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Personality and Individual Differences 31 (2001) 1181–1191

PERSONALITY AND
INDIVIDUAL DIFFERENCES

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Fingerprint asymmetry predicts within sex differences in the performance of sexually dimorphic tasks

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Received 30 May 2000; received in revised form 16 October 2000; accepted 6 November 2000

Abstract

Finger ridge counts (FRC) based on the dermal ridges of the human fingerprint are known to be asymmetrical with the majority of individuals having more ridges on the right hand ($R >$) while a minority have more on the left ($L >$). Using 48 adult participants, we investigated the association between sex, FRC asymmetry and performance on a battery of six cognitive tasks (two female-favouring, two male-favouring and two sex-neutral). Sex differences in task performance were in the predicted direction although the size of the difference was task dependent. The major finding was an association between FRC asymmetry and task performance. Irrespective of sex, female-favouring tasks were performed better by $L >$ individuals, male-favouring tasks were performed better by $R >$ individuals, while sex-neutral tasks showed no group differences. These FRC-related differences in cognitive performance, that are present within each sex, could contribute to the elusive nature of sex differences in cognitive abilities. In addition, given that finger ridge development is complete by the 16th foetal week, the relationship between FRC asymmetry and pattern of cognitive performance that we have found is consistent with the view that prenatal biological factors, possibly gonadal steroids, exert an organizing influence on neuropsychological development. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Dermal ridge asymmetry; Human fingerprints; Cognitive tasks; Sex differences; Gonadal hormones

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1. Introduction

In an influential review, Maccoby and Jacklin (1974) concluded that, on average, men tend to excel at spatial and certain mathematical tasks whereas women excel at verbal and fine motor tasks. Subsequently, the existence of sex differences in cognitive abilities has generated controversy. Some authors have emphasised the large number of null findings and denied the existence of sex differences in cognitive performance (e.g. Caplan, MacPherson & Tobin, 1985; Hyde & Linn, 1988) while others have reached the opposite conclusion on the basis of the same data (Halpern, 1992). Null findings arise for two reasons. First, tasks differ in the extent to which they reveal sex differences, ranging from strongly female-favouring through sex-neutral to strongly male-favouring. Second, the data show marked individual differences giving rise to a large within sex range and an extensive overlap between the sexes such that some women show a male-typical and some men a female-typical pattern of performance. In this paper we address both of these issues and also the perennial question concerning the influence of biological, as opposed to socio-cultural factors, on sex differences in cognitive performance.

A major biological difference between the sexes is the level of testosterone to which individuals are exposed early in life. There is a wealth of evidence that perinatal exposure to testosterone exerts powerful organizational effects on brain and behaviour in animals (see Breedlove, 1992; Nelson, 2000) and an increasing number of studies have revealed evidence for similar prenatal organizational effects in humans (Collaer & Hines, 1995). Biological sex divides individuals into two groups typically exposed to different prenatal levels of testosterone: high in men and low in women. If prenatal testosterone exposure does influence the pattern of cognitive performance we might expect clear differences in cognitive performance. However, as we have seen, one of the characteristics of male and female performance on sexually dimorphic tasks is the existence of a large within sex range and a marked overlap between the sexes. Some of this variance may arise from the adult activational effects of gonadal steroids on performance (Hampson & Kimura, 1992; Sanders & Wenmoth, 1998a, b; Van Goozen, Cohen-Kettenis, Gooren, Frijda & Van de Poll, 1994, 1995). However, individual differences in performance may also result from differential prenatal exposure to the organizing effects of hormones and/or other biological events. Insofar as the variance in performance arises from biological rather than sociocultural influences, biological sex may be no more than a crude marker for effective differential exposure. There may be biological characteristics other than sex that are better markers for the critical prenatal organizing events operating within, as well as between, the sexes to give rise to individual differences in the performance of sexually dimorphic tasks.

Levy (1969, 1971) suggested that sex differences in cognitive abilities might be explained by sex differences in functional cerebral asymmetry such that right hemisphere development and performance underlie the superior performance of spatial tasks as seen in men. Subsequently, Levy and Levy (1978) suggested that sex hormones might affect the development of body asymmetries, including brain asymmetries. Animal studies have provided some support for this view. Sex-related neuroanatomical asymmetries have been reported for rats where the right hemisphere is thicker than the left in males but not in females (Diamond, Dowling & Johnson, 1981). These asymmetries appear to be modified by neonatal gonadectomy (Diamond, 1984) suggesting that they are one of many characteristics that are influenced by the organizational effects of perinatal sex hormones.

Geschwind and Galaburda (1985) have argued specifically that prenatal androgens affect the development of right and left cerebral hemispheres. In conjunction with asymmetric neural development, prenatal androgens may, as suggested by Levy and Levy (1978), influence somatic asymmetry resulting in correlations between body asymmetries, brain asymmetries and sexually dimorphic patterns of cognitive abilities. In support of this view, correlations between somatic characteristics and patterns of cognitive ability have been reported. Using breast volume in women and testicular volume in men Kimura (1994) found that men and women with larger right sides performed better on male-favouring tasks while those larger on the left performed better on the female-favouring tasks.

Another somatic characteristic that has been investigated is dermatoglyphics, the dermal ridges found on the palms and soles of primates. The ridge pattern that constitutes the human fingerprint is complete by the 16th foetal week and, in the absence of major skin damage, remains unaltered throughout life (Holt, 1968, p. 7). On average both men and women have a higher finger ridge count (FRC) on their right hands ($R >$), however, a minority have a higher FRC on the left hand ($L >$; Holt, 1968, p. 53). Using sexually dimorphic and sex-neutral tasks, Kimura and Carson (1995) found that, irrespective of sex, $R >$ individuals obtained higher composite scores on masculine than on feminine tasks while $L >$ individuals showed the reverse pattern.

In the present study our primary concern was the relationship of cognitive performance with sex and FRC asymmetry. However, two other variables, familial sinistrality (McKeever, 1986) and directionality (Alter, Rein & Toro, 1989) that maybe associated with cognitive performance were also recorded. A battery of six cognitive tasks, two female-favouring, two sex-neutral and two male-favouring were administered to adult women and men selected to form equal groups of $L >$ and $R >$ individuals. We made the following predictions: (1) women and $L >$ individuals will perform the female-favouring tasks better than the male-favouring tasks; (2) men and $R >$ individuals will perform the male-favouring tasks better than the female-favouring tasks; and (3) the groups will not differ in their performance on the sex-neutral tasks.

2. Method

2.1. Participants

Volunteers from the local student population were screened for handedness and dermatoglyphic asymmetry to identify right-handed participants with a higher FRC on the left hand ($L >$) and others higher on the right ($R >$). In all, 48 participants were selected to form four equal sized groups: 12 $L >$ women (age range 22–29, mean 24.75 years), 12 $R >$ women (age range 18–38, mean 25.83 years), 12 $L >$ men (age range 21–48, mean 26.42 years) and 12 $R >$ men (age range 22–31, mean 25.83 years).

2.2. Procedure

2.2.1. Handedness

On attending the laboratory potential participants were screened for handedness using a six item questionnaire. Those indicating that they used their right hand for writing and for at least

four of five other unimanual activities (throwing, using scissors, holding a spoon, a racquet and a hammer) were classified as right-handed and asked to provide fingerprints. Individuals who met the criterion for asymmetrical finger ridge counts were asked to participate in the study.

2.2.2. *Familial sinistrality and directionality*

Our right-handed participants were classified as familial sinistrality positive (FS+) if one or more of their first-degree relatives (father, mother, siblings) were left-handed or as FS- if none of these relatives were left-handed. Directionality was assessed using the procedure described by Alter et al. (1989) with teapot replacing pitcher for our UK participants.

2.2.3. *Finger ridge counts*

Participants washed and dried their hands thoroughly before providing fingerprints from the thumb and little finger of each hand. The palmar surface of the fingertip was rolled on an ink pad (Elimination Pad supplied by K9 Scene of Crime Equipment Limited, PO Box 260, Northampton, NN1 3SA, UK) and then onto paper. The original prints were enlarged ($\times 2$) on a photocopier to facilitate counting which was conducted using the Henry classification system as described by Holt (1968, p. 40). First, the core and triradial (delta) points were located and a line drawn between them. The ridge count was obtained by counting the number of dermal ridges intersecting this line, excluding the core and triradial points. Counts were restricted to the thumb and little finger (Kimura & Carson, 1995) because the three middle fingers have a higher incidence of arch patterns for which the ridge count is zero. We considered individuals to have asymmetrical ridge counts if the total ridges for the thumb and little finger of one hand exceeded the total for the other by three or more.

2.2.4. *Cognitive test battery*

The test battery comprised six tasks, four chosen because they are reported to be sexually dimorphic, two favouring women, two favouring men, plus two sex-neutral tasks that typically show no significant sex differences.

2.2.4.1. *Female-favouring tasks.* Two tests from Ekstrom, French, Harman and Dermen (1976) were used. The Controlled Associations task allowed participants 6 min to write as many synonyms as possible to the four target words, *clear, dark, strong, wild*. In the Things Categories test participants were allowed 3 min to write as many names as possible of things that are round or more often round than any other shape.

2.2.4.2. *Male-favouring tasks.* The Mental Rotation test (Vandenberg & Kuse, 1978) required participants to indicate which of four rotated figures corresponded to a target figure. Ten of the original 20 items were used and a time limit of 5 min was imposed. The standard scoring procedure gave a maximum score of 20 for this task. Form H of the Judgement of Line Orientation task (Benton, Hamsher, Varney & Spreen, 1983) required participants to match a pair of shortened target lines to two of 11 lines in a protractor-like array. There was no time limit for this task and the maximum score was 30.

2.2.4.3. *Sex-neutral tasks.* Participants completed the Digit Span subtest of the Wechsler Adult Intelligence Scale (Wechsler, 1981) and a Vocabulary task (Thurstone, 1963) in which partici-

pants were allowed 4 minutes to select, from five possibilities, the word that means the same, or almost the same, as a target word. The maximum score was 60, one point for each correct response on this 60-item test.

3. Results

3.1. Sex, FRC, FS, D and cognitive performance

The scores for the six cognitive tasks were subjected to a two (Sex) by two (FRC) by two (FS) by three (D) MANOVA. In addition, as a check against possible group differences in general ability, the scores for the two sex-neutral tasks, Digit Span and Vocabulary, were used as covariates in a two (Sex) by two (FRC) by two (FS) by three (D) MANCOVA on the data from the four sexually dimorphic tasks. Neither the MANOVA nor the MANCOVA revealed significant interactions nor were the main effects of FS and D significant so these variables were omitted and the scores from the six cognitive tasks were re-analysed using the two variables of prime interest, Sex and FRC. The absence of group differences in general ability is shown by performance on the two sex-neutral tasks, Digit Span and Vocabulary (Tables 1 and 2).

3.2. Sex, FRC and cognitive performance

A two (Sex) by two (FRC) MANOVA indicated that the main effects of Sex ($F_{6,39}=2.36$, $P=0.049$) and FRC ($F_{6,39}=4.47$, $P=0.002$) were significant but the interaction was not ($F_{6,39}=0.89$, $P=0.51$). The absence of an interaction between Sex and FRC suggests that FRC

Table 1
Sex differences and dermatoglyphic asymmetry differences as revealed by F ratio ($F_{1,44}$), probability (P) and effect size in standard deviation units (d) for appropriate comparisons

Tasks	Sex differences Women 'v' Men ($n=12$ L> and 12 R> per group)			Dermatoglyphic differences FRC L> 'v' FRC R> (12 women and 12 men per group)		
	$F_{1,44}$	P	d	$F_{1,44}$	P	d
<i>Female-favouring</i>						
Things Categories	0.013	0.909	+0.03	4.07	0.050	+0.57
Controlled Associations	3.53	0.067	+0.51	4.88	0.032	+0.59
<i>Sex-neutral tasks</i>						
Digit Span	0.307	0.582	+0.35	0.40	0.531	+0.06
Vocabulary	1.46	0.233	+0.16	0.04	0.841	+0.19
<i>Male-favouring</i>						
Line Orientation	1.12	0.295	-0.28	8.37	0.006	-0.78
Mental Rotation	7.25	0.010	-0.66	13.61	0.001	-0.91

Effect sizes with positive values indicate better performance by women and L> individuals
Effect sizes with negative values indicate better performance by men and R> individuals

asymmetry has the same association with cognitive performance in men and women and this is confirmed by the group means (Table 2). In the analyses that follow, univariate *F*-tests were used to investigate performance separately for Sex and FRC on each of the six cognitive tasks.

3.3. Sex and cognitive performance

Fig. 1 displays the performance of the 24 men (12 L > plus 12 R >) and the 24 women (12 L > plus 12 R >) on each of the six cognitive tasks and Table 1 shows the outcome of the associated univariate *F*-tests. As predicted, neither Digit Span nor Vocabulary generated significant sex differences, thus confirming their status as sex-neutral tasks. The expected male advantage appeared for Mental Rotation while the female advantage on Controlled Associations approached significance, however, the performances of men and women on both Line Orientation and the Things Categories Test were not significantly different. The absence of sex differences for Line Orientation and the Things Categories Test is probably related to the nature of the present sample that differs from the normal population because it contains equal numbers of L > and R > men and women. This point is addressed further in Section 4.

3.4. FRC and cognitive performance

Fig. 2 shows the performance on each of the six cognitive tasks of the same 48 participants as Fig. 1 but here these women and men are grouped to compare the 24 L > individuals (12 female and 12 male) with the 24 R > individuals (12 female and 12 male). Univariate *F*-tests confirmed the predicted outcomes for all six tasks (Table 1). The L > participants performed better than the R > on both of the female-favouring tasks (Controlled Associations and Things Categories Test) while the R > participants performed better than the L > on both of the male-favouring tasks (Mental Rotations and Line Orientation). On the two sex-neutral tasks (Digit Span and Vocabulary) the two groups did not differ significantly. The absence of an interaction between Sex and FRC suggests that the association of dermatoglyphic asymmetry with cognitive performance is

Table 2

Mean (S.E.M) of the scores for FRC L > and R > groups of women and men for each of the cognitive tasks

Tasks	Women		Men	
	L > (n = 12)	R > (n = 12)	L > (n = 12)	R > (n = 12)
<i>Female-favouring</i>				
Things Categories	23.08 (1.66)	21.25 (1.49)	24.33 (1.21)	20.33 (1.38)
Controlled Associations	25.00 (1.28)	23.25 (1.60)	23.83 (2.54)	17.75 (1.40)
<i>Sex-neutral tasks</i>				
Digit Span	88.83 (3.83)	87.83 (2.21)	88.08 (2.78)	85.00 (3.81)
Vocabulary	44.67 (1.69)	41.00 (2.37)	38.50 (2.86)	41.17 (2.82)
<i>Male-favouring</i>				
Line Orientation	26.96 (0.60)	28.62 (0.37)	27.83 (0.36)	28.67 (0.34)
Mental Rotation	5.92 (1.17)	11.00 (1.45)	9.75 (1.31)	13.92 (1.05)

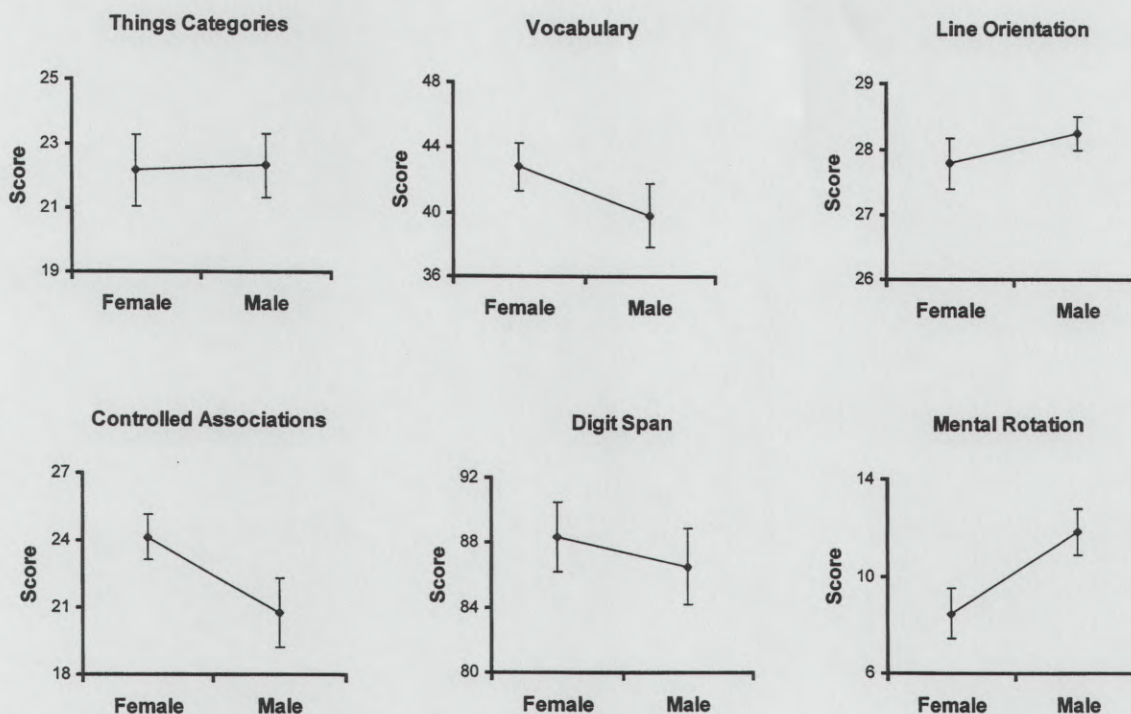


Fig. 1. Mean score (\pm S.E.M.) for female and male participants on six cognitive tasks: two (Things Categories and Controlled Associations) female-favouring, two (Digit Span and Vocabulary) sex-neutral, favouring neither sex, and two (Line Orientation and Mental Rotation) male-favouring. It should be noted that, with segregation of the participants by sex, each group was composed of 12 L> and 12 R> individuals, i.e. a higher proportion of individuals with more finger ridges on the left hand (L>) than the normal population.

the same irrespective of sex. This conclusion is confirmed by the individual group means (Table 2) which show that both R> men and R> women perform male-favouring tasks better while L> individuals of both sexes excel at female-favouring tasks.

Table 1 shows the effect sizes for sex and FRC, expressed in standard deviation units (d) for each of the six cognitive tasks. The effect sizes for sex were strong for the male-favouring Mental Rotations and female-favouring Controlled Associations, weaker for Line Orientation and negligible for the Things Categories Test. These values stand in contrast to those for FRC where the effect sizes are large for both male tasks, moderate for both female tasks and negligible for the sex-neutral tasks. However, when viewing the sex difference data we should remember that 50% of our participants exhibited the minority L> characteristic. The potential influence of equal numbers of L> and R> individuals within our sample population is considered in Section 4.

4. Discussion

In the present study we have demonstrated a clear relationship between dermatoglyphic asymmetry, as measured by finger ridge count (FRC) and the performance of sexually dimorphic,

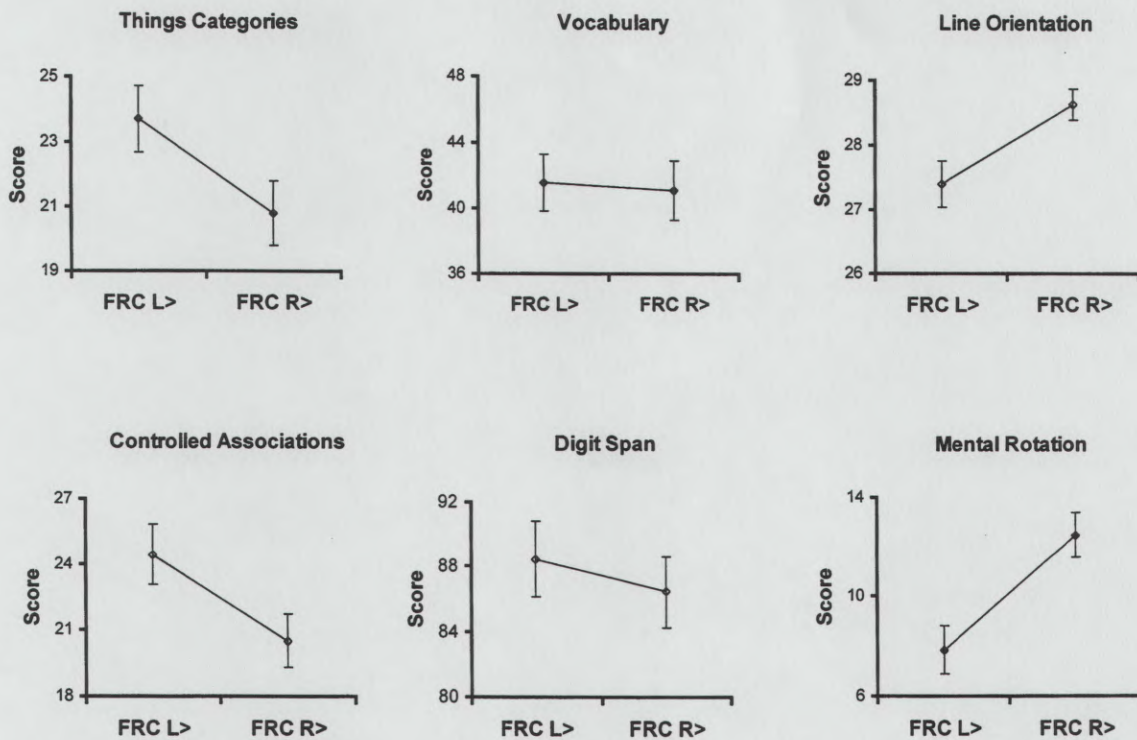


Fig. 2. Mean score (\pm S.E.M.) for the same tasks and the same participants as shown in Fig. 1 but in this plot the participants are segregated, according to dermatoglyphic asymmetry, into those with more finger ridges on the left hand (FRC L>) and those with more on the right (FRC R>). Each of the FRC groups contains 12 women and 12 men.

but not sex-neutral, cognitive tasks (Fig. 2). As seen in Table 2, irrespective of sex, female-favouring tasks were performed better by individuals with a higher FRC on the left hand (L>) whereas male-favouring tasks were performed better by individuals with a higher FRC on the right (R>). The absence of group differences in performance on the two sex-neutral tasks, Digit Span and Vocabulary (Tables 1 and 2), indicates that there were no group differences in general ability. The present findings confirm and extend an earlier study (Kimura & Carson, 1995) in which the authors used composite scores to demonstrate that R> men and women scored higher on masculine than on feminine tasks while L> individuals of both sexes showed the reverse pattern. The presence of these FRC-related differences in cognitive performance, that are present within each sex, could contribute to the elusive nature of sex differences in cognitive abilities.

We selected our female-favouring, sex-neutral and male-favouring tasks on the basis of reports in the literature. Analysis by sex (Fig. 1) confirmed all but two of these classifications. The exceptions were the Things Categories and Line Orientation tasks that did not generate the expected sex differences. An explanation for this outcome may be found in the nature of both the tasks and our sample. First, of the four sexually dimorphic tasks the female-favouring Controlled Associations (Hines, 1990) and male-favouring Mental Rotation (Halpern, 1992) are known to be among the strongest sexually dimorphic tasks in their class. Second, compared with the normal population our sample had a L> bias. The literature is in agreement that L> is the minority

condition with estimates varying from 15–20% (Saucier & Kimura, 1996) up to 28–33% (Holt, 1968, pp. 52–53). Hence, the increased proportion of L > individuals, 50% in our sample, may have been sufficient to obliterate the sex difference for the two weaker sexually dimorphic tasks.

An additional reason may be the existence of a sex difference in the incidence of the L > condition. Kimura and Carson (1995) reported that 24% of women but only 13% of men were L > individuals. These proportions of L > individuals were confirmed by Sanders and Kadam (2001) but not by Holt (1968, pp. 52–53) or Slabbekoorn, van Goozen, Sanders, Gooren, and Cohen-Kettenis (2000). If the sex bias in the incidence of L > individuals does exist then, compared with the normal population, the proportion of L > individuals in our sample is increase two-fold among women from 24 to 50% and four-fold among men from 13 to 50%. The net result would be a group of men whose overall performance would be differentially biased towards the female-typical pattern thus contributing to the size of the group differences on the sexually dimorphic tasks.

In Section 1, we noted that prenatal gonadal steroids are known to influence the development of brain and behaviour and we argued that certain somatic characteristics may act as markers for prenatal gonadal steroid levels, thus, providing a link between prenatal organizational effects and adult patterns of cognitive ability. Jamison (1990) suggested that prenatal testosterone could influence the development of dermal ridges through its stimulatory effect on the production of Epidermal Growth Factor and Nerve Growth Factor, two polypeptide hormones associated with the development of the skin and the nervous system. Jamison, Meier and Campbell (1993) reported an association between dermatoglyphic asymmetry and adult salivary testosterone levels in men, which they ascribed to the influence of prenatal testosterone because the development of the dermal ridges is complete by the 16th foetal week.

Indirect support for the view that dermatoglyphics (and other limb features) may act as markers for prenatal testosterone levels is provided by demonstrations that gonadal and limb development are genetically linked. Recent animal studies (Herault et al., 1997; Peichel, Prabhakaran & Vogt 1997; Kondo, Zakary Innis & Duboule 1997) have shown that the Homeobox genes (*Hoxa* and *Hoxd*) are critical for the integrity of the urinogenital system, limbs and digits of mammals. Thus, the prenatal development of the gonads is genetically linked to the development of the hands and feet. In addition to FRC, sex differences have been reported for two other limb characteristics, foot size (Levy & Levy, 1978, although this finding was not confirmed by Pomerantz & Harris, 1980) and the ratio of the lengths of the 2nd finger to 4th finger (Baker, 1888; Manning, Scutt, Wilson & Lewis-Jones, 1998). The existence of this developmental link is consistent with the view that limb characteristics, of which asymmetrical FRC is but one, may reflect prenatal levels of testosterone.

In conclusion, the relationship between FRC and pattern of cognitive performance that we have demonstrated suggests that prenatal events, which differ in the same direction between R > and L > individuals as they do between male and female, exert an influence on neuropsychological development. The prime candidate for prenatal effects is testosterone or its metabolite, oestradiol. It would appear that the adult pattern of cognitive performance is the product of both prenatal organizational and adult activational effects. Initially, prenatal events influence the development of brain organization such that both men and women may be predisposed towards a pattern of cognitive performance that is either female-typical (as in L > individuals) or male-typical (as in R > individuals). Subsequently, in adulthood the pattern of cognitive abilities may be modulated by the phasic activational effects of gonadal steroids. Continued investigation of

the relationship between potential markers for prenatal gonadal steroid levels and cognitive performance would appear to be a fruitful avenue for research.

Acknowledgements

We are grateful to Yvonne Linney for assistance with the statistical analyses.

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