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DERMATOGLYPHIC ASYMMETRY: RELATION TO SEX, HANDEDNESS AND COGNITIVE PATTERN

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Summary—The number of ridges on the fingertips has a major genetic contribution, and is fixed by the fourth month of fetal life. Most people have a higher count on the right-hand side (R >), approx. 20% have a higher left-hand side (L >) count. The incidence of higher left count is greater in women and in homosexual men. Direction of dermatoglyphic asymmetry was not found to be related to handedness in heterosexual subjects, although it had been related to hand preference in homosexual men. Groups of subjects with higher-left or higher-right counts, were compared on cognitive tasks previously shown to be sensitive to other measures of body asymmetry. As predicted from previous research, both men and women with L > count were better at tasks on which women typically excel, while R > subjects were better at tasks on which men typically excel. In addition, unlike the previous body-asymmetry study, R > subjects achieved higher scores on sex-neutral reasoning tests. The data suggest that intellectual pattern is significantly influenced before birth.

INTRODUCTION

The number of dermal ridges on the fingertips is fixed by about the fourth month of fetal life (Holt, 1968). A significant genetic contribution to the ridge count is indicated by the fact that the correlation between identical twins of the total ridge count is over 0.95, whereas the correlation between dizygotic twins is around 0.50, as it is for siblings (Bouchard, Lykken, McGue, Segal & Tellegen, 1990; Holt, 1968; Scarr & Carter-Saltzman, 1982). The total count is inversely related to the amount of material in the sex chromosomes with males having a higher count than females, but Turner's syndrome individuals, with only one X chromosome, having the highest count of all (Holt, 1968; Penrose, 1967). It has been suggested that the ridge count positively reflects the rate of early embryonic growth, and consequently a higher ridge count represents more rapid cell division in the corresponding period of embryonic development (between 8 and 16 weeks) (Mittwoch, 1977; Netley & Rovet, 1982). Some features of the dermal ridge pattern may be susceptible to such factors as variation in levels of sex hormones (Jamison, Meier & Campbell, 1993) and prenatal stress (Newell-Morris, Fahrenbruch & Sackett, 1989).

One feature of the ridge count in humans is its systematic asymmetry, with the right hand reported to show a higher count in both males and females (Holt, 1968). This would imply more rapid cell division on one side of the body, in early development. In this study we asked whether this asymmetry was strictly comparable in males and females (Kimura & Carson, 1993) and also whether it was related to a measure of functional asymmetry, such as hand preference.

It has been shown that direction of gonad and breast asymmetry is related to cognitive pattern (Kimura, 1994). Both men and women with a right-larger somatic pattern scored relatively higher on tests which typically favor males; whereas those with a left-larger pattern scored relatively higher on tests which usually favor females. No effects were found for sex-neutral tests. In that study, somatic asymmetry had been determined by self-inspection. Because it was felt desirable to have a measure of body asymmetry which was more objectively assessed, in the present study we determined finger-ridge counts on the two hands in normal young *S*s, and compared individuals with higher-right and higher-left ridge counts. We again employed cognitive tests previously found to be sensitive to other biological variables such as sex and hormonal status.

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METHODS

Subjects

The *S*s were undergraduate paid volunteers obtained through advertisements posted around campus. They were first solicited for the imprinting of fingerprints, at which time a handedness questionnaire was also administered (Kimura, 1973). Right-handers were solicited first, and later left-handers were solicited separately. Finger-ridge counts, and direction of asymmetry were determined on all *S*s (see *Procedure*). For approximately half of our *S*s, sexual orientation was determined to be heterosexual through the use of the Kinsey scales (Kinsey, Pomeroy & Martin, 1948). The remaining *S*s could safely be presumed to be overwhelmingly heterosexual, since the incidence of homosexuality is typically under 10%.

Sex. Initially, men and women were invited for fingerprinting, but when fewer men with a L > ridge count were found, we invited men only in a supplementary phase of testing. In all, 154 right-handed men and 96 right-handed women were tested.

Hand preference. After all right-handers had been assessed, we solicited non-right-handers (adextrals) to enable a comparison of the direction of dermatoglyphic asymmetry. Twenty-eight adextral men and 32 adextral women were examined for fingerprint asymmetry.

Cognitive testing. Criteria for inclusion in the final data analysis were: Caucasian, right-handed, English as a first or main language, and the direction of the higher ridge count (L > or R >). *S*s who satisfied these criteria were asked to return for cognitive testing. Because of the known low incidence of the L > pattern. *all S*s with a L > count were asked to return. An attempt was made to keep the numbers in each group approximately equal. Twenty of 23 females and 19 of 20 males with L > counts returned for cognitive testing. Of the R > *S*s, 25 females and 18 males were invited to return and satisfied inclusion criteria. The resulting four groups were well matched for age and program of study, and were approximately equal in sample size—20 L > females, 25 R > females, 19 L > males, 18 R > males. An attempt was made to have all *S*s complete all tests, but the occasional *S* missed a test due to scheduling constraints.

Procedure

Finger ridge count. E rolled each finger on an inked glass surface and then onto a standard fingerprint form (available from Criminal Research Products, Conshohocken, U.S.A.). Slightly enlarged laser photocopies were subsequently made of these prints and the photocopies used to determine the count. (An inter-rater reliability co-efficient of 0.98 for the total count was obtained for a different set of 26 *S*s.)

Pattern types were first determined by the second author according to the Henry classification system (Cummins & Midlo, 1943; Holt, 1968), by determining the triradial and core points (Fig. 1). Using a magnifier equipped with Henry glass (which has a red line for easy demarcation between points), the ridge counts were done from the photocopies, but for the first 20 *S*s were verified against the original prints. The concurrence was within + or − 1 with the photocopy. The ridge counts excluded secondary ridges, triradial and core points, but included all ridges intersected between these two points. A total ridge count for one hand usually includes ridge counts from all five fingers. However, because the incidence of arch patterns on the three middle fingers is higher than on thumb and little finger, and arches by the Henry convention yield a ridge count of zero, it was decided there would be less artifact if totals were taken of only the thumb and little finger. Because of the potential counting error involved (+ or − 1 per finger), individuals with a summed ridge count difference of less than two between hands were considered to have equal ridge counts. All others were classified as having either L-higher or R-higher counts.

Cognitive tests. Tests were chosen on the basis of past sensitivity to sex differences and/or hormonal fluctuations. Such clusters of tests typically distinguish not only between males and females, but between groups of within-sex individuals high or low in androgens (Gouchie & Kimura, 1991), between individuals with left-larger or right-larger gonad or breast size (Kimura, 1994), across hormonal phases of the menstrual cycle in women (Hampson, 1990), across hormonally different seasons in men (Kimura & Hampson, 1994), etc. They are thus demonstrably sensitive to biological variation of various kinds.

Fig. 1. An example of a 'loop' fingerprint pattern, showing a line joining the triradial and core points, between which the ridges are counted.

Neutral tests. These were three tests of general intelligence and reasoning, which have not in our studies shown sex differences: Advanced Vocabulary, and Inferences from the ETS kit (Ekstrom, French, Harman & Dermen, 1976), and a modification (Harshman, Hampson & Berenbaum, 1983) of the Raven's Standard Progressive Matrices.

'Masculine' tests. (Masc) Tests which typically show sex differences favoring males. Three are spatial tasks—Paperfolding (considered a Visualization test) and Hidden Figures (flexibility of closure) from the ETS kit (Ekstrom *et al.*, 1976), and the Vandenberg and Kuse (1978) paper-and-pencil version of the Shepard–Metzler Mental Rotations test. A fourth test, Mathematical Aptitude from ETS, is considered a mathematical reasoning test.

'Feminine' tests. (Fem) Tests which typically favor females—two 'perceptual speed' tests, Identical Pictures and Finding A's from ETS (Ekstrom *et al.*, 1976); and a test of ideational fluency, a modification of Things category from ETS.

RESULTS

Sex

The total number of right-handed *S*s fingerprinted was 96 females (23 L >, 53 R >, 20 no difference) and 154 males (20 L >, 96 R >, 38 no difference). The sex difference in incidence of L > pattern, compared to R > -plus–No-difference is significant ($\chi^2 = 5.0$, d.f. = 1, $P < 0.03$). This is consistent with the findings on testicular and breast asymmetry, but on the latter measures, men and women actually show *different* prevailing directions, i.e. women have predominantly a left-larger pattern and men predominantly a right-larger pattern (Kimura, 1994). We also confirmed that men have a higher total ridge count. Thus the total count (four fingers—thumb and little finger, left plus right hand) for dextral men = 65.6 (SD = 16.1), and for dextral women = 59.2 (SD = 19.2) ($t = 2.72$, d.f. = 248, $P < 0.01$); for adextral men = 68.1 (17.1) and for adextral women = 58.2 (19.3) ($t = 2.08$, d.f. = 58, $P < 0.05$).

Handedness

Of 28 adextral men, six showed a L > pattern, as compared with 23 of 154 dextrals ($\chi^2 = 1.09$, d.f. = 1, NS). In women, similarly, four of 32 adextrals had a L > pattern compared with 23 of 96

Table 1. Direction of finger-ridge asymmetry and handedness

	Number Left >	Number Left not >
Dextrals	43	207
Adextrals	10	50

$\chi^2 = 0.0097$, d.f. = 1, NS.

dextrals ($\chi^2 = 1.89$, d.f. = 1, NS). For men and women combined (Table 1), 10 of 60 adextrals had a L > pattern, compared with 43 of 250 dextrals ($\chi^2 = 0.0097$, d.f. = 1, NS).

Cognitive tests

Raw data (see Table 2). An overall analysis was not done on raw scores because there were unequal numbers of tests in the test-types. Instead, separate two-by-two (sex, direction of ridge count) analyses of variance were done on each test-type (Neutral, Masculine, Feminine). There was the expected effect of sex on the Masculine tests [$F(4,73) = 6.454$, $P < 0.0005$], with men having higher scores, and the opposite effect on Fem tests, i.e. women had the higher score [$F(3,74) = 2.696$, $P = 0.05$]. There was, as expected, no effect of sex on the Neutral tests [$F(3,74) = 1.587$, $P < 0.20$].

Direction of ridge count had a significant effect on the Masculine tests [$F(4,73) = 3.471$, $P = 0.012$], with Right-higher *S*s performing better. There was also a significant effect on Feminine tests, but the direction was opposite to that of Masculine tests, with Left-higher *S*s better [$F(3,74) = 3.229$, $P < 0.03$]. Neutral tests showed a trend in the same direction as the Masculine tests.

There was no interaction of direction with sex, indicating that the effect of ridge asymmetry was similar for both men and women.

Standard score composites. In order to compare across test-types with different numbers of tests, and with different maxima, all test raw scores were converted to standard z scores, with the mean at zero, and the standard deviation at 1.0. Because there are sex differences on Masculine and Feminine tests, and because the numbers in each sex-ridge asymmetry group were not precisely equal, the standard scores were calculated *within-sex*, before males and females were combined. This eliminates the factor of sex differences on the tests, and since there was no interaction of sex with ridge asymmetry (above), provides a clearer picture of the effect of ridge-asymmetry direction. *Composites* of scores for each test-type were calculated as the mean of all tests of that type, e.g. the composite score for the Neutral tests for each *S* was the mean of the three within-sex z scores (Vocabulary, Inferences, Raven's Matrices).

Analysis of variance was performed across the three test-types (Neutral, Masculine, Feminine; repeated measures) and two directions of ridge asymmetry (L >, R >).

The overall effect of ridge asymmetry was significant, in that R > *S*s achieved higher scores overall than L > *S*s [$F(10,67) = 3.047$, $P = 0.003$].

Table 2. Direction of finger-ridge asymmetry and scores on cognitive tests

Test	Max score	Left > Right *N*	Left > Right Mean	Left > Right (SD)	Right > Left *N*	Right > Left Mean	Right > Left (SD)
Neutral							
Vocabulary	18	39	6.99	(3.26)	43	7.45	(2.61)
Inferences	10	38	6.62	(1.83)	40	7.74	(1.68)
Raven's	23	38	18.53	(4.45)	40	19.60	(2.19)
Masculine							
Mental rotation	24	39	9.79	(6.14)	43	9.14	(5.27)
Paperfolding	10	39	5.49	(3.29)	43	6.28	(2.14)
Hidden figures	9	38	4.00	(2.41)	40	5.04	(2.29)
Math aptitude	15	39	5.06	(2.88)	43	6.57	(2.96)
Feminine							
Identical pictures	48	39	38.94	(6.70)	43	35.23	(6.97)
Findings As	100	39	33.18	(8.80)	43	34.51	(7.50)
Things	—	38	10.53	(4.56)	40	9.02	(3.30)

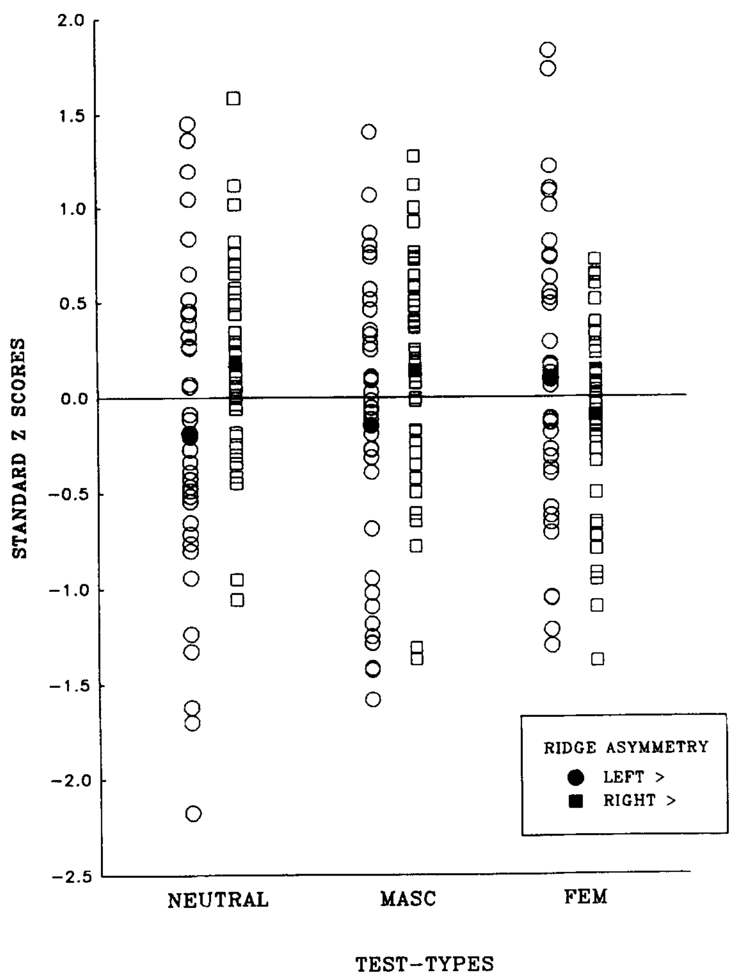

Fig. 2. Performance on standard-score composites of Neutral, Masculine and Feminine tests, by *S*s with L-higher and R-higher finger-ridge counts.

There was also a significant ridge-asymmetry by test-type interaction [$F(2,152) = 6.34$, $P < 0.01$]. Standard-score composites are shown for each test-type in Fig. 2. As the figure shows, the interaction consisted in part in Masculine and Feminine tests showing different directional advantages, with R > *S*s scoring better at Masculine tests, and L > *S*s better at Feminine tests. Unexpectedly, Neutral tests showed a pattern almost identical to Masculine tests.

Within-subject scores. To neutralize the possible effects of overall intelligence, an intra-individual score was also derived, using a Feminine-minus-Masculine, Neutral-minus-Masculine and Feminine-minus-Neutral difference score *within* Ss for each of the L > and R > groups. There was a significant difference between laterality groups for Feminine–Masculine tests [$F(1,76) = 7.747$, $P = 0.007$], and for Feminine–Neutral tests [$F(1,76) = 10.415$, $P = 0.002$], but not for Neutral–Masculine tests [$F(1,76) = 0.212$, $P = 0.647$]. That is, again L > *S*s were relatively better on Feminine tests, R > relatively better on Masculine and Neutral tests.

Viewing the sexes separately on the Feminine–Masculine score, it is apparent that the relation between direction of asymmetry and cognitive pattern is very similar in men and women (Fig. 3).

DISCUSSION

The data are consistent with earlier reports (Holt, 1968) that the dermal ridge count is higher on the right hand than the left, and higher in males than in females. We nevertheless found that there was a significantly greater incidence of the minority left-higher pattern in women than in men,

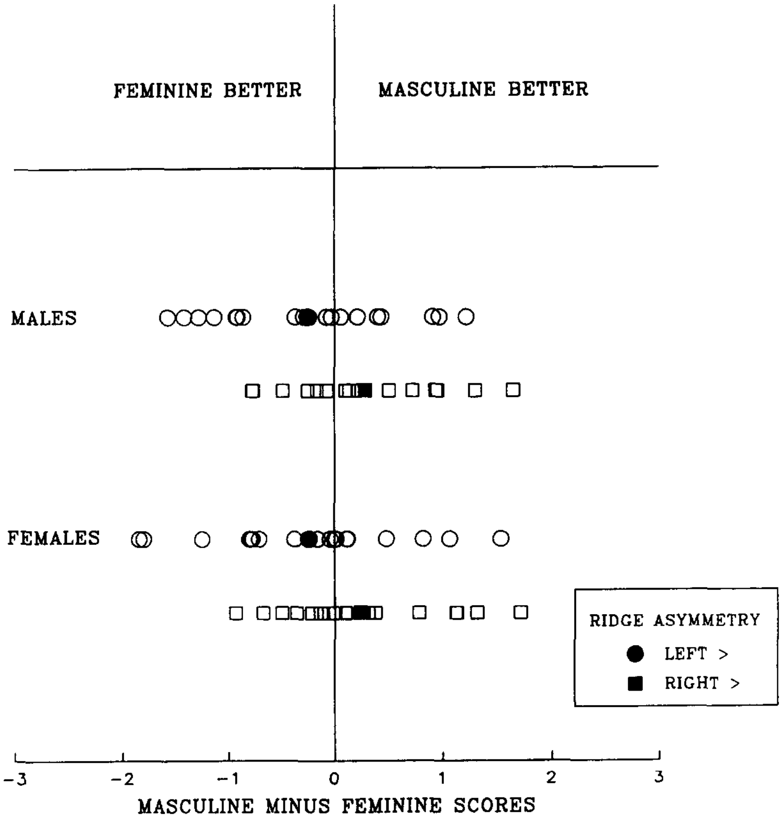

Fig. 3. Intra-individual Feminine–Masculine composite scores for *S*s with L-higher and R-higher finger-ridge counts.

consistent with studies suggesting that females may have enhanced left somatic growth patterns, while males show the reverse (Kimura, 1994; Levy & Levy, 1978).

We did not find that dermal ridge-count asymmetry related to hand preference, in either sex. This contrasts with the finding that there is such a relation in homosexual men (Hall & Kimura, 1994), suggesting that the mechanisms for determination of hand preference may be different in homosexual and heterosexual individuals.

This study further confirms findings from previous research on the relation between direction of somatic asymmetry (determined by self-inspection), and cognitive pattern. That finding was that leftward and rightward directions favor 'feminine' and 'masculine' abilities, respectively (Kimura, 1994). Three of the four male-favoring tests showed an advantage in rightward *S*s, and the other showed no difference. Two of the three female-favoring tests showed an advantage in the leftward *S*s, and the other showed no difference. Thus, the analysis of abilities according to whether they favor men or women appears to have some biological validity. Whether some other breakdown will show a better fit can only be determined by further research.

It is known that early exposure to androgens (Resnick, Berenbaum, Gottesman & Bouchard, 1986) and the level of adult androgens (Gouchie & Kimura, 1991) are factors in the performance of several male-biased spatial tasks, and to some degree also in math reasoning. The fact that in the present study, leftward bias favored feminine tasks, and rightward bias masculine tasks, *in both men and women*, makes it somewhat unlikely that androgens are a major influence mediating the difference between laterality groups. We did not, however, have measures of testosterone on a large enough sample of our *S*s to be able to comment conclusively on this factor. Nevertheless, adult androgen levels have so far been shown to relate only to male-biased sexually-dimorphic tasks, not to Perceptual Speed, which favors females (Gouchie & Kimura, 1991; Kimura & Hampson, 1994).

In the present study, an unexpected finding was that neutral tests, which by definition do not show sex differences, were also performed better by rightward *S*s. This was particularly true of Inferences, a verbal reasoning test, on which the difference between leftward and rightward *S*s was comparable to that of mathematical reasoning, on which males typically excel. This finding might suggest that not only is there favoring of Masculine tests in rightward individuals, but that some general intellectual or reasoning function may also be enhanced. Alternatively, it may be that even non-mathematical reasoning favors males to a slight degree, since this has been reported in studies employing very large samples (Owen & Lynn, 1993; Stumpf & Jackson, 1994). Since this is a point of divergence with the previous body-asymmetry study, however, it needs to be replicated before further commentary is warranted.

A relation between direction of finger-ridge asymmetry and cognitive functioning suggests contemporaneous development *in utero* of particular neuro-cognitive systems and lateralized somatic growth patterns. The direction of somatic asymmetry may parallel structural/functional brain asymmetry; or may merely reflect the adventitious co-development of dermatoglyphic asymmetry and specific cognitive systems, regardless of brain hemispheric representation. That dermal asymmetry need not parallel brain asymmetry is suggested by the lack of a relation between handedness and direction of dermal asymmetry in the *S*s of the present study.

To address this question more directly, studies in our laboratory have employed dichotic listening as a measure of speech lateralization. The findings indicate that the typical right-ear superiority (indicative of left-hemisphere speech) is smaller in individuals with L > ridge counts than in those with R > counts. This is true for both homosexual (Hall & Kimura, 1993) and heterosexual *S*s (Saucier & Kimura, 1995). A smaller right-ear effect, however, is not consistent with the idea of a more developed *left* hemisphere, paralleling the L > somatic pattern. A more plausible explanation might invoke enhanced commissural systems in L > individuals, which would make the left-ear input more accessible to the left hemisphere, and thus reduce the right-ear effect. The report that women and homosexual men have larger anterior commissures than heterosexual men would be consistent with this interpretation (Allen & Gorski, 1992), given the higher incidence of L > pattern in the former.

Whatever the ultimate neural mechanism, since dermatoglyphic pattern is established early in the second trimester, the findings of the present study suggest that cognitive pattern is significantly influenced before birth. Subsequent environmental events, other than direct damage, do not affect the fingerprints. Moreover, neither the *S*s nor their parents are aware of their fingerprint patterns and both are certainly ignorant of any directional asymmetry. The relation between directional asymmetry and intellectual function is similar in both sexes. It appears that sociological explanations of cognitive function are untenable for that portion of the variance related to dermatoglyphic asymmetry.

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