orientation differences are fractionated across domains of spatial cognition (Eals & Silverman, 1994; Moffat, Hampson, & Hatzipantelis, 1998). Given the large effects reported here, investigators should be aware of the potential confounding influence of sexual orientation in studies using tests such as the Benton JLO and in standardization studies of neuropsychological measures in which gender differences are significant.

References


Received November 29, 2001
Revision received May 14, 2002
Accepted May 27, 2002

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