Performance Differences Between Adult Heterosexual and Homosexual Men on the Digit-Symbol Substitution Subtest of the WAIS–R

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ABSTRACT

Previous evidence suggests that sexual orientation influences performance on a number of cognitive functions known to be sexually dimorphic. This investigation examined the performance of 240 right-handed subjects (60 heterosexual men, 60 homosexual men, 60 heterosexual women and 60 homosexual women) on one of the most commonly used neuropsychological tests to show normative sex differences, the Digit-Symbol Substitution test of the WAIS–R. Analysis of scaled Digit-Symbol scores revealed that heterosexual women and homosexual men outperformed heterosexual men. The magnitude of these differences were modest by standard criteria. No differences were found between heterosexual and homosexual women. The findings implicate within-sex variation in one test that relies on intact executive function.

Sex differences in certain cognitive functions are well-documented. Men are found, on average, to excel on certain tests of mental rotation, spatial perception and mathematical problem-solving, while women perform, on average, better on certain tests of verbal fluency, object location memory and facial emotion processing (e.g., Acevedo et al., 2000; Herlitz, Nilsson, & Backman, 1997; Kimura, 1999; McClure, 2000; Monsch et al., 1992; Voyer, Voyer, & Bryden, 1995). Women also appear to be superior to men in the domain of visual-perceptual skills called “perceptual speed.” Perceptual speed refers to the ability to make rapid comparisons among a number of figures, such as numbers, designs or letters. A number of tests index this skill, including the Identical Pictures test (Ekstrom, French, & Harman, 1976) and the Symbol-Digit test (Smith, 1967). However, by far the most widely used measure is the Digit-Symbol substitution test from the Wechsler Adult Intelligence Scale (WAIS). In this test, a single number and symbol are paired in a key visible throughout the test, and the subject is required to fill in as many symbols corresponding to stimulus numbers in an array within 90 s. The Digit-Symbol test (and other perceptual speed tests) in fact involves several processes, including visual scanning, mental flexibility, sustained attention, psychomotor speed, and speed of information processing (Lezak, 1995). While the test is not regarded as a classic test of working memory, it also requires the temporary maintenance of information occurring over a period of seconds in anticipation of a motor response. Therefore, this task may at least partially assess memory functions mediated by the...
prefrontal cortex. Clinically, it is relied on and reported as a measure of short-term visual learning and attentional abilities (Lezak, 1995).

Performance on the Digit-Symbol subtest is typically female favoring with studies reporting medium effect sizes (Cohen’s $d = 0.5$; Herlitz & Yonker, 2002; Schaie & Willis, 1993; Snow & Weinstock, 1990). These differences have also been reported cross-culturally (Lynn & Dai, 1993; Mann, Sasanuma, Sakuma, & Masaki, 1990) and in large samples of children (Kelly & Britton, 1996). The female advantage on such tasks is claimed to be explicable in terms of sex differences in rapid recognition, attentional shifting or information processing capacity (Royer, 1971). However, Majeres (1988) reported that on a recognition task in which two strings of digits were shown sequentially, so that the second string had to be compared with the previously seen string, a sex difference was not found. In contrast, on an evaluation task in which the two strings were presented together, a significant sex difference was found. Majeres (1988) concluded that sex differences in speeded symbol matching were not the result of differences in recognition (matching a previously seen string) but due to differences related to symbol comparison and decision processes. Additionally, Majeres (1990) reported that sex differences could be observed with short digit strings (2, 3 or 4 digits). Strings of this size should have been minimally taxing on memory resources making it unlikely that sex differences were due to differences in information processing capacity. Thus, overall, it appears that the female advantage in perceptual speed, specifically the Digit-Symbol substitution test, is robust, but it is unclear which cognitive processes are involved in the sex difference. However, there is evidence that it may be due to comparison and decision processes in speeded matching.

There has been growing evidence for an influence of sexual orientation on cognitive functions that show sexual dimorphism in terms of performance. A series of studies have reported female-typical performance by homosexual men on mental rotations, judgement of line orientation, some verbal fluency measures, Verbal and Performance IQ scores of the WAIS and on lexical decision-making (Gladue, Beatty, Larson, & Staton, 1990; McCormick & Witelson, 1991; Rahman, Abrahams, & Wilson, 2003; Rahman & Wilson, 2003; Sanders & Ross-Field, 1987; Wegesin, 1998). The most replicable difference appears to be on mental rotations (Neave, Menaged, & Weightman, 1999; Rahman & Wilson, 2003; Wegesin, 1998). However, one study failed to find any sexual orientation related cognitive differences (Gladue & Bailey, 1995). Few of these studies have employed perceptual speed measures. For example, Sanders and Wright (1997) and Willmott and Brierley (1984) utilised WAIS–R subtests to derive Verbal and Performance IQ’s (for which they report sexual orientation effects) but they did not include the Digit-Symbol subtest in their batteries. However, two studies have used the Digit-Symbol subtest and both reported no significant differences between heterosexual and homosexual men (McCormick & Witelson, 1991; Tuttle & Pillard, 1991).

Although the evidence has not demonstrated sexual orientation effects in Digit-Symbol performance, the differences reported in a number of sexually dimorphic cognitive functions suggest that further cognitive variation may be expected in visual-perceptual functions. It is therefore perplexing that prior investigations have not found such sexual orientation related variation in the Digit-Symbol substitution test (one that consistently elicits a female advantage). Previous studies have suffered from relatively small samples and poor control over subject factors that may have obscured effects. Additionally, although these studies have tested homosexual women, this population has been substantially underrepresented and appears to show a cognitive profile congruent with their sex. One study has reported a male-typical trend (nonsignificant) in mental rotation performance by homosexual women (Wegesin, 1998), while another reported worse scores by homosexual than heterosexual women on the Water Level Test (Gladue et al., 1990; Thomas, Jamison, & Hummel, 1973). Rahman and Wilson (2003) reported that homosexual women were higher than heterosexual women in total correct scores on mental rotation, but there were no differences in judgement of line orientation and an accuracy-only measure of...
mental rotation, despite a large sample size (60 subjects per group). The influence of sexual orientation on cognitive performance remains to be elucidated and necessitates further study with larger samples of homosexual women and examination of subject factors that may modulate performance differences.

The current study aimed to explore whether there were any sexual orientation related differences in performance on the Digit-Symbol substitution test, previously shown to be sexually dimorphic, using a more robust design. Based on the results from previous studies for sexual orientation effects in certain sexually dimorphic cognitive functions, the following predictions were made: Heterosexual women would achieve higher scaled scores on the Digit-Symbol test compared to heterosexual men. Homosexual men would score higher than heterosexual men. Finally, heterosexual and homosexual women were not expected to differ in performance.

METHODS

Subjects

The data reported here are from the sample of Rahman and Wilson (2003) and Rahman, Abrahams, and Wilson (2003) in a large study of the neurocognitive correlates of human sexual orientation. This comprised 60 heterosexual men, 60 homosexual men, 60 heterosexual women, and 60 homosexual women (18 and 40 years of age). Subjects were screened to exclude any history of head injury, psychoactive medication or drug use and were asked a more general screening question on psychiatric and neurological illness with examples provided. Any subject who stated that they had a history of psychiatric and/or neurological morbidity, or were unsure of this, were not recruited into the study. Additionally, there was no evidence of learning disabilities in our sample as mean group scores on the Raven’s Standard Progressive Matrices (SPM) test fell between the 74th (intelligently average) and 79th (above average in intelligence) percentiles (Raven, 1958).

Heterosexual subjects were recruited from university sources, through advertisements in local press and social networks. Homosexual subjects were recruited from university gay and lesbian organisations, gay/lesbian press, and social networks. Recruitment advertisements stated that volunteers were required to take part in a study of “gender, sexuality, individual differences and cognition” for which remuneration would be given. The complete sample comprised individuals from the London and Southeast regions of England. The possibility that volunteer biases were operating in our sample cannot be excluded. The homosexual subjects may comprise those who are open about their sexual orientation and involved in gay/lesbian community activities. Heterosexual subjects may be over-sampled from university sources. These sampling issues must be noted when considering the ecological validity of the results. Sexual orientation was assessed using a modified Kinsey scale (Kinsey, Pomeroy, & Martin, 1948). This involved responding to questions about self-identification, sexual/romantic attraction, sexual/romantic fantasies and sexual behaviour on a 7-point scale (ranging from 0 = ‘exclusively heterosexual’ to 6 = ‘exclusively homosexual’). Those scoring 5 and 6 were classified as homosexual, those scoring 0 and 1 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 (classified by self-report as White, Black, South Asian, East Asian, Hispanic or Other). Subjects were classified by parental socio-economic status into the following categories according to the Standard Occupational Classification (Office of Population Censuses and Surveys, 1991): (1) Professional, (2) Managerial and Technical occupations, (3) Skilled occupations – nonmanual, (4) Skilled occupations – manual, (5) Partly skilled occupations and (6) Unskilled occupations. A two-way ANOVA on number of years spent in full-time education since the age of 5 revealed no significant main effects of sex ($F = 0.021, df = 1, 239, p = .885$) or sexual orientation ($F = 0.027, df = 1, 239, p = .870$) or their interaction ($F = 1.856, df = 1, 239, p = .174$). There were no group differences in ethnicity (collapsed into ‘white’ vs. ‘nonwhite’; $\chi^2 = 3.127, df = 3, N = 240, p = .373$) or parental socio-economic status (categories 5 and 6 collapsed; $\chi^2 = 21.430, df = 12, N = 225, p = .124$). Only right-handed subjects (those scoring $> + 31$ on the Edinburgh Handedness Inventory (EH1; Oldfield, 1971) were included. There were no significant differences in mean EHI scores between the groups; main effect of sex ($F = 2.055, df = 1, 239, p = .153$), main effect of sexual orientation ($F = 0.119, df = 1, 239, p = .731$) and interaction ($F = 0.239, df = 1, 239, p = .626$). There was, however, a significant effect of sex ($F = 13.460, df = 1, 239, p < .001$) and sexual orientation ($F = 10.722, df = 1, 239, p < .001$) on age. The mean ages ($SD$) were as follows: heterosexual men, 29.91 (6.60); homosexual men, 32.08 (5.66); heterosexual women, 26.80 (5.87) and homosexual women, 29.61 (5.35). General intelligence was evaluated using Raven’s Standard Progressive Matrices test (SPM;
Raven, 1958). For this test there was a significant main effect of sexual orientation only \((F = 4.012, \ df = 1, 239, \ p = .046)\), homosexuals having lower scores (mean = 45.19, \(SD = 6.55\)) compared to heterosexuals (mean = 46.95, \(SD = 7.05\)). Therefore, age and IQ were entered as covariates in further analyses.

**Digit-Symbol Substitution**

In the Digit Symbol subtest of the WAIS–R (Wechsler, 1981) a single number and symbol are paired in a key visible throughout the test. The subject was required to fill in as many symbols as possible corresponding to a set of stimulus numbers displayed in an array. Ninety seconds were allowed for the whole test. A practice trial containing seven stimulus numbers was completed initially, on which subjects were corrected if an incorrect response was given. Subjects received 1 point for each correct symbol, the maximum score being 93. Scores were scaled according to standardised instructions from the WAIS–R manual, thus only scaled scores were used in analysis.

**Procedure**

Subjects were tested individually on the Digit-Symbol subtest as part of a larger study of the neurocognitive correlates of sexual orientation (the entire testing session lasting approximately 2 h). Subjects provided demographic information at the end of the session and each was remunerated £20 for their 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, a box-plot was computed for Digit-Symbol scaled scores and visual inspection of this plot confirmed normality. Group differences were analysed using a General Linear Model (GLM) factorial (sex by sexual orientation) analysis of covariance (ANCOVA), with age and IQ as covariates, using the Statistical Package for the Social Sciences (SPSS) Version 8.0. Decomposition of significant interactions involved a series of \(t\) tests (Bonferroni corrected alpha level of 0.01 for multiple comparisons). All other alphas were set at 0.05. The effect size for these comparisons is also reported according to standard criteria (Cohen’s \(d\)) where \(d = 0.2\) is a small effect, \(d = 0.5\) a medium effect and 0.8 a large effect (Cohen, 1988).

**RESULTS**

An unadjusted two-way factorial ANOVA revealed a significant main effect of sex \((F = 5.239, \ df = 1, 239, \ p = .023)\), with women achieving higher scaled scores than men overall (see Table 1 for unadjusted and adjusted means). There was no significant main effect of sexual orientation \((F = 0.977, \ df = 1, 239, \ p = .324)\), but there was a significant sex by sexual orientation interaction \((F = 9.103, \ df = 1, 239, \ p = .003)\). Decomposition of this interaction revealed that heterosexual women and homosexual men had higher scaled scores than heterosexual men \((t = -3.520, \ df = 118, \ p < .001, \text{ and } \ t = -2.793, \ df = 118, \ p = .006, \text{ respectively})\). Heterosexual and homosexual women did not differ significantly from each other \((t = 1.456, \ df = 118, \ p = .148)\). Inspection of Table 1 shows that the scores of heterosexual women and homosexual men differed little. The effect sizes were modest for the comparison between heterosexual men and women, and between heterosexual and homosexual men (Table 2).

An adjusted ANCOVA model (covarying for the influence of Age and IQ) revealed little change in the pattern of significant effects. Here the significant main effect of sex just reached

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<tr>
<th>Group</th>
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<tr>
<td></td>
<td>Unadjusted</td>
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<tr>
<td>Heterosexual men</td>
<td>10.76 (2.74)</td>
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<tr>
<td>Homosexual men</td>
<td>12.05 (2.26)</td>
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<tr>
<td>Heterosexual women</td>
<td>12.46 (2.54)</td>
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<tr>
<td>Homosexual women</td>
<td>11.81 (2.34)</td>
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*Note. Adjusted for covariates age and IQ (Raven’s SPM score).*

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<tr>
<th>Comparison</th>
<th>Cohen’s (d)</th>
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<tr>
<td>Heterosexual men versus</td>
<td>0.64</td>
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<td>heterosexual women</td>
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<td>Heterosexual men versus</td>
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<td>Heterosexual women versus</td>
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Table 1. Unadjusted (SD) and Adjusted Group Means for Digit-Symbol Scaled Scores.*

Table 2. Effect Sizes of the Group Comparisons for Digit-Symbol Scaled Scores.
significance ($F = 3.880, df = 1, 239, p = .050$). Examination of the adjusted means (Table 1) suggests that women were still scoring higher than men overall. The main effect of sexual orientation just failed to reach significance ($F = 3.798, df = 1, 239, p = .053$), and inspection of Table 1 gives some indication that homosexuals tended to score higher than heterosexuals. The interaction however remained clearly significant ($F = 11.189, df = 1, 239, p < .001$). Age was not a significant covariate in this model ($F = 1.312, df = 1, 239, p = .253$) but IQ was ($F = 29.027, df = 1, 239, p < .001$).

DISCUSSION

The profile of results above confirmed our predictions. There was an overall sex difference in Digit-Symbol substitution performance favouring women. Heterosexual women outperformed heterosexual men, homosexual men outperformed heterosexual men (and were no different from homosexual women), and, finally, homosexual women did not differ significantly in their scores from heterosexual women. Thus, the present study confirmed the consistently reported female superiority on symbol substitution tests, and demonstrated, for the first time, a significant cross-sex shift in performance of homosexual men on the Digit-Symbol subtest. Additionally, the two female groups did not differ from each other, confirming observations of no differences between heterosexual and homosexual women on most sexually-dimorphic cognitive functions.

The findings reported here support prior work on sex differences favouring women on tests of visual perceptual speed (e.g., Herlitz & Yonker, 2002; see also Kimura, 1999). The effect size for the difference between heterosexual men and women in the present analysis conforms to that reported in prior work (i.e., it is a medium sized effect). However, it is unclear which of the many component skills that constitute performance on Digit-Symbol (such as sustained attention, speed of information processing, psychomotor speed, mental flexibility, motor persistence and visuomotor co-ordination) is responsible for the female superiority (Lezak, 1995).

The findings here show for the first time that Digit-Symbol test performance differs between heterosexual and homosexual men, the latter demonstrating the expected female-typical performance. They contrast with the reports of McCormick and Witelson (1991) and Tuttle and Pillard (1991) who found no difference between heterosexual and homosexual men on this test. However, examination of the direction of the means from McCormick and Witelson’s study shows that heterosexual women scored highest, followed by homosexual men, then heterosexual men, although these differences were not significant. A number of factors may explain the disparities, including the small sample size of these previous studies which may have been inadequate to detect what may be modest differences (as found here).

Generally, these findings are consistent with the female-typical cognitive profile of homosexual men demonstrated in prior work (e.g., Gladue et al., 1990; McCormick & Witelson, 1991; Neave et al., 1999; Wegesin, 1998). The modest effect size for the difference between heterosexual and homosexual men reported here is also comparable to the heterosexual sex difference, supporting a model of sexual orientation effects which posits that sexual orientation differences in neurobehavioural functions are comparable in magnitude, as well as parallel in direction, to sex effects per se (Sanders & Ross-Field, 1987). Homosexual women demonstrated sex-typical performance in their Digit-Symbol scaled scores. This is consistent with previous studies showing no differences between homosexual and heterosexual women on sexually-dimorphic cognitive measures.

It is important to comment on the results of the ANCOVA analysis. Although the main effects and interaction terms did not change once Age and IQ were covaried, there was an attenuation of the main effect of sex and an accentuation of the main effect of sexual orientation. IQ was the only significant covariate in this model, therefore implying that if the groups did not differ on IQ then the main effect of sex attenuates. Additionally, if the groups did not differ on IQ then the main effect of sexual orientation was accentuated slightly, explaining the lack of a significant main effect of sexual orientation in the unadjusted model. However, because the interaction term
remained significant, IQ as a significant covariate simply contributes variance but does not account completely for group differences. The key point from these data is that differences in IQ are associated with performance on the Digit-Symbol subtest. Indeed, speed of information processing, as well as being indexed by the Digit-Symbol subtest, is also suggested to be a component of general intelligence and hence forms part of the most widely employed measure of intellectual function, the WAIS battery.

Performance on the Digit-Symbol test may have its underlying neural basis in the frontal cortex, and is often used as a test of frontal lobe function particularly in relation to ageing and dementia (being one of the first abilities to decline in these conditions; Meguro et al., 2001; Parkin & Java, 1999). Thus neuroanatomical and/or functional brain differences may underlie the sexual orientation effects reported here, although the role of such differences in sexual orientation is unclear as variance in Digit-Symbol performance can be observed with nonspecific cerebral damage (Lezak, 1995).

Neither does the suggestion of neural differences imply specific types of etiological factors, either biological or psychosocial, as responsible for them. Hormonal influences on Digit-Symbol performance in adulthood have been demonstrated. In older men, higher levels of circulating testosterone, and administration of exogenous testosterone, is related to improved performance on Digit-Symbol, and estrogen levels with poorer performance (Kenny, Bellantionio, Gruman, Acosta, & Prestwood, 2002; Yaffe, Lui, Zmuda, & Cauley, 2002; c.f. Silverman, Kastuk, Choi, & Phillips, 1999, in a sample of younger men). Recent reports have implicated prenatal androgens in both the development of sexual orientation and sex differences in cognitive abilities (Grimshaw, Sitarenios, & Finegan, 1995; Williams et al., 2000), partially consistent with the prenatal androgen theory which predicts that homosexual men and women should show neurobehavioural shifts in opposite-sex directions due to the actions of prenatal hormones (primarily androgens; Ellis & Ames, 1987). However, women exposed to elevated androgens prenatally (in the condition of congenital adrenal hyperplasia) show no differences in perceptual speed measures when compared to controls, and yet report an elevation in homosexual or bisexual attraction (Hines, 2000).

In conclusion, homosexual men demonstrate a significant, yet modest, cross-sex shift in performance on an established sexually dimorphic measure of perceptual speed – the Digit-Symbol subtest of the WAIS–R. As this test relies on intact executive functioning and is particularly sensitive to cerebral damage, the findings reported here suggest that underlying cerebral variation may be responsible for differences in executive functioning between homosexual and heterosexual men. Investigators should be aware of the potential influence of sexual orientation in commonly used neuropsychological measures.

ACKNOWLEDGMENT

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REFERENCES


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