Biosocial factors, sexual orientation and neurocognitive functioning

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Summary It has been proposed that sexual orientation related differences in cognitive performance are either due to the actions of prenatal factors early in development or the influence of gender role learning. This study examined the performance of 240 healthy, right-handed heterosexual and homosexual males and females ($N = 60$ per group) on a battery of cognitive tasks comprising mental rotation, judgement of line orientation (JLO), verbal fluency, perceptual speed and object location memory. Measures were also taken of the psychological gender, birth order, sibling sex composition and the 2nd to 4th finger length ratios of the right and left hands. A series of stepwise regression analyses revealed that sex and sexual orientation were the strongest predictors of cognitive performance, with IQ also contributing considerable variance. Psychological gender (M/F scores) added a small, but significant, amount of variance to mental rotation and perceptual speed scores in addition to these main factors, but prenatal hormone related indices, such as 2nd to 4th finger ratios, birth order and sibling sex composition added no independent predictive power. These findings are discussed in relation to biosocial influences on cognitive differences between heterosexuals and homosexuals.

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1. Introduction

Sex differences in certain cognitive functions are well documented. Males, on average, outperform females in the tests of mental rotation, spatial perception, mathematical problem-solving and spatial navigation, while females do better than males in the tests of phonological and semantic fluency, perceptual speed, and memory for object locations (e.g. Voyer et al., 1995; Herlitz et al., 1997; Astur et al., 1998; Kimura, 1999; Acevedo et al., 2000; Collaer and Nelson, 2002). Often, these differences are task-specific. For example, although males excel at mathematical problem-solving, females do better in tests involving serial computation (Kimura, 1999). In the domain of spatial memory, the two sexes diverge in their performance as a function of the type of process examined; males performing better at navigation and place learning and females at memory for the spatial location of objects (McBurney et al., 1997; Astur et al., 1998).

It is therefore unsurprising that, the issue has been complicated further by the existence of...
cognitive differences between heterosexual and homosexual males and females, these within-sex variations contributing to the often elusive nature of "normative" sex differences (Sanders et al., 2002). Several studies have reported female-typical performance by homosexual males on mental rotations, spatial perception (for example on the water level test: Thomas et al., 1973), single item measures of letter and category fluency, verbal and performance IQ scores of the WAIS and on lexical decision-making (Sanders and Ross-Field, 1986, 1987; Gladue et al., 1990; McCormick and Witelson, 1991; Wegesin, 1998). The most replicable difference appears to be on mental rotations (Wegesin, 1998; Neave et al., 1999). However, one study failed to find any sexual orientation related cognitive differences (Gladue and Bailey, 1995). Most of these studies report no differences between heterosexual and homosexual females. In the most recent investigations in this area, using a large sample, homosexual males have been found to show female-typical performance in mental rotation, judgement of line orientation (JLO), phonological and semantic fluency, digit-symbol substitution and object location memory (Rahman et al., 2003a; Rahman et al., 2003a, b; Rahman et al., in press). Rahman et al. (2003b) also reported that homosexual females scored in male-typical directions on phonological and semantic fluency measures. They did not differ from heterosexual females in any other cognitive task. The effect sizes for these sexual orientation related differences were usually modest to large effects by standard definitions (Cohen’s $d = 0.5–1.2$), often comparable to the heterosexual sex difference. These findings support the "sexual orientation model" which proposes that sexual orientation exerts an influence just as powerful as sex per se on sexually dimorphic cognitive performance (Sanders and Ross-Field, 1987).

Although the existence of sexual orientation related cognitive differences may be robust, it is far from clear as to which factors are formative in these neurocognitive patterns. Empirical debate around the origins of sex differences in neurobehavioural measures polarises between those proposing gender role socialisation factors as important determinants versus those emphasising biological, primarily hormonal, factors.

Males and females differ in both these broad factors, as well as a myriad of other biological and experiential variables. Gender role socialisation theorists propose that internalised stereotypical notions about male and female personality from the social and cultural context, or from parental gender role reinforcement, lead to engagement in sex-differentiated activities and behaviour. These, in turn, are said to reinforce specific psychological mechanisms that ultimately form the basis for specific cognitive functions which themselves show sex differences, usually by adulthood (Caplan and Caplan, 1994). Although many studies show associations between measures of psychological gender, often ascribed to gender role socialisation, and spatial ability, such as mental rotation, the effect of sex is often greater than the effects of psychological gender (e.g. Jamison and Signorella, 1987; Hamilton, 1995; Parmeswaran, 1995; Weekes et al., 1995; Saucier et al., 2002).

Males and females also differ in their prenatal exposure to sex steroids (i.e. androgens, estrogens and progestins) and these hormones, probably in concert with other biological and nonbiological factors, almost certainly play a role in the development of cognitive and other behavioural sex differences (Collaer and Hines, 1995; Hines, 2000). Experimental manipulations in animals have demonstrated clear sex steroid effects on cognitive functions such as spatial memory (Williams et al., 1990). In humans, exposure to elevated androgens in utero (most obviously in the condition of congenital adrenal hyperplasia in females) appears likely to influence childhood play behaviour, sexual preferences, propensity towards aggression, but the evidence is weaker and less consistent for prenatal hormone effects on sexually dimorphic cognitive functions in these populations (reviewed in Hines, 2000). Studies of the activational effects of serum and saliva levels of sex hormones show either positive, negative, null or curvilinear effects on cognition, i.e., they are inconsistent (e.g. Silverman et al., 1999), whilst exogenously administered hormones, such as those given to transsexuals, lead to an improvement in male-typical spatial functions, such as mental rotation ability, and occasionally in female favouring functions, such as verbal fluency, although this is not consistently demonstrated at follow-up (Van Goozen et al., 1994, 1995; Miles et al., 1998; Slabbery et al., 1999). Studies of menstrual cycle effects show that both estrogens and testosterone modulate sex-dimorphic (but not sex-neutral) cognitive performance and cerebral asymmetries (Hausmann et al., 2000; Maki et al., 2002).

Recently, interest has turned to non-invasive somatic markers often ascribed to the effects of prenatal androgens. One focus of the present investigation is on the 2nd to 4th finger length ratio (2D:4D), often ascribed to prenatal androgen influences. In fact, the evidence for such a link is reasonably strong. The 2D:4D ratio is sexually dimorphic, with men showing reduced ratios and women greater (Manning et al., 1998, 2000).
dies of foetal material suggest relative finger length is established in utero by week 14 (Garn et al., 1975), and there is cross-sectional evidence that the 2D:4D ratio is fixed at least as early as two years, showing no substantial change thereafter (Phelps, 1952; Manning et al., 1998). Serum levels of testosterone show negative associations with 2D:4D in men (Manning et al., 1998). Manning et al. (1998) have argued that, if 2D:4D is fixed prenatally, it is likely that these correlations reflect in utero relationships between 2D:4D and sex steroids. Support for this comes from the following observations: (a) the waist:hip ratio of mothers, a positive correlate of testosterone and a negative correlate of estradiol, is negatively related to the 2D:4D ratio of their female and male children (Manning et al., 1999) and (b) males and females with congenital adrenal hyperplasia (being exposed to high levels of androgens in utero) have low values of 2D:4D compared to controls (Brown et al., 2001). Finally, Manning et al. (1998) have pointed out that the ontology of the digits and gonads is influenced by the same set of Homeobox or Hox genes (Kondo et al., 1997). Patterns of development of the former may therefore reflect the function of the latter. In relation to cognition, four studies from samples in London, Merseyside (UK) and Hungary report that 2D:4D ratios are negatively associated with rotation scores in males (Sanders et al., 2000; Manning and Taylor, 2001). Thus, putatively lower levels of prenatal androgens are associated with better performance in males. Such measures provide a promising avenue for further hormonal explorations of within-sex differences in cognition.

As on date, there has been no investigation of factors that may contribute to sexual orientation effects per se on sex-dimorphic cognitive functioning. However, there are several reasons to suspect that the two domains of influence described above may indeed contribute to such differences. Firstly, homosexual males and females are consistently shown to report sex-typical psychological gender in traditional masculinity–femininity dimensions, and on scales of occupational interests and activities (see Lippa, 2002, for review). Such differences may be preceded by childhood gender non-conformity, reported retrospectively and prospectively in homosexual males and females (Bailey and Zucker, 1995). Interestingly, two studies reported that boys who showed elevated gender non-conformity demonstrated diminished performance on two spatial tasks (Block Design and Object Assembly) and better verbal performance (on vocabulary and verbal comprehension tests) compared to controls (Finegan et al., 1982; Grimshaw et al., 1991). Secondly, homosexual males and females have been shown to differ in somatic markers of prenatal hormones, particularly the 2D:4D ratio, where homosexual males and females show lower ratios compared to heterosexual males and females (Rahman and Wilson, 2003a, b; Rahman et al., in press). Both psychological gender and 2D:4D ratios have been implicated in sexually dimorphic cognitive functions. Further evidence, employing the 2D:4D ratio, also suggests that homosexual males with older brothers may be exposed to higher levels of androgens prenatally (Williams et al., 2000). Thus, it is possible that the number of older brothers, specifically, may be associated with a variety of sexually dimorphic traits, and notably those cognitive differences found to be associated with homosexual orientation. These findings add to a large body of evidence for a later birth order in homosexual males in relation to their brothers (and not their sisters), known as the fraternal birth order effect (see Blanchard, 2001, for review). Blanchard and Klassen (1997) have proposed that the later birth order relative to male siblings shown by homosexual males may be due to progressive maternal immunisation of male-linked H-Y antigens with each male fetus, shifting neural sexual differentiation of successive male fetuses in a feminising direction prenatally. An additional hypothesis proposed by Blanchard et al. (2002) is that fraternal birth order may correlate with visuo-spatial ability among homosexual males or males in general. They argue that lower fraternal birth order may be associated with poorer visuo-spatial performance.

The present report derives from a large investigation of sexual orientation related cognitive differences (Rahman and Wilson, 2003a; Rahman et al., 2003a, b; Rahman et al., in press). This study utilised a series of cognitive measures and acquired data on a range of potential predictor variables. These predictor variables were right-hand 2D:4D ratio, left-hand 2D:4D ratio, psychological gender, birth order, sibling sex composition, age and general intelligence. It therefore provides a novel opportunity to investigate the hypothesis that factors previously shown to be associated with homosexuality in humans, and sex effects in cognition, would also contribute to sexual orientation effects on sexually dimorphic cognitive performance.
2. Method

2.1. Subjects

The sample comprised of 60 heterosexual males, 60 homosexual males, 60 heterosexual females, and 60 homosexual females (between 18 and 40 years of age and screened to exclude any history of head injury, psychoactive medication or drug use). The subjects were asked a 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 was unsure of this, was not recruited into the study. Heterosexual subjects were recruited from university sources, through newspaper advertisements and social networks. Homosexual subjects were recruited from university gay and lesbian organisations, gay/lesbian press, and social networks. Recruitment advertisements requested volunteers 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 geographical regions of the UK. Sexual orientation was assessed using a modified Kinsey item (Kinsey et al., 1948). This involved responding to a question 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 gay or lesbian, those scoring 0 and 1 classified as heterosexual (subjects with intermediate 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). The subjects were classified by parental socioeconomic status into the following categories according to the Standard Occupational Classification (Office of Population Census and Surveys, 1991): (1) professional, (2) managerial and technical, (3) skilled—non-manual, (4) skilled—manual, (5) partly skilled and (6) unskilled. Only predominantly right-handed subjects (those scoring > +31 on the Edinburgh Handedness Inventory (EHI): Oldfield, 1971) were included.

2.1.1. Pubertal onset

Timing of pubertal onset was measured by a seven-item questionnaire (following Tenhula and Bailey, 1998) asking about age (in years) when significant pubertal events (for females: growth of pubic hair, growth of breasts, age of menstrual onset, and for males: growth of pubic hair, age of first ejaculation, voice change) occurred. The final item asked subjects to rate their perception of the relative timing of these events overall compared to their peers on a 5-point scale (1 = much earlier, more than 2 years; 2 = somewhat earlier, between 6 months and 2 years; 3 = same time, within 6 months; 4 = somewhat later, between 6 months and 2 years; 5 = much later, more than 2 years).

2.1.2. Erotic role identification

Only homosexual subjects completed this measure. They were asked to respond to two statements: "I think of myself primarily as butch or active" and "I think of myself primarily as femme or passive" on an 11-point scale from 0 (definitely not true) to 10 (definitely true). There was a significant negative correlation between the two scales (for gay men: \( r = -0.591, p < 0.001 \), for lesbians: \( r = -0.348, p < 0.001 \)) indicating that, consistent with previous studies, they measure two ends of much the same dimension (Singh et al., 1999). Thus, a single index was computed by subtracting the femme rating from the butch one. This measure (termed "degree of butchness") ranged from −10 (strongly femme identified) to +10 (strongly butch identified).

2.2. Predictors

2.2.1. Psychological gender (M–F)

The subjects completed the 20-item sub-scale ("masculinity–femininity") of the Eysenck Personality Profiler (EPP) (Eysenck et al., 1996). The subjects could score between 0 and 40 on this scale, as delineated in the EPP manual. High-scorers were classified as "masculine" whilst low-scorers were classified as "feminine". This scale was used, as it is UK based, with recent norms (Eysenck et al., 1996). It comprises items that, empirically, show maximum separation between typical men and women, ranging from concern about crawling insects, to tolerance of obscenity, interest in children and clothes, and willingness to express emotion (e.g. by crying publicly).

2.2.2. Finger length ratios

Briefly (see Rahman and Wilson, 2003b), electrostatic photocopies of the subjects’ left and right hands were made. The lengths of the second and fourth digits were measured on the ventral (palm) surface of the hand, from the basal crease of the digit to the tip of the digit. Where there was a band of creases at the base of the digit (most common with the fourth digit), the most proximal of these creases was measured (Manning et al.,...
This was done twice on both hands. Digital callipers measuring to 0.01 mm were used for all measurements. Finger digit measures have a high level of repeatability (Manning, 1995). Finger length measurements were then averaged and the ratios calculated by dividing the length of the second digit by that of the fourth (=2D:4D) for the right and left hands separately (Manning et al., 1998, 2000).

2.2.3. Birth order and sibling sex composition
The subjects were asked to list the number of older brothers they had, the number of older sisters, younger brothers and younger sisters. Only biological siblings on the side of the mother were to be listed (that is siblings whom the subject’s biological mother gave birth to). The subjects also listed their birth order relative to that of their siblings, and the corresponding sex and age of each sibling in a table. Birth order was calculated by dividing the number of siblings older than the proband by older siblings plus younger siblings. The index cannot be computed for only children. For all other individuals, regardless of sibship size, it expresses birth order as a quantity between 0 and 1, where 0 corresponds to first born and 1 corresponds to last born.

2.3. Cognitive measures

2.3.1. Mental rotation
This 20-item test (Vandenberg and Kuse, 1978; adapted from Shepard and 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. The subjects were given 10 min to complete the task. Each test item has two correct and two incorrect choices. For each item, participants received two points if they marked both correct choices and one point if one choice was correct (but the other incorrect). All other responses received a score of 0 for the item. The maximum possible score was thus 40 points. This was the "total correct" measure for speed and accuracy. "Number of trials attempted" was scored for speed per se. "Percentage correct" was finally 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. This task consistently favours men.

2.3.2. Judgement of line orientation (JLO)
This visuo-perceptual test (Benton et al., 1983) consists of 30 items. For each item, the subjects were required to judge which lines in a complex array are in the same spatial orientation as 2 line fragments appearing above the array. Subjects scored 1 point for the two correct choices, and 0 points for any other response. The maximum possible score is thus 30. This task is also male favouring.

2.3.3. Verbal fluency
The subjects completed three measures of verbal fluency: letter fluency, category fluency and synonym fluency. Letter fluency was assessed using the Controlled Oral Word Association test (COWA; Benton and Hamsher, 1978). The subjects were allowed 60 s to generate as many words as possible beginning with a specific letter. The test letters were "P", "R" and "W", and the score was the sum of all acceptable words generated (excluding proper nouns, and repetitions). For category fluency, the subjects were asked to generate as many words as possible belonging to the categories "animals" (from the COWA), "fruit" and "vegetables" (used by Acevedo et al., 2000). The subjects were allowed 60 s for word generation per category. The score was the sum of all correctly produced words (excluding non-category terms and repetitions). For synonym fluency (derived from Hines, 1990), the subjects were presented with six familiar English words ("strong", "happy", "pretty", "sharp", "dark" and "clear") and asked to generate as many synonyms for each word (60 s per word) as possible. The score was the sum of all acceptable words (excluding non-synonyms or word associations, and repetitions). Two raters determined whether the answers were correct using a thesaurus and dictionary. All three tests are female favouring.

2.3.4. Perceptual speed
Perceptual speed was evaluated using the digit-symbol subtest of the Wechsler Adult Intelligence Scale Revised (Wechsler, 1981). The subjects were required to fill in as many symbols corresponding to a set of stimulus numbers as possible (by using a key visible throughout the test in which a number and symbol are paired). Ninety seconds were allowed for the whole test. The subjects received 1 point for each correct symbol, the maximum score being 93. The scores were scaled according to standardised instructions from the WAIS-R manual, thus only scaled scores are used in analysis. This test is female favouring.

2.3.5. Object location memory
Object location memory was assessed using Smith and Milner (1981, 1989) spatial memory test. This
is a test of incidental spatial memory in which the subjects are asked to estimate (verbally) the prices of 16 everyday objects arranged in a random order in a 50 cm by 50 cm cardboard array. Following a delay of 30 min (during which the subjects completed the rest of the cognitive battery), the subjects were asked to recall the names of objects, identify the objects among a set of foils, and finally, to place all the objects back in their original positions as best they could remember. The task is scored by calculating the absolute deviation (in millimetres) in the positions of objects at the encoding stage (price estimation) and retrieval stage (place in which objects were subsequently placed). This is a measure of location memory. For the purposes of this report, only the location memory measure is used in further analysis.

2.3.6. General intelligence

General cognitive ability was assessed using Raven’s Standard Progressive Matrices test (Raven, 1958). The SPM is a paper and pencil non-verbal test and contains 60 items of increasing difficulty. The subjects are required to select one among six or eight alternatives to complete a matrix pattern. Raw scores were used in the analysis (maximum score 60).

2.4. Perceived stress

Moderate levels of stress can enhance neuropsychological performance, whilst high levels of stress often impede performance. Thus, it is reasonable to ask whether stress levels during task performance (or because of task performance) modulate any sex and sexual orientation related differences. In the present work, the subjects were asked to rate their level of stress (at the end of the testing session) as experienced during completion of the whole battery of tests from 0 indicating “not at all stressed” to 10 “extremely stressed”.

2.5. Procedure

Each subject was tested individually. Firstly, the subjects provided demographic information and completed questionnaire measures. The cognitive battery was then administered, in a randomised fashion across the subjects with the exception of the object location memory task. This was administered in two parts because of the requirement for a 30-min delay. The first stage (price estimation) was administered upon completion of the questionnaires. All other cognitive tasks were then completed during the delay, after which the recall stages of the object location memory task were administered. The subjects then completed Raven’s SPM. Finally, the subjects completed the Perceived Stress Scale. Upon completion of the entire battery, the subjects were taken to a photocopy room in order to take electro-static photocopies of their hands. The whole procedure lasted 2 h, and the subjects were remunerated the sum of £20 for their time. The Ethical (Research) Committee of the Institute of Psychiatry and Maudsley Hospital, London, approved all procedures.

2.6. Statistical analysis

To determine whether the data were normally distributed, a series of box plots were computed for each continuous variable. Socio-economic status (SES) and ethnicity were analysed by $\chi^2$. Group differences in age, years in education, handedness scores, pubertal onset measures, psychological gender, birth order, sibling sex composition, finger length ratios, IQ and perceived stress scores were analysed by the General Linear Model (GLM) factorial (gender by sexual orientation) analyses of variance (ANOVA) using the Statistical Package for the Social Sciences (SPSS) version 8.0. The remaining cognitive tasks were analysed using analysis of covariance (with age and IQ as covariates) and post-hoc tests to decompose significant interactions.

To examine the contribution of putative predictors of any sexual orientation related cognitive variation, a series of forced entry stepwise multiple regressions were conducted between performance on each cognitive task and the predictor variables. The first predictor was a dummy coded variable comprising the subject groups (homosexual males, homosexual females and heterosexual females, with heterosexual males as the reference group; $K−1$). For all analyses, “group” (from hereon called “sexual orientation” to refer to both sex and sexual preference group membership) was force entered into the first block of the regression equation, which allows all between-group differences to be attributed to sexual orientation. The remaining predictor variables (age, IQ—Raven’s SPM score, psychological gender, number of older brothers, number of older sisters, number of younger brothers, number of younger sisters, birth order, right 2D:4D, and left 2D:4D) were entered into the second block in a stepwise fashion. Reported in Table 3 are the $r$ and $r^2$ which detail the amount of variance explained cumulatively with the addition of successive predictors and the $r^2$ change which details the variance accounted for with the addition of each individual predictor in subsequent steps. The $p$-value for the $r^2$ change is also presented. The assumptions of regression were found to have
been met on visual inspection of the residual plots for each regression which confirmed homoscedasticity, whilst inspection of the correlation matrix showed no evidence of multi-collinearity (all $r_s < 0.8$).

A series of partial correlations, controlling for age and IQ, were computed between each cognitive performance measure and variables of secondary interest to this investigation. These variables were: age of first ejaculation and overall self-rating of pubertal onset in relation to same-sex peers (which differed between the male groups only) and degree of butchness (for homosexuals only and split by sex).

3. Results

3.1. Subject characteristics

There were no significant group differences in education, ethnicity, parental socio-economic status or in mean EHI scores (all $p$s > 0.05). However, there was a significant effect of sex ($F = 13.460$, df = 1, 239, $p < 0.001$) and sexual orientation ($F = 10.722$, df = 1, 239, $p < 0.001$) on age; males being older than females, and homosexuals being older than heterosexuals.

Pubertal onset was analysed separately for males and females as it varies substantially between the sexes (Johnson and Everitt, 1988) (see Table 1). There were no significant differences between heterosexual and homosexual males in age at first pubic hair growth (all $p$s > 0.05). However, homosexual males reported significantly earlier age at first ejaculation than heterosexual males ($t = 2.438$, df = 118, $p = 0.016$, Cohen's $d = 0.45$) and rated their overall pubertal onset as earlier relative to their peers than did heterosexual males ratings ($t = 4.641$, df = 118, $p = 0.000$, Cohen's $d = 0.84$). There were no significant differences between heterosexual and homosexual females in any pubertal onset measure (all $p$s > 0.05).

3.2. Sexual orientation related cognitive differences

The results of the statistical analyses on sexual orientation related differences in cognitive performance are presented elsewhere (see Rahman and Wilson, 2003a; Rahman et al., 2003a, b; Rahman et al., in press). Suffice to say here that analysis of covariance (controlling for age and IQ) revealed significant sex by sexual orientation interactions for all tasks (all $p$s < 0.001). Post-hoc tests (corrected for multiple comparisons to $p < 0.01$) revealed that heterosexual males scored higher than heterosexual females and homosexual males on mental rotation and JLO (all $p$s < 0.001). On letter, category and synonym fluency tests, spatial location memory and digit-symbol substitution, homosexual males scored in female-typical directions (i.e. higher than heterosexual males; $p$s < 0.001). Homosexual females had a significantly male-typical profile of performance on all three verbal fluency tests (i.e. performed poorer than heterosexual females; $p$s < 0.001), but did not differ from heterosexual females on any other cognitive measure. See Fig. 1 for presentation of standardised scores ($z$) for each cognitive task across the groups.

3.3. Perceived stress scores

There were no significant main effects of sex ($F = 3.283$, df = 1, 239, $p = 0.071$), sexual orientation ($F = 0.807$, df = 1, 239, $p = 0.370$) or their interactions ($F = 3.723$, df = 1, 239, $p = 0.06$) in perceived stress scores.

3.4. Sexual orientation related differences in the predictor variables

3.4.1. Psychological gender (M–F)

There was a significant main effect of sex ($F = 35.990$, df = 1, 239, $p < 0.001$), with males scoring higher (indicating psychological masculinity) than females, a main effect of sexual orientation ($F = 7.775$, df = 1, 239, $p = 0.006$), with homosexuals scoring lower than heterosexuals, and a significant interaction ($F = 25.094$, df = 1, 239, $p < 0.001$). Table 2 lists the mean scores per group. Decomposition of this interaction revealed that heterosexual males scored higher than heterosexual females ($t = 8.495$, df = 118, $p < 0.001$), homosexual males scored lower than heterosexual males (indicating more gender-atypicality in psychological gender scores) ($t = 5.742$, df = 118, $p < 0.001$), and there was no difference between heterosexual and homosexual females ($t = -1.513$, df = 118, $p = 0.133$). The effect size for the heterosexual differences was large ($d = 1.55$) as was the difference between heterosexual and homosexual males ($d = 1.04$).

3.4.2. Finger-length ratios

Factorial ANCOVAs were applied to the finger-length ratio data with age, height and weight as covariates (Rahman and Wilson, 2003b). For right-hand ratios, there was a significant main effect of sexual orientation ($F = 24.237$, df = 1, 239, $p < 0.001$); homosexuals having lower right-hand
2D:4D ratios than heterosexuals. There were no significant sex or interaction effects (all $p > 0.05$). Overall, the difference between homosexuals and heterosexuals constituted a moderate to large effect ($\eta^2 = 0.09$). For left-hand ratios, a significant main effect of sexual orientation emerged ($F = 5.436$, df = 1, 239, $p = 0.021$); homosexuals showing lower left-hand 2D:4D ratios compared with heterosexuals. There were no significant sex or interaction effects (all $p > 0.05$). The overall difference between homosexuals and heterosexuals in left-hand ratios was small ($\eta^2 = 0.02$), indicating that the right-hand 2D:4D ratio may be more closely related to sexual orientation than the left-hand ratio (see Table 2 for mean ratios).

### 3.4.3. Birth-order and sibling sex composition

The data are reported here separately for males and females, as birth-order effects have been ascribed to male, but not female sexual orientation in the literature (Blanchard, 2001) (See Table 2). There were no significant differences between heterosexual and homosexual males in

#### Table 1: Subject characteristics (means and frequencies are presented where appropriate. Standard deviations are presented in parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Heterosexual males</th>
<th>Heterosexual females</th>
<th>Homosexual males</th>
<th>Homosexual females</th>
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<tr>
<td>Age (years)</td>
<td>29.91 (6.60)</td>
<td>26.80 (5.87)</td>
<td>32.08 (5.66)</td>
<td>29.61 (5.35)</td>
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<td>Years in education</td>
<td>15.96 (3.29)</td>
<td>16.65 (3.29)</td>
<td>16.51 (3.86)</td>
<td>15.95 (3.71)</td>
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<tr>
<td>Handedness (EHI scores)</td>
<td>82.67 (19.42)</td>
<td>87.33 (16.96)</td>
<td>83.02 (20.19)</td>
<td>85.31 (18.46)</td>
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<tr>
<td>Pubertal onset (male)</td>
<td>12.32 (1.64)</td>
<td>N/A</td>
<td>12.06 (1.30)</td>
<td>N/A</td>
</tr>
<tr>
<td>Pubertal onset (pubic hair)</td>
<td>13.08 (1.63)</td>
<td>N/A</td>
<td>12.41 (1.33)</td>
<td>N/A</td>
</tr>
<tr>
<td>Pubertal onset (ejaculation)</td>
<td>13.69 (1.28)</td>
<td>N/A</td>
<td>13.22 (1.45)</td>
<td>N/A</td>
</tr>
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<td>Pubertal onset (voice break)</td>
<td>3.21 (0.80)</td>
<td>N/A</td>
<td>2.55 (0.76)</td>
<td>N/A</td>
</tr>
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<td>Pubertal onset (female)</td>
<td>N/A</td>
<td>11.45 (1.27)</td>
<td>N/A</td>
<td>11.44 (1.51)</td>
</tr>
<tr>
<td>Pubertal onset (breasts)</td>
<td>N/A</td>
<td>11.55 (1.59)</td>
<td>N/A</td>
<td>11.89 (1.53)</td>
</tr>
<tr>
<td>Pubertal onset (first period)</td>
<td>N/A</td>
<td>12.32 (1.59)</td>
<td>N/A</td>
<td>12.57 (2.23)</td>
</tr>
<tr>
<td>Pubertal onset (overall rating)</td>
<td>N/A</td>
<td>2.86 (0.81)</td>
<td>N/A</td>
<td>3.01 (1.04)</td>
</tr>
<tr>
<td>Perceived stress</td>
<td>3.55 (2.30)</td>
<td>3.51 (2.15)</td>
<td>2.75 (1.95)</td>
<td>3.80 (2.32)</td>
</tr>
<tr>
<td>Degree of ‘’butchness’’</td>
<td>N/A</td>
<td>N/A</td>
<td>1.41 (4.02)</td>
<td>-0.96 (4.48)</td>
</tr>
</tbody>
</table>

N/A = not applicable to that group

![Fig. 1. Standardised (z) cognitive scores across groups. Object location memory scores are reversed.](image-url)
Variables rejected by the regression model were number of older brothers, number of younger brothers, number of older sisters, number of younger sisters, birth order, right 2D:4D and left 2D:4D. In summary, sexual orientation explained most of the variance in MR—total correct scores, with M–F being the second best predictor. There was no contribution of any other predictor.

For mental rotation—percentage scores (MR—percentage), sexual orientation explained 8.3% of the variance in MR—percentage scores (adjusted $r^2 = 0.070$). The addition of IQ led to a significant 11.1% increase in the amount of variance explained while the addition of M–F led to a significant 3.6% increase. In the final step, the overall amount of variance explained by the variables under consideration was 23% (adjusted $r^2 = 0.211$). Variables rejected by the model were age, number of older brothers, number of younger brothers, number of older sisters, number of younger sisters, birth order, right 2D:4D and left 2D:4D. In summary, “sexual orientation” and IQ were the strongest predictors of MR—percentage scores.

### 3.5.2. Prediction of judgement of line orientation (JLO) performance

In Rahman and Wilson (2003a), JLO scores were transformed because they violated the assumption of normality for parametric statistics. Therefore, only transformed scores were used in the present analysis. Sexual orientation accounted for 23.5% of the variance (adjusted $r^2 = 0.224$). The addition of IQ in the second step led to a significant increase in variance explained by 7.7%. The addition of number of older sisters at the third and final step accounted for an extra 1.3%, leading to attenuation in the $p$-value for the final prediction.
model. Predictors rejected by the model were age, M–F, number of older brothers, number of younger brothers, number of older sisters, number of younger sisters, birth order, right 2D:4D and left 2D:4D. Thus, overall, sexual orientation explained most of the variance in JLO scores.

3.5.3. Prediction of verbal fluency performance

For letter fluency scores, sexual orientation accounted for 25.5% of the variance (adjusted $r^2 = 0.245$). The addition of age on the second and final step led to a significant 1.5% increase, although examination of Table 3 shows that the $p$-value was attenuated. Variables rejected by the model were M–F, IQ, number of older brothers, number of younger brothers, number of older sisters, number of younger sisters, birth order, right-hand 2D:4D and left-hand 2D:4D. For category fluency scores, sexual orientation explained 31.2% of the variance (adjusted $r^2 = 0.303$). The addition of age on the second step led to an increase in variance explained by 2.3%, and the addition of IQ at the third and final step led to an increase of 1.3% in variance explained. Variables rejected by the model were M–F, number of older brothers, number of younger brothers, number of older sisters, number of younger sisters, birth order, right-hand 2D:4D and left-hand 2D:4D. For synonym fluency scores, sexual orientation accounted for 42.7% of the variance (adjusted $r^2 = 0.419$). The addition of age on the second and final step in this model led to an increase of 1.3% in variance explained. Variables rejected by the model were M–F, IQ, number of older brothers, number of younger brothers, number of older sisters, number of younger sisters, birth order, right-hand 2D:4D and left-hand 2D:4D. Thus, sexual orientation explains by far the greatest amount of variance in verbal fluency scores.

3.5.4. Prediction of perceptual speed

For digit-symbol scaled scores, sexual orientation accounted for 7% of the variance (adjusted $r^2 = 0.057$). The addition of IQ in the second step led to an increase of 9.6% and the addition of M–F in the third and final step led to an increase of

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Summary of each forced entry regression model for each cognitive task</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r^2$</td>
</tr>
<tr>
<td>Mental rotation—total correct</td>
<td></td>
</tr>
<tr>
<td>Step 1: sexual orientation</td>
<td>0.126</td>
</tr>
<tr>
<td>Step 2: sexual orientation, M–F</td>
<td>0.220</td>
</tr>
<tr>
<td>Step 3: sexual orientation, M–F and IQ</td>
<td>0.247</td>
</tr>
<tr>
<td>Step 4: sexual orientation, M–F, IQ and age</td>
<td>0.265</td>
</tr>
<tr>
<td>Mental rotation—percentage correct</td>
<td></td>
</tr>
<tr>
<td>Step 1: sexual orientation</td>
<td>0.083</td>
</tr>
<tr>
<td>Step 2: sexual orientation, IQ</td>
<td>0.193</td>
</tr>
<tr>
<td>Step 3: sexual orientation, IQ and M–F</td>
<td>0.230</td>
</tr>
<tr>
<td>JLO</td>
<td></td>
</tr>
<tr>
<td>Step 1: sexual orientation</td>
<td>0.235</td>
</tr>
<tr>
<td>Step 2: sexual orientation, IQ</td>
<td>0.312</td>
</tr>
<tr>
<td>Step 3: sexual orientation, IQ, number of older sisters</td>
<td>0.325</td>
</tr>
<tr>
<td>Letter fluency</td>
<td></td>
</tr>
<tr>
<td>Step 1: sexual orientation</td>
<td>0.255</td>
</tr>
<tr>
<td>Step 2: sexual orientation and age</td>
<td>0.270</td>
</tr>
<tr>
<td>Category fluency</td>
<td></td>
</tr>
<tr>
<td>Step 1: sexual orientation</td>
<td>0.312</td>
</tr>
<tr>
<td>Step 2: sexual orientation, age</td>
<td>0.336</td>
</tr>
<tr>
<td>Step 3: sexual orientation, age and IQ</td>
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<tr>
<td>Synonym fluency</td>
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<tr>
<td>Step 1: sexual orientation</td>
<td>0.427</td>
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<tr>
<td>Step 2: sexual orientation and age</td>
<td>0.440</td>
</tr>
<tr>
<td>Digit-symbol scores</td>
<td></td>
</tr>
<tr>
<td>Step 1: sexual orientation</td>
<td>0.070</td>
</tr>
<tr>
<td>Step 2: sexual orientation, IQ</td>
<td>0.167</td>
</tr>
<tr>
<td>Step 3: sexual orientation, IQ and M–F</td>
<td>0.218</td>
</tr>
<tr>
<td>Spatial location memory</td>
<td></td>
</tr>
<tr>
<td>Step 1: sexual orientation</td>
<td>0.116</td>
</tr>
</tbody>
</table>
5.1% in the amount of variance explained. Variables rejected by the model were age, number of older brothers, number of younger brothers, number of older sisters, number of younger sisters, birth order, right-hand 2D:4D and left-hand 2D:4D. Thus, in contrast to the previous regression models, all three variables—sexual orientation, IQ and M–F—emerged as the strongest predictors of digit-symbol scaled scores.

3.5.5. Predicting of object location memory
Sexual orientation emerged as the only predictor of variance in spatial location memory scores, explaining 11.6% of the variance (adjusted \( r^2 = 0.104 \)). Variables rejected by the model were age, IQ, M–F, number of older brothers, number of younger brothers, number of older sisters, number of younger sisters, birth order, right-hand 2D:4D and left-hand 2D:4D.

3.6. Associations between cognitive performance and pubertal onset, and ”degree of butchness”

Regarding age of first ejaculation and overall self-rating of pubertal onset, for heterosexual males, there were no significant associations between age of first ejaculation, overall pubertal onset and any cognitive measure (all \( ps > 0.05 \)). Similarly, for homosexual males, there were no significant associations between age of first ejaculation, overall pubertal onset and any cognitive measure (all \( ps > 0.05 \)).

Analysis for ”degree of butchness” was split between homosexual males and homosexual females. There were no significant associations between ”degree of butchness” scores and any cognitive measure for both groups (all \( ps > 0.05 \)).

4. Discussion

To aid clarity, the following summary of the findings is provided:

1. Sexual orientation was the strongest predictor of performance on judgement of line orientation, letter fluency, category fluency, synonym fluency and spatial location memory, accounting for between 12 and 42% of the variance in the scores of these tasks.

2. Sexual orientation and psychological gender (M–F) were strong predictors (sexual orientation being the strongest—12% of the variance) of mental rotation—percentage correct scores (accounting jointly for 19% of the variance) and digit-symbol scaled scores (IQ the stronger predictor accounting for 9%, and with sexual orientation, for 16% of the variance).

3. There was no contribution of the 2nd to 4th finger length ratios or sibling sex composition and birth order to cognitive performance separated from other factors: IQ, sex, sexual orientation, and psychological gender.

4. There were no associations between pubertal onset measures and cognitive performance for heterosexual and homosexual males. Finally, there were no associations between ”degree of butchness” and cognitive performance for either homosexual males or females.

The aim of this investigation was to provide new information on the contentious issue of what factors contribute to sexual orientation related differences in sex-dimorphic cognitive performance. The findings presented above, the first of their kind, show little support for any influence of prenatal hormone related factors on sexually dimorphic cognitive performance in addition to IQ, sex and sexual orientation. There was, however, some support for the role of psychological gender in MR—total correct scores. Unsurprisingly, IQ explained some variance in MR—percentage scores and digit-symbol test scaled scores. However, by far the most powerful predictor of cognitive differences was sexual orientation.

The results presented here do not support the work of others who report associations between somatic markers of prenatal sex hormones and performance on sex-dimorphic cognitive tasks in unselected heterosexual samples, particularly those reporting a negative association between 2D:4D ratios and mental rotation performance (Sanders et al., 2000; Manning and Taylor, 2001; Sanders and Kadam, 2001; Sanders and Waters, 2001). They also do not support the suggestion of Blanchard et al. (2002) that number of older brothers may be associated with variation in sex-dimorphic traits associated with homosexual orientation. Yet, both these traits, that is low 2D:4D ratios and excess of older brothers, are associated with homosexuality (the latter in males only). Thus, these traits, or more precisely, the real difference underlying the variation in these traits (prenatal hormonal influences on the developing brain), should theoretically predict behavioural differences also associated with homosexual orientation. However, it appears that insofar as these factors affect cognitive function-
The influence of sex hormones on cognitive performance, whether they be organisational or activational, is a matter of considerable debate, and findings include positive, negative or null results (Silverman et al., 1999). Many studies have failed to find differences in sex-dimorphic cognitive performance in populations exposed to elevated levels of prenatal androgens, yet report elevation in homosexual or bisexual preferences, for example in women with CAH (Hines, 2000). Thus, overall, the influence of prenatal hormones on sex differences in cognitive performance is far from clear and it would not be surprising to find that any association to sexual orientation related differences would be similarly inconclusive. Of the number of possible biological predictors of sexual orientation in humans, the present study examined a very narrow range of measures. Further work will need to take account of multiple factors.

The finding that psychological gender, an individual’s relative degree of masculinity or femininity (M–F), was a predictor of mental rotation (total correct) scores in addition to sexual orientation is partially consistent with studies that report a similar association between M–F measures, such as the Personal Attributes Questionnaire (PAQ) and Bem Sex Role Inventory (BSRI), and sex differences in mental rotation and water level test performance in unselected heterosexual men and women (e.g. Jamison and Signorella, 1987; Hamilton, 1995; Parameswaran, 1995; Saucier et al., 2002). They are inconsistent with the findings of Wegesin et al. (1998) who reported that levels of masculinity and femininity were not related to mental rotation and spatial perception (tests unspecified) performance in homosexual females. The studies in unselected samples also report that the influence of sex is greater than that of psychological gender, consistent with the present findings. For example, Saucier et al. (2002) reported that PAQ scores explained 6.3% of the variance in mental rotation scores outside of sex, which itself explained 13.5%. Nevertheless, some authors often conclude that such associations indicate an influence of “gender role socialisation” on mental rotation performance. The assumption is that scores on M–F measures reflect the internalisation of cultural gender stereotypes throughout an individual’s development. However, it is far from clear how this should then translate into mechanisms through which different cognitive specialisations, based on sex, are acquired. Moreover, recent work has shown that variance in gender-related interests, occupational preferences and hobbies (supposedly even more reflective of the adoption of cultural sex stereotypes) can largely be accounted for by genetic factors (Lippa and Hershberger, 1999). This is not surprising, as biological theories of sexual differentiation tend to predict stronger links between sex and psychological gender than do psychosocial theories (Lippa, 2002). It is then particularly difficult to tease apart the contribution of these two traits if they have substantial overlapping variance. This is particularly the case with sexual orientation, where sexual orientation related differences in M–F are closely related to the core trait itself (Gangestad et al., 2000; Lippa, 2002). Thus, although the measure of M–F in this study predicted some of the variance in mental rotations in addition to sex and sexual orientation, it is not immediately clear whether the influence is prenatally or post-natally (possibly psychosocial) determined.

The current finding that sexual orientation exerted the most powerful influence on cognitive performance is particularly intriguing. Prenatal hormones might operate on cognitive functioning via sex and sexual orientation, but other pathways are also possible. Recent work shows that the sex determining genes SRY and ZRY are transcribed directly in the hypothalamus, and the frontal and temporal cortex of the adult male brain (Mayer et al., 1998). This may extend to other sexual differentiation related genes, particularly those on the X chromosome, which shows an abundance of such genes (Saifi and Chandra, 1999). Thus, neural differences may acquire their sex specific properties independent of their hormonal environment. There is some evidence for an X-linked genetic locus to male sexual orientation (Hamer et al., 1993; Hu et al., 1995; cf. Rice et al., 1999). Interestingly, sequence variation in the androgen receptor gene is not a determinant of male sexual orientation (Macke et al., 1993). In other words, although there may be genetic factors in male sexual orientation, they may not necessarily act via hormonal mechanisms. If such genes also influence sexual orientation, then it is possible that they confer hormone-independent sex-linked neural differentiation which underscores variation in sex-linked cognitive functions. Such theorising is inherently speculative but it would be fair to say that human sexual orientation probably has multiple determinants (including genetic, hormonal and postnatal factors which influence neurodevelopment) and these, in concert, produce the profile of neurobehavioural differences between heterosexual and homosexual males and females.

The results of the partial correlations demonstrated no influence, overall, of the variables of
secondary interest to this investigation beyond that subsumed within sexual orientation. The present study found that although homosexual males report starting puberty earlier than heterosexual males, this did not affect cognitive performance. This is inconsistent with "Waber's (1976) hypothesis that early maturing adolescents, irrespective of sex, should perform better in verbal tasks (as homosexual males do in the current investigation) than in spatial tasks compared to later maturing adolescents. Other studies in unselected samples of heterosexual male and female adolescents also contradict Waber's hypothesis (e.g. Hassler, 1991; Davidson and Susman, 2001).

Finally, Singh et al. (1999) reported that "butch" lesbians demonstrate greater self-reported childhood gender-atypicality, higher waist-to-hip ratios, higher salivary testosterone and less desire to give birth than "femme" lesbians. They argue that such within-sexual orientation differences should extend to cognitive functions where sexual orientation effects have been demonstrated. The present study found no support for this assertion (using the same "degree of butchness" measure as Singh et al., 1999) in either homosexual males or homosexual females. Therefore, it appears that erotic role identification (possibly another measure of "psychological gender") has negligible influences on sexual orientation related differences in cognitive functions.

In conclusion, the present study has shown that measures of prenatal hormonal influences (2D:4D ratio, birth-order and sibling sex composition), previously shown to differentiate homosexuals from heterosexuals, added no independent predictive power to sexual orientation related differences in performance on a large battery of sex-dimorphic cognitive tasks. There was some influence of psychological gender on mental rotation and perceptual speed scores although the nature of the association is unclear. Sex and sexual orientation were the strongest predictors of cognitive differences, over-riding the effect even of IQ.

Acknowledgements
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References


