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BRIEF COMMUNICATIONS

Developmental Instability Is Associated With Neurocognitive Performance in Heterosexual and Homosexual Men, but Not in Women

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Little is known about the neurodevelopmental nature of human cognitive abilities. This investigation presents evidence consistent with a hypothesis that interindividual and within-sex cognitive variations are associated with vulnerabilities to environmental sources of developmental stress. A large sample of healthy heterosexual and homosexual men and women ($N = 240$) completed a series of visuospatial and verbal tests. A composite fluctuating asymmetry (FA) measure was computed from the lengths of the finger digits. In heterosexual men, higher FA scores were associated with poorer line orientation judgment; and in homosexual men, with poorer verbal fluency and perceptual speed. No associations were found in heterosexual or homosexual women. These results suggest that developmental instability is linked to neurocognitive integrity in men, but not in women.

There is wide interindividual variability in cognitive abilities, and a number of theories have been proposed to account for this variation. Among these are the well-described genetic models of Annett (1985) and McManus and Bryden (1992), which propose that a single autosomal gene influences cerebral lateralization for language and handedness. Others have focused on the effects of gonadal hormones (Collaer & Hines, 1995). Gonadal hormones have often been suggested to account for a major source of individual differences in cognition: sex. Cognitive sex differences are well documented, with men, on average, performing better than women on tests of mental rotation and spatial perception (Collaer & Nelson, 2002; Kimura, 1999; Voyer, Voyer, & Bryden, 1995) and women, on average, outperforming men on verbal fluency, verbal memory, perceptual speed, object location memory, and emotion processing (Herlitz, Nilsson, & Backman, 1997; Kimura, 1999; McBurney, Gaulin, Devineni, & Adams, 1997). There is also within-sex variation in cognitive performance related to sexual orientation. Several reports show that homosexual men perform more poorly on tests of mental rotation and spatial perception but are better on tests of verbal fluency and object location memory compared with heterosexual men (Gladue, Beatty, Larson, & Staton, 1990; McCormick & Witelson, 1991; Neave, Menaged, & Weightman, 1999; Rahman & Wilson, 2003a; Rahman, Wilson, & Abrahams, 2003; Sanders & Ross-Field, 1986; Wegesin, 1998). Homosexual women have been shown to perform more poorly than heterosexual women on verbal fluency only (Rahman, Abrahams, & Wilson, 2003).

Nonetheless, the role of genetic and hormonal factors in the sources of individual differences in cognition remains unclear. Were a single genetic pathway to influence cerebral lateralization globally, the variety of cognitive functions dependent on hemispheric dominance should correlate substantially, yet they do not. Also, the relationships between gonadal hormones and cognitive differences have included positive, negative, quadratic, and null findings (for a summary, see Silverman, Kastuk, Choi, & Phillips, 1999).

A neglected alternative suggestion has been that individual variation in neural function may be the outcome of *developmental instability* (DI), which refers to imprecise expression of the ontogenetic plan for neurodevelopment design caused by environmental or genetic perturbations (Moller & Swaddle, 1997). Markers of DI include *minor physical anomalies* (MPAs), which are morphological variations in specific somatic features caused by disrupted fetal growth rates. More often used are measures of *fluctuating asymmetry* (FA), which refers to the unsigned deviation from symmetry in bilateral physical traits, such as foot breadth, ankle breadth, wrist breadth, ear breadth and length, but more often the finger lengths (Gangestad, Bennett, & Thornhill, 2001; Martin, Manning, & Dowrick, 1999; Moller & Swaddle, 1997; Van Valen, 1962).

To date there are very few studies on the role of DI in neurocognitive functioning. Furlow, Armijo-Prewitt, Gangestad, and Thornhill (1997) reported a robust negative correlation between scores on a measure of general intelligence (Cattell's Culture-Fair Intelligence Test [CFIT]) and FA (using finger lengths and other markers) in two samples (total $N = 240$) of undergraduate students. Yeo, Gangestad, Thoma, Shaw, and Repa (1997) reported that individuals ($N = 146$ students) with higher FA (using finger lengths and MPAs) had more atypical lateralization scores on a dichotic listening task, line bisection, the Chimeric Faces test and the Cartoon Faces test. Finally, Jung, Yeo, and Gangestad (2000)

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reported that increased DI was associated with greater caffeine-induced verbal memory deficits (as assessed by the Rey Auditory Verbal Learning test). Measures of FA are also elevated in individuals with neurodevelopmental and learning disabilities (for a review, see Thornhill & Moller, 1997; Yeo & Gangestad, 1993). Thus, there is precedent for viewing DI as an important source of variation in neurocognitive functioning. Nonetheless, these studies cited in support have their limitations. One had a large sample (Furlow et al., 1997) but examined IQ only and not a broader range of cognitive functions. The others (Jung et al., 2000; Yeo et al., 1997) had relatively small sample sizes, and Yeo et al. (1997) limited their focus to measures of cerebral FA. Two further studies have indicated a neurological basis for possible cognitive variation associated with DI. Thoma, Yeo, Gangestad, Lewine, and Davis. (2002) reported that DI was associated with deviations from typical brain asymmetry, the size of the corpus callosum, and atypical asymmetry in the somatosensory cortex. Yeo, Hill, Campbell, Vigil, and Brooks (2000) reported that greater DI predicted reduced frontal lobe metabolism (using proton magnetic resonance spectroscopy of frontal neurometabolites) and working memory performance in children.

The aim of the present study was to examine the associations between markers of FA and performance on a broad range of cognitive functions in a large sample of healthy men and women recruited as part of an investigation of within-sex cognitive variation.

Method

Participants

Participants were 60 heterosexual men, 60 heterosexual women, 60 homosexual men, and 60 homosexual women (between 18 and 40 years of age). Full details of this sample are provided in Rahman and Wilson (2003a). Briefly, all participants were screened to exclude any history of head injury and psychoactive medication or drug use. Heterosexual subjects were recruited from university sources, through advertisements in local press and social networks. Homosexual subjects were recruited from university gay and lesbian organizations, gay and lesbian press, and social networks. Sexual orientation was assessed with a single-item question about self-identification, sexual/romantic attraction, sexual/romantic fantasies, and sexual behavior rated on a 7-point scale (ranging from 0 = *exclusively heterosexual* to 6 = *exclusively homosexual*). Only those scoring 5 and 6 (homosexual) and 0 and 1 (heterosexual) took part. The groups did not differ in number of years in full-time education since the age of 5, ethnic grouping (the categories White, Black, South Asian, East Asian, Hispanic, and Other were collapsed into "white" vs. "non-white"), or parental socioeconomic status (classified according to the *Standard Occupational Classification*; Office of Population Censuses and Surveys, 1991; all *p*s $> .05$). Only predominantly right-handed subjects (those scoring $> +31$ on the Edinburgh Handedness Inventory [EHI]; Oldfield, 1971) were included, and there were no group differences in mean EHI scores (all *p*s $> .10$). However, the groups did differ in age: main effect of sex, $F(1, 239) = 13.46$, $p < .01$, and main effect of sexual orientation, $F(1, 239) = 10.72$, $p < .01$. 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). The groups also differed in general intelligence (assessed with the Standard Progressive Matrices test, [SPM]; Raven, 1958), with a significant main effect of sexual orientation only, $F(1, 239) = 4.01$, $p = .04$; homosexuals having lower scores ($M = 45.19$, $SD = 6.55$) compared to heterosexuals (mean = 46.95, $SD = 7.05$). There was no evidence of learning disability in the present sample, as mean SPM scores fell between the 74th (intellectually average) and 79th (above average in intelligence) percentiles. Age, IQ, and EHI scores were controlled in subsequent analyses.

Procedure

Informed consent was obtained. Participants completed the battery of tests and measurements individually. The cognitive battery was administered in a pseudorandom order. Participants were remunerated £20 for their time. The following tests and measurements were administered:

FA. Digit calipers measuring to 0.01 mm were used to take bilateral measurements of the second and fourth finger lengths from electrostatic photocopies of participants' hands (for full details, see Rahman & Wilson, 2003b). Finger lengths were measured on the ventral surface of the hand, from the basal crease to the tip of the finger. If there was more than one crease at the base of the finger, the most proximal of these was used. These measurements were taken twice. Similar to published norms (Manning, 1995), our finger length measures showed a high level of repeatability (for right-hand measurements, Pearson's $r = .95$; left hand measurements, $r = .96$). FA was calculated by subtracting the right from the left finger lengths.

Cognitive measures. Full details of tasks used are provided elsewhere (Rahman & Wilson, 2003a; Rahman, Abrahams, & Wilson, 2003; Rahman, Wilson & Abrahams, 2003; Rahman, Wilson, & Abrahams, in press). Briefly, the following seven visuospatial and verbal measures were used:

1. *Mental Rotation.* This 10-min, 20-item test (Vandenberg & Kuse, 1978; adapted from Shepard & Metzler, 1971) required participants to view and match a test item (a two-dimensional representation of a three-dimensional cuboid) to four foils. Each test item had two correct and two incorrect choices. For each item, participants received 2 points if they marked both correct choices and 1 point if they marked only one correct choice. The maximum score was 40.

2. *Judgment of Line Orientation.* This 30-item test (Benton, Hamsher, Varney, & Spreen, 1983) required participants to judge, for each item, which lines in a complex array were in the same spatial orientation as two line fragments appearing above the array. Participants scored 1 point for the two correct choices and 0 points for any other response. The maximum score was 30.

3. *Letter fluency.* Participants were allowed 60 s to generate as many words as possible beginning with the letters *P, R,* and *W.* The score was the total number of acceptable words generated.

4. *Category fluency.* Participants were allowed 60 s to generate as many words as possible belonging to the categories *animals, fruits,* and *vegetables.* The score was the total number of acceptable words generated.

5. *Synonym fluency.* Participants were asked to generate as many synonyms as possible for the words *strong, happy, pretty, sharp, dark,* and *clear* (60 s per word). The score was the sum of all acceptable words.

6. *Perceptual speed.* This was assessed with the Digit–Symbol subscale of the Wechsler Adult Intelligence Scale—Revised (WAIS–R; Wechsler, 1981). Participants were required to draw (in 90 s) as many symbols as possible corresponding to a set of stimulus numbers (by using a key visible throughout the test in which a number and symbol were paired). Participants received 1 point for each correct symbol, the maximum score being 93. Scores were scaled according to standardized instructions from the WAIS–R manual.

7. *Object Location Memory.* This test (Smith & Milner, 1981, 1989)

required participants to estimate (verbally) the prices of 16 everyday objects arranged in a random order in a 50 × 50-cm array. Following a delay of 30 min (during which subjects completed the rest of the cognitive battery), subjects were asked to place all the objects back in their original positions as best they could remember. Object location memory was scored as the absolute deviation (in millimeters) in the positions of objects at the encoding stage (price estimation) and retrieval stage (place in which objects were subsequently placed).

Results

Theoretically, the signed FAs of the finger lengths should be normally distributed around a parametric mean of zero. This was tested for by using a one-sample *t* test (mean set at zero). No evidence of deviation between the distributions of right and left finger FAs was found: second finger, $t(239) = -1.734$, $p = .084$; fourth finger: $t(239) = -1.073$, $p = .285$. Thus these traits appear to show normative FA comparable to published norms (e.g., Trivers, Manning, Thornhill, & Singh, 1999). The signs from these FAs were removed, and each distribution was standardized (*z* score), then summed to obtain a composite FA score for each participant.

The mean composite FA scores for each group were as follows: heterosexual males, $M = 0.01$, $SD = 1.22$; heterosexual women, $M = 0.01$, $SD = 1.16$; homosexual men, $M = -0.003$, $SD = 1.23$; and homosexual women, $M = -0.02$, $SD = 0.96$ (Rahman & Wilson, 2003b). These means were not significantly different from each other: main effect of sex, $F(1, 239) = 0.00$, $p = .95$; main effect of sexual orientation, $F(1, 239) = 0.03$, $p = .84$; interaction term, $F(1, 239) = 0.00$, $p = .92$.

There was a small, yet significant, negative correlation between composite FA and Raven's SPM scores (our measure of general intelligence) for the whole group ($r = -.13$, $p = .04$), which remained after controlling for the effects of age and handedness scores ($r = -.12$, $p = .04$), confirming Furlow et al.'s (1997) findings using a different measure of IQ (the CFIT). However, this association was lost when the analysis was split by group, as a result of a reduction in the magnitude of *r* (all *p*s > .10).

A series of partial correlations (controlling for age, IQ, and EHI scores) was computed between composite FA and each cognitive performance measure for the whole sample and separately for each group. For the whole sample, there was a significant negative correlation between composite FA and category fluency scores only ($r = -.14$, $p = .03$), although there were nonsignificant negative trends with letter fluency ($r = -.10$, $p = .09$) and synonym fluency ($r = -.11$, $p = .08$). There were no other significant associations (all *p*s > .10).

However, an interesting pattern of correlations emerged when the sample was split by group. Whereas there were no significant associations between composite FA and cognitive performance in heterosexual and homosexual women (see Table 1), in heterosexual men there was a significant negative association between composite FA and Judgment of Line Orientation scores ($r = -.32$, $p = .01$), and in homosexual men there were significant negative associations between composite FA and letter fluency ($r = -.29$, $p = .02$), category fluency ($r = -.37$, $p < .01$), synonym fluency ($r = -.27$, $p = .04$), and Digit–Symbol substitution ($r = -.36$, $p < .01$). There were no other significant correlations (see Table 1).

Discussion

The main findings of this study were the significant negative correlations between FA and one measure of spatial ability (Judgment of Line Orientation) in heterosexual men, and three measures of verbal fluency and one measure of perceptual speed in homosexual men. No associations between FA and cognitive performance were found in heterosexual and homosexual women. In addition, the present report confirms the negative association between FA and general intelligence reported by Furlow et al. (1997) in a sample size similar to the present one. The current findings add to three other studies (Jung et al., 2000; Yeo et al., 1997, 2000) and confirm, in a larger sample with a broad range of cognitive tasks, that FA (and thus its underlying construct, DI) is related to atypical neurocognitive functioning. This is the first study to systematically investigate the relationship between DI and multiple cognitive functions in a large sample of men and women.

The use of the term *atypical* neurocognitive functioning needs to be contextualized in terms of normative within-sex cognitive variation. Our findings suggest that high FA is related to shifts in what are "normal" patterns of cognitive performance for heterosexual men (where male-typical performance is normal; Collaer & Nelson, 2002; Kimura, 1999; Voyer et al., 1995) and homosexual men (where female-typical performance is normal; McCormick & Witelson, 1991; Rahman & Wilson, 2003a; Rahman, Abrahams & Wilson, 2003; Rahman, Wilson & Abrahams, 2003; Wegesin, 1998), at least in some of those tasks that are sensitive to sex

Table 1
Partial Correlation Coefficients (Controlling for Age, IQ, and Handedness) Between Composite Fluctuating Asymmetry and Cognitive Performance by Group

Test	Heterosexual men	Heterosexual women	Homosexual men	Homosexual women
Mental Rotation	.01	−.13	−.05	.03
Judgement of Line Orientation	−.32*	−.13	−.10	.20
Letter fluency	−.25	−.01	−.29*	.11
Category fluency	.07	−.24	−.37**	−.11
Synonym fluency	−.08	−.19	−.27*	.01
Digit–Symbol Substitution	.12	−.15	−.36**	.26
Object Location Memory	−.12	−.19	−.03	.05

* $p < .05$. ** $p < .01$.

differences. In other words, FA is not negatively correlated with all cognitive measures, but only those that the particular group does better at on average.

The association between FA and IQ suggests that high body FA may relate to compromised neural integrity as a result of stress during the early development of both physical features (such as the finger lengths) and the central nervous system. Furlow et al. (1997) have proposed that developmental instability may cause poorer "neural efficiency" (higher information processing errors and/or slower processing speed). Alternatively, the association may be related to relative metabolic inefficiency such that the competing demands on energy budgets among high-FA individuals reduce energy available for neural functioning (Yeo et al., 2000). For example, metabolic resources may be redistributed to bolster immunological competence in the face of developmental stress (Furlow et al., 1997). There is some suggestion from the present findings for a role of FA in compromising frontal cortical (on which verbal fluency and perceptual speed are dependent; Gourovitch et al., 2000; Milner & Petrides, 1984; Mummery, Patterson, Hodges, & Wise, 1996) and parietal cortical (on which the Judgment of Line Orientation is dependent; Ng et al., 2000) development and/or function.

Finger lengths are most likely determined toward the end of the first trimester of development (Garn, Burdi, Babler, & Stinson, 1975; Manning, 2002). Thus, cognitive variation seems to be linked to those physical features that are determined early in fetal development. However, the precise mechanisms are unclear, as variation in finger lengths may be due to genetically determined differences in phalange bone growth or hormonally determined growth of the dermal tissue (Mortloc & Innus, 1997). Although it is uncertain what environmental and/or genetic sources of neurodevelopmental stress are responsible for the associations between FA and cognitive function reported here, various factors have been proposed to account for interindividual variation in human sexual orientation and neurocognitive functions. These include genetic factors (Hamer, Hu, Magnuson, Hu, & Pattatucci, 1993; Hu et al., 1995), exposure to prenatal gonadal steroids (Grimshaw, Sitarenios, & Finnegan, 1995; Williams et al., 2000), circulating gonadal steroids (from the postnatal to adult phase of development; Neave et al., 1999; Silverman et al., 1999), and maternal stress or teratogenic agents during gestation (Ellis & Cole-Harding, 2001; cf. Bailey, Willerman, & Parks, 1991). The finding of associations between FA and cognitive performance in men only support the notion that females are more resilient developmentally than males. Some support for this comes from evidence for a lower rate of neurodevelopmental disorders, non-right handedness, and learning disabilities in females (e.g., Flannery, Liederman, Daly, & Schultz, 2000; Lalumiere, Blanchard, & Zucker, 2000).

A clear limitation with the present study was the use of one anatomical measure: finger digit length. Studies show that using composite measures of several anatomical markers and not multiple measurements of the same structure better reflects underlying DI (Gangestad et al., 2001). Further studies might use a wider range of markers than those used here, such as FA of the elbows, wrists, ankles, feet, and ears, and MPAs, such as those traditionally examined with the Waldrop scale (Waldrop & Halverson, 1971). The sample restriction to right-handed individuals may have biased against finding effects of DI, insofar as non-right handedness is a putative indicator of DI. Thus the present study would have excluded subjects showing evidence of high DI.

In summary, the present report has shown that certain markers of DI are negatively related to cognitive performance in men, and partly depend on male sexual orientation. On the other hand, cognitive function in women appears less susceptible to the sources of neurodevelopmental stress.

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