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# Ear Asymmetry and Left-Side Cradling

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**Women and girls tend to cradle infants and dolls on the left side of the body. Left-sided cradling is found in chimpanzees and gorillas, is cross-cultural and present in historical works of art, and is transmitted down the human maternal line. One explanation for the left-cradling tendency is that it facilitates the flow of affective information from the infant via the left ear and eye to the center for emotional decoding, that is, the right hemisphere of the mother. We show that the developmental stability of the ear, as measured by ear asymmetry, is negatively correlated with the left-sided cradling tendency. Left-cradling English women holding infants and Jamaican girls holding dolls had a strong tendency to show lower ear asymmetry than right cradlers, whereas no such relationship was found in boys nor for various measures of asymmetry of the hand, with the possible exception of the wrist in Jamaican girls. Degree of handedness, as measured by the Annett peg-moving test, did not predict cradling preference in the Jamaican children, and the relationship between ear asymmetry and cradling preference was independent of hand preference. Our results suggest that developmental instability of the ear (including the pinna, external auditory meatus, and middle ear) may interfere with the flow of affective information to the right hemisphere. Ear asymmetry also showed evidence of strong maternal but not paternal transmission. It is suggested that between-individual**

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variation of in utero stress may explain patterns of maternal transmission of lateral cradling tendencies. © 1997 Elsevier Science Inc.

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**M**ost human females show a tendency to cradle infants or a facsimile of an infant on the left side of the body (Salk 1960, 1973; Weiland 1964). This tendency appears to: (1) be shared by chimpanzees and gorillas (Manning and Chamberlain 1990; Manning et al. 1994); (2) arise early in girls, as shown by doll-holding behavior, but is not present in boys (De Chateau and Andersson 1976; Manning and Chamberlain 1991); (3) be well developed in women but not in men (see discussion in Manning 1990; Bruser 1981; Lockard et al. 1979; Rheingold and Keene 1965; Richards and Finger 1975) (4) be independent of handedness (De Chateau et al. 1978; Saling and Tyson 1981); and (5) show widespread occurrence both in contemporary human cultures (Bruser 1981; Richards and Finger 1975; Saling and Cooke 1984) and, as shown by works of art, in historical cultures (Finger 1975; Grusser 1983).

As cultural traits tend to be highly malleable, this pattern suggests a genetic influence on the expression of left-side cradling. Manning and Chamberlain (1990, 1991) and Manning and Denman (1994) have suggested that genes influence a female's cradling preference by determining her degree of hemispheric lateralization for emotional decoding. The right side of the brain is specialized for the interpretation of affect (Leventhal and Tomarken 1986), and this is particularly so in females (Burton and Levy 1989). This lateralization applies to the affective information in facial expressions and voice intonation (Davidson and Sutton 1995). Cross-over of visual and auditory fibers means that stimuli presented to the left of the visual field and to the left ear are transmitted directly to the right hemisphere (Hellige 1993). Women who are right hemisphere lateralized for emotional decoding may cradle on the left in order to facilitate the interpretation of their infant's emotional state. Therefore, genes that affect the lateralization of emotional decoding may also influence lateral cradling preferences in women.

At present there is contradictory evidence for the importance of visual cues of affect in the maintenance of left cradling. Manning and Chamberlain (1991) have shown that an image of a baby, when transmitted from the left side of the cradler's visual field, is a necessary stimulus for the left-side cradling preference. On the other hand, Lucas et al. (1993) were unable to find a relationship between doll-holding preferences and the degree of hemispheric lateralization for affect in a group of nulliparous females. It may be that the critical feature here is that of affect in infant facial expressions. Denman and Manning (1997) have found that the left-cradling tendency (LCT) is significantly related to accuracy of identifying infant facial expressions via the left eye.

Manning and Denman (1994) have shown that there are significant correlations between the left-side cradling frequencies of mothers and daughters, sisters, and maternal grandmothers and granddaughters. Strong maternal effects such as these may result from sex-limited genes influencing the development of hemispheric lateral-

ization for emotional decoding and/or a maternal influence on infant development that affects the development of lateralization. Developmental instability is one such influence that may modify the developmental trajectory of the brain that leads to right-brain lateralization for affect in females. As a result, developmentally stable individuals would show a left preference for infant holding whereas developmentally unstable females would not. Developmental stability may be assessed from the magnitude of deviations from perfect bilateral symmetry shown in normally bilaterally symmetric traits (fluctuating asymmetry [FA]). With FA it is assumed that the optimal condition is perfect symmetry and deviations from this indicate increasing developmental instability (Van Valen 1962). FA is increased by genetic and environmental stressors such as harmful mutations, homozygosity resulting from inbreeding, high parasite load, niche destruction, and pollution (Manning and Chamberlain 1994; Møller 1992; Parsons 1992). In humans FA is generally measured from paired traits such as ear size, digit length, wrist diameter, ankle circumference, foot length, etc. (Manning 1995). High levels of FA are found in many conditions associated with neural abnormalities, such as schizophrenia, autism, learning disorders, and hyperactivity (review in Thornhill and Møller 1997). One effect of developmental instability may be in altering the developmental pathway to anatomical and modal functional asymmetries in the brain. Thus, Thoma (1995) found that FA correlated positively with left-right cortical asymmetries and negatively with corpus callosum area and cortical volume. Deviations from modal handedness are associated with markers of developmental instability such as dermatoglyphic FA (Yeo and Gangestad 1993; Yeo et al. 1993). Nonmodal cognitive asymmetries are also associated with high levels of FA. Yeo et al. (1997) have found that women who are not strongly right hemisphere lateralized for affect have high FA.

The following hypothesis may therefore explain the expression of LCT among humans: (1) sex-limited genes influence the development of right-hemisphere emotional decoding so that women are more intensely lateralized than men, leading to left-sided preferences in women's cradling behavior; (2) developmental instability caused by genetic and environmental stressors results in nonmodal functional asymmetry for affect and influences cradling preferences; and (3) LCT shows strong maternal transmission, therefore developmental instability should also show maternal effects.

The purpose of this work was to test parts 2 and 3 of this hypothesis.

## INVESTIGATION 1

### Left-Side Cradling and Asymmetry in Women

Asymmetry and LCT were measured in 69 Caucasian women with a mean age of  $43.40 \pm 1.80$  (*SE*) years. LCT was established from inspection of family album photographs (Manning 1990; Manning and Denman 1994). Subjects supplying photographs were told the work was an investigation into interactions between adults and children and that they were not to select photographs in any way. Photographs were categorized by the child's position, that is, to the right or left of the carrier.

When the child was positioned in the midline or where multiple photographs of one pose were available, those photographs were discarded. Interobserver reliability of the scoring of lateral holding has a very high repeatability (Manning and Denman 1994). LCT was calculated by dividing the number of left-holding poses by the total number of photographs. The number of photographs per subject varied from 6 to 37 with a mean of 10.7 per female. LCTs standardized for sample number ( $p$ ) were calculated by using a transformation suggested by Zar (1984):

$$p = 0.5\{(X/n + 1) + (X + 1/n + 1)\} , \quad (1)$$

where  $X$  is the number of left-sided photographs and  $n$  is the total number of photographs. In order to ensure sufficient representation of right-cradling women, some subjects were recruited from a previous study. This meant that the mean LCT of 61% was lower than the usual level of LCT found in photographic surveys (Manning 1990; Richards and Finger 1975; Salk 1973).

Asymmetry was measured in four traits (ear height and the length of the third, fourth, and fifth digits). All measurements were made with callipers measuring to 0.05 mm. The traits were measured twice. Absolute signed asymmetry was obtained by subtracting the measurement of the right side from that of the left (L-R). Repeatabilities ( $r_1$ ) were calculated for signed asymmetries and a repeated measures ANOVA was used to test the ratio between the within-subjects variance (measurement error) and the between-subjects variance. All traits showed high and significant  $r_1$  values; ears:  $r_1 = .90$ ,  $F = 19.21$ ,  $p = .0001$ ; third digit,  $r_1 = .86$ ,  $F = 13.14$ ,  $p = .0001$ ; fourth digit,  $r_1 = .81$ ,  $F = 9.41$ ,  $p = .0001$ ; fifth digit,  $r_1 = .87$ ,  $F = 14.48$ ,  $p = .0001$ . In order to further eliminate measurement error we calculated the mean asymmetry for each trait.

The signed asymmetries of ideal FA have a mean of zero and are normally distributed. We tested the former with  $t$ -tests with mean set at zero and the latter with tests of skewness ( $g_1$ ) and kurtosis ( $g_2$ ) (Palmer and Strobeck 1992). The signed asymmetries of ears showed an excess of right ears larger than left ears that was not significant ( $\bar{x} = -0.27$  mm,  $t = 1.61$ ,  $p = .11$ ) but significant skewness ( $g_1 = 1.33$ ,  $Z = 4.72$ ,  $p = .0001$ ) and kurtosis ( $g_2 = 4.57$ ,  $Z = 7.75$ ,  $p = .0001$ ) was present. The third and fifth digits also showed deviations from ideal FA (third digit,  $\bar{x} = -0.45$  mm,  $t = 2.43$ ,  $p = .018$ ,  $g_1 = .09$ ,  $Z = .31$ ,  $p = .74$ ,  $g_2 = .29$ ,  $Z = .49$ ,  $p = .62$ ; fifth digit,  $\bar{x} = -0.53$  mm,  $t = 2.78$ ,  $p = .007$ ,  $g_1 = .34$ ,  $Z = 1.17$ ,  $p = .24$ ,  $g_2 = .10$ ,  $Z = .17$ ,  $p = .46$ ). The fourth digit showed no evidence of directional asymmetry or significant skewness or kurtosis ( $\bar{x} = -0.32$  mm,  $t = 1.89$ ,  $p = .06$ ;  $g_1 = .44$ ,  $Z = .75$ ,  $p = .45$ ;  $g_2 = .43$ ,  $Z = .91$ ,  $p = .36$ ). The skewing of the sample toward right-side cradlers may have introduced these deviations from ideal FA.

Table 1 shows the results of second-order polynomial regressions of LCTs and unsigned asymmetry. Because unsigned asymmetry scores have a truncated distribution we used a log  $(1+x)$  asymmetry transformation in all our analyses. Ear asymmetry shows a significant curvilinear relationship with LCT (Figure 1). The lowest asymmetry is around an LCT of about 70%. A simple linear regression of ear asymmetry on LCT is also significant but with a substantially lower  $r^2$  value than

**Table 1. Second-Order Polynomial Regression Analyses of Asymmetry on LCT**

	Second-order polynomial regression		
	Coeff. (x)	r <sup>2</sup>	p
Ears	-.011	.15	.004
Third digit	-.002	.048	.19
Fourth digit	-.004	.018	.54
Fifth digit	-.001	.001	.95

The dependent variable is log (1 + x) asymmetry.

that shown by the second-order analysis ( $b = -.002$ ,  $r^2 = .08$ ,  $p = .018$ ), indicating the former analysis is more appropriate. Subjects with low LCTs, that is, right cradlers, had higher ear asymmetry than participants with high LCTs (LCT = 0–49%, ear FA  $\bar{x} = 0.34$  mm, 0.04 SE; LCT = 50–100%, ear FA  $\bar{x} = 0.24$ , 0.02 SE,  $t = 2.27$ ,  $p = .025$ ).

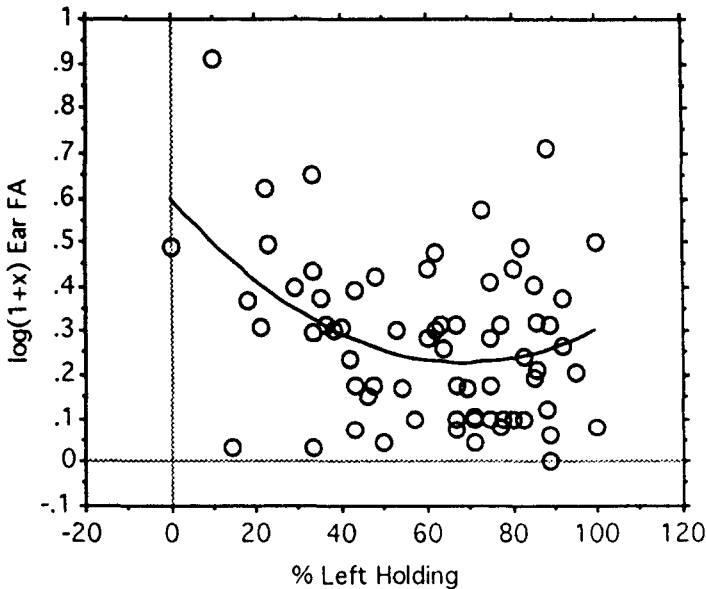
## INVESTIGATION 2

### Doll Holding in a Rural Jamaican Population

Doll-holding preferences were noted as part of a large study of asymmetry in a rural Jamaican population of children drawn from Southfield in the parish of St. Elizabeth.

Our sample consisted of 179 children (101 girls and 78 boys) aged between 5 and 11 years. The doll was presented to the midline of each subject. The child was

**FIGURE 1.** Line of best fit for a second-order polynomial regression of log (1 + x) ear asymmetry on left-cradling tendency in 69 Caucasian women.



**Table 2. Descriptive Statistics of the Signed Asymmetries of Seven Traits Measured in Investigation 2**

	$\bar{x}$	$p$	Skewness	$p$	Kurtosis	$p$
Ears	-0.48	.0001	.27	.13	.27	.48
Third digit	0.28	.008	.44	.02	1.92	.0001
Fourth digit	0.003	.7	.20	.27	.49	.18
Fifth digit	0.054	.62	.07	.70	.26	.48
Elbows	1.82	.0001	2.05	.0001	12.08	.0001
Wrists	0.12	.19	.18	.16	.06	.86
Hands	0.73	.0001	.15	1.65	.61	.09

asked to "Look at this doll and imagine it is a small baby. Now hold it as if it is a small baby." The position of cradling, that is, right, left, or midline, was then recorded.

We measured seven paired traits: ear height, third to fifth digit length, elbow width, wrist thickness, and hand breadth. Callipers measuring to 0.05 mm were used for all traits. Repeatabilities ( $r_i$ ) were calculated for signed absolute asymmetries (L-R) and a repeated measures ANOVA was used to test the ratio between the within-subjects variance (measurement error) and the between-subjects variance. All traits showed significant  $r_i$  values; ears,  $r_i = .78$ ,  $F = 8.04$ ,  $p = .0001$ ; third digit,  $r_i = .71$ ,  $F = 5.96$ ,  $p = .0001$ ; fourth digit,  $r_i = .69$ ,  $F = 5.48$ ,  $p = .0001$ ; fifth digit,  $r_i = .78$ ,  $F = 7.92$ ,  $p = .0001$ ; elbows,  $r_i = .79$ ,  $F = 8.28$ ,  $p = .0001$ ; wrists,  $r_i = .51$ ,  $F = 3.11$ ,  $p = .0001$ ; hands,  $r_i = .71$ ,  $F = 5.90$ ,  $p = .0001$ . In order to further eliminate measurement error we calculated the mean asymmetry for each trait.

The results of the tests for ideal FA are shown in Table 2. In contrast to the weak relationship in Investigation 1, ears showed a highly significant tendency toward directional asymmetry with the right ear larger than the left ( $\bar{x} = -.48$  mm,  $t = 5.38$ ,  $p = .0001$ ); however, there was no significant skewness or kurtosis ( $g_1 = .27$ ,  $Z = 1.53$ ,  $p = .13$ ;  $g_2 = .26$ ,  $Z = .69$ ,  $p = .48$ ). Of the remaining traits, fourth and fifth digit length and wrist thickness showed ideal FA.

Of the 101 girls, 28 (28%) held the doll on the right, 56 (55%) on the left, and 17 (17%) on the midline of the body. The boys had lower frequencies of right and left cradling (14 [18%] and 31 [40%], respectively) and higher levels of midline holding (33 [42%]). There was a highly significant sex difference in holding preference ( $\chi^2 = 14.24$ ,  $DF = 2$ ,  $p = .0008$ ).

A comparison of log (1 + x) asymmetries in right- and left-holding girls and boys showed that, in common with the result of Investigation 1, the girls had significantly lower asymmetries for left holders in ears ( $t = 2.65$ ,  $p = .008$ ). Wrists also showed significantly lower asymmetry in left holders ( $t = 2.14$ ,  $p = .036$ , Table 3).

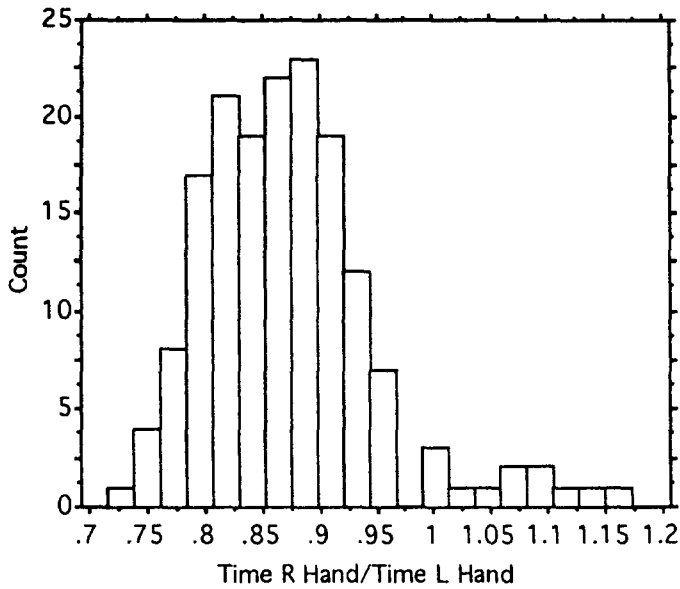
Our finding that right cradlers have more asymmetric ears than left cradlers could be the result of handedness. For example, left handers may cradle on the right in order to keep their preferred hand free and they also may have high FA. This explanation seems unlikely as lateral cradling preferences are essentially the same in right and left handers (De Chateau, et al. 1978; Saling and Tyson 1981; Salk 1973). However, there is considerable natural variation in hand preference that is not repre-

**Table 3. Mean Asymmetries of Left- and Right-Cradling Girls and Boys from Investigation 2**

	FA right cradling	FA left cradling	<i>t</i>	<i>p</i>
<b>Girls</b>				
Ears	.35	.26	2.64	.008
Third digits	.28	.30	.50	.62
Fourth digits	.27	.32	1.24	.22
Fifth digits	.32	.29	.66	.52
Elbows	.43	.44	.27	.79
Wrists	.31	.24	2.14	.04
Hands	.34	.32	.47	.64
<b>Boys</b>				
Ears	.24	.24	.01	.99
Third digits	.19	.27	1.67	.10
Fourth digits	.27	.25	.35	.73
Fifth digits	.30	.30	.02	.98
Elbows	.39	.40	.13	.90
Wrists	.28	.29	.49	.60
Hands	.35	.31	.82	.42

*Note.* Left-holding girls had significantly lower ear asymmetry than right-holding girls ( $t = 2.66, p = .008$ ). A sequential Bonferroni test reduced this to  $p = .056$  (but see Bonferroni adjustment of result of multiple regression test). Left-holding girls also had lower wrist asymmetry than right holders ( $t = 2.14, p = .036$ ), and this was reduced to  $p = .22$  by Bonferroni adjustment (but see Bonferroni correction of multiple regression test). The dependent variable was  $\log(1 + x)$  asymmetry.

sented by a simple right- and left-handed dichotomy (Annett 1987). We assessed relative hand performance (HP) by the Annett peg-moving test (Annett 1985). Subjects were asked to move, with one hand, 10 pegs from a back row to an empty row of holes about 5 inches in front. They were timed from the moment the hand touched the first peg until the last peg was placed in its hole. There were five repetitions for each hand. The mean left and right hand times were then calculated. In order to calculate HP we divided the mean right hand time by the mean left. The distribution of HP is shown in Figure 2. It can be seen that most subjects had HPs of  $< 1$ , that is, they were faster with their right hand in the peg-moving test. We had HPs for 165 doll-holding subjects (90 females and 75 males). HP did not predict cradling preference in the total sample (HP right cradlers,  $\bar{x} = .88$ ; left cradlers,  $\bar{x} = .86$ ; midline cradlers,  $.88$ , ANOVA,  $F = 1.08, p = .34$ ) or for girls (HP right cradlers,  $\bar{x} = .87$ ; left cradlers,  $\bar{x} = .86$ ; midline cradlers,  $\bar{x} = .87$ , ANOVA,  $F = .37, p = .69$ ) or boys (HP right cradlers,  $\bar{x} = .90$ ; left cradlers,  $\bar{x} = .88$ ; midline cradlers,  $\bar{x} = .89$ , ANOVA,  $F = .47, p = .63$ ). In addition, multiple regression tests with  $\log(1 + x)$  FA ears or  $\log(1 + x)$  FA wrists as the  $y$  variable and HP and side preference (right and left cradlers, coded as dummy variable 1 and 2, respectively) as  $x$  variables showed that side-cradling preference predicted ear FA and wrist FA independently of HP (ear FA, cradling preference, coeff. =  $-.11, SE = .04$ , st. coeff. =  $-.29, t = 2.69, p = .007$ ; HP, coeff. =  $.01, SE = .24$ , st. coeff. =  $-.005, t = .043, p = .97$ ; wrist FA, cradling preference, coeff. =  $-.09, SE = .034$ , st. coeff. =  $-.29, t = 2.70, p = .008$ ; HP, coeff. =  $.39, SE = .21$ , st. coeff. =  $.21, t = 1.87, p = .065$ ). The  $p$  values of ear and wrist FA remained significant after Bonferroni adjustment ( $p = .049$  and  $.048$ , respectively).



**FIGURE 2.** Hand preference scores on the Annett peg-moving test. The mean time taken to complete the test with the right hand was divided by the mean time taken with the left hand. Most subjects were faster with the right hand than the left, that is, their score was  $< 1$ . Participants who were faster with their left hands had scores  $> 1$ .

## INVESTIGATION 3

### Maternal Effects in FA

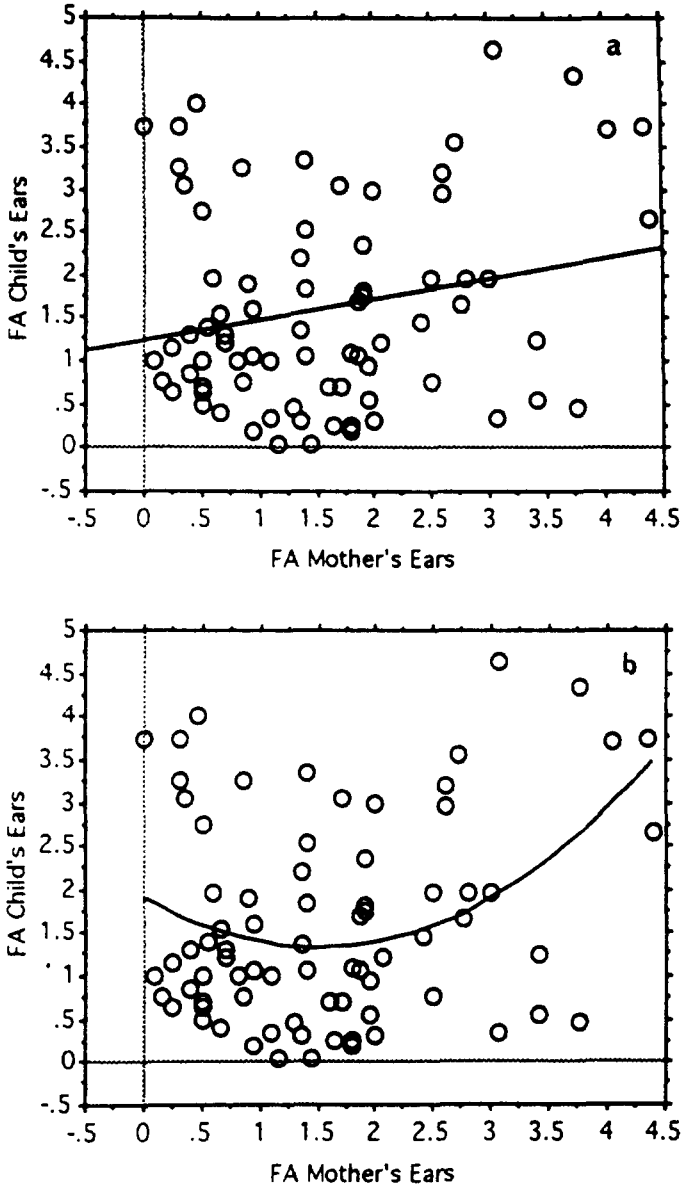
It may be that the strong pattern of maternal transmission of LCT reported by Manning and Denman (1994) is caused by maternal effects (e.g., in utero stress) on developmental stability. We therefore investigated the relationships between the ear asymmetries of parents and their children.

Absolute and relative asymmetries in children are known to be negatively correlated with age (Wilson and Manning 1996). Child age was therefore controlled for by measuring children from year 10 (14 to 15 years old) from secondary schools in NW England. There were 224 participants in the sample, 79 children, 77 mothers, and 68 fathers.

Ear height was measured with vernier callipers measuring to 0.05 mm. Absolute asymmetries were calculated by subtracting the size of the right ear from the left (L-R). Repeat measurements were made on 20 participants. A repeated measures ANOVA test on the signed asymmetries showed a significant repeatability and a significant ratio of between-subjects and within-subjects variance ( $r_1 = .41$ ,  $F = 2.38$ ,  $p = .03$ ).

The signed asymmetries of all three samples showed evidence of directional asymmetry with right ears on average larger than left ears. This trend was significant for fathers and children and almost significant for mothers (one-sample  $t$ -test; fathers  $\bar{x} = -.73$  mm,  $t = 3.31$ ,  $p = .002$ ; mothers,  $\bar{x} = -.40$  mm,  $t = 1.85$ ,  $p =$

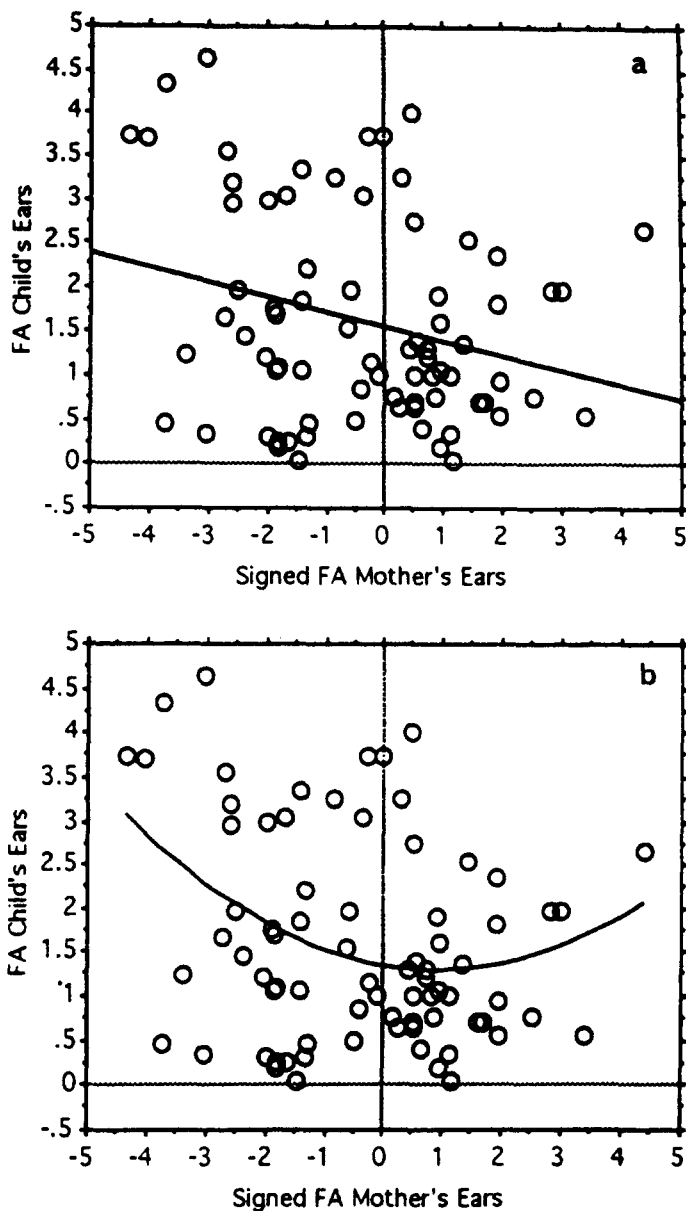




**FIGURE 3.** Lines of best fit for (a) linear and (b) second-order polynomial regression of children's ear asymmetry on asymmetry of the ears of their mothers.

.07; children,  $\bar{x} = -.57$  mm,  $t = 2.64$ ,  $p = .01$ ). Tests of skewness and kurtosis indicated that all samples were normally distributed (fathers,  $g_1 = .26$ ,  $Z = .88$ ,  $p = .38$ ,  $g_2 = .08$ ,  $Z = .13$ ,  $p = .88$ ; mothers,  $g_1 = .04$ ,  $Z = .13$ ,  $p = .90$ ,  $g_2 = .50$ ,  $Z = .89$ ,  $p = .38$ ; children,  $g_1 = .09$ ,  $Z = .34$ ,  $p = .74$ ,  $g_2 = .51$ ,  $Z = .92$ ,  $p = .36$ ).

There were no significant relationships between father and child's ear asymmetry (independent variable father's ear asymmetry and dependent variable  $\log(1+x)$ )



**FIGURE 4.** Lines of best fit for (a) linear and (b) second-order polynomial regressions of children's asymmetry on signed asymmetry of the ears of their mothers.

ear asymmetry of children; linear regression,  $r^2 = .0003$ ,  $F = .0002$ ,  $p = .99$ ; second-order polynomial regression,  $r^2 = .00005$ ,  $F = .002$ ,  $p = .99$ ).

The ear asymmetries of mothers and that of their children were positively associated. Figure 3 shows lines of best fit for a simple linear regression and second-order polynomial regression of children's ear asymmetry on that of their mothers. The former relationship was not significant but the latter showed a skewed U-shaped

association so that women with an asymmetry of about 1.5 mm had the most symmetric children (independent variable mother's ear asymmetry and dependent variable  $\log(1+x)$  child's ear asymmetry; linear regression,  $r^2 = .04$ ,  $F = 2.27$ ,  $p = .10$ ; second-order polynomial,  $r^2 = .11$ ,  $F = 4.45$ ,  $p = .02$ ). Linear and second-order polynomial regressions of children's asymmetry on the *signed* asymmetry of mothers showed women with negative asymmetry, that is, with right ears larger than left, had more asymmetric children than women with positive asymmetry, that is, with left ears bigger than right. Figure 4 indicates this effect is strongest in the second-order polynomial analysis, which shows the optimal class to be women with approximately + 1.0 mm asymmetry (independent variable signed mother's asymmetry and dependent variable  $\log(1+x)$  signed children's ear asymmetry; linear regression,  $r^2 = .04$ ,  $F = 3.06$ ,  $p = .09$ ; second-order polynomial regression,  $r^2 = .084$ ,  $F = 3.35$ ,  $p = .04$ ).

## DISCUSSION

The results of Investigations 1 and 2 indicate that right-cradling women and girls are more asymmetric than left cradlers and that the lowest asymmetry in women appears to be related to a 70% LCT. However, it seems unlikely that this is simply the result of generalized developmental instability disrupting normal development toward right hemisphere lateralization for affect. There was an association between wrist asymmetry and cradling preference in Investigation 2. In general, however, our data suggest that it is ear asymmetry that predicts LCT and that ear asymmetry shows evidence of weak directional rather than fluctuating asymmetry.

FA of the pinna may correlate with developmental instability of the ear. Gross abnormalities of the pinna, for example, Treacher Collins syndrome (Treacher Collins 1990) and hemifacial microsomia (Cousley and Wilson 1992), are associated with external ear canal defects, middle ear anomalies, and conductive deafness. At least one such syndrome (Treacher Collins) has an excess of affected offspring from affected females and of normal offspring from affected males. Transmission may therefore show sex-limited tendencies through the female line (Smith 1972). The asymmetries of the pinna we report are not major malformations nor are they minor physical anomalies. They are on the order of a few millimeters and, therefore, characteristic of small perturbations in developmental stability. However, they may indicate, in common with the major syndromes, errors in morphogenesis of the first and second branchial arches. In other words, asymmetries of the pinna may have little functional consequence but could reflect errors that affect auditory perception, such as malformations in the external auditory meatus and the middle ear. It has been argued that left-side cradling is associated with the transmission of visual and auditory information from the left eye and ear to centers specialized for emotional decoding in the right hemisphere (Manning 1991; Manning and Chamberlain 1990, 1991; Manning et al. 1994). Developmental instability of the ear may therefore affect the LCT.

In Investigation 1 we found evidence of a curvilinear relationship between ear asymmetry and LCT. The lowest FA values occur around the 70% value for left cra-

dling. Modal values of LCT in large cross-cultural surveys also tend to occur around 70% (Lockard et al. 1979; Saling and Cooke 1984). This finding suggests that extreme values (i.e., greater than the modal value) of left-side cradling in addition to right-side cradling are associated with elevated FA. A similar situation appears to apply in deviations from mean lateralization of language processing and processing of emotional facial expression (Yeo and Gangestad 1993; Yeo et al. 1997). The cross-over of nerve fibers from the left side of the body may also be important in the perception of touch while holding the infant. High FA in the wrists of right-cradling girls may indicate that developmental instability could affect this. However, we were not able to confirm such a relationship in the FA of digits or hands.

In support of an association between stress and low LCTs we found evidence in Investigation 3 of maternal but not paternal transmission of ear asymmetry, which is consistent with similar patterns of maternal transmission of cradling tendencies (Manning and Denman 1994). That this effect is restricted to mothers suggests that *in utero* stresses may be characteristic of some maternal lines. It is known that preterm infants and their mothers have higher developmental instability than full-term infants and their mothers (Livshits et al. 1988). LCT is also related to gestational duration. Salk (1970) and De Chateau et al. (1978) have found that high left-side cradling scores were not found in mothers separated from their babies immediately after birth. Many of these infants were preterm. Stressors such as overcrowding, poor diet, infection, and inbreeding may also help to explain some puzzling observations of low LCT. No left-sided tendency or even a right-sided tendency has been shown in studies of cradling in: (1) a small group of captive chimpanzees held in a biomedical facility (Dienke et al. 1995); (2) certain historical periods of pre-Columbian and Western art (Alvarez 1990; Grusser 1983); and (3) some present day human populations in the Malagasy Republic (Nakamichi 1996).

Our samples show weak directional asymmetry in pinna size. Opinions differ as to whether directional asymmetry can be used to estimate developmental instability (Graham et al. 1993; Palmer and Strobeck 1992; Simmons and Ritchie 1996). Ideal FA has an optimal class of zero, and deviations in either direction, that is, + or - asymmetries, are suboptimal. Our data from the ear asymmetries of mothers and children suggest that mothers with weak positive asymmetry, that is, left ears slightly larger than right, produce the most symmetric children. Mothers with negative ear asymmetries, that is, right ears bigger than left, produce the most asymmetric children (Figure 3). This suggests that the optimal class is not zero asymmetry but is slight positive ear asymmetry. Some support for this comes from Investigation 2. Mean signed asymmetries of right- and midline-holding girls showed higher negative asymmetry ( $\bar{x} = -.74$  mm and  $-.72$  mm, respectively) than left-holding girls ( $\bar{x} = -.34$  mm); however, the differences were not significant (ANOVA,  $F = 1.40$ ,  $p = .25$ ). Therefore, we do not know the exact value of the optimal class. However, the evidence supports the assumption that it is close to zero and that deviations from this may be regarded as suboptimal.

Overall our data suggest an important effect of developmental stability of the ear on the expression of lateral cradling preferences. We think this relationship with ear asymmetry may be causal. That is, developmental instability, not just of the pinna

but of the external auditory meatus and middle ear, could influence the flow of affective information from the left ear to the right hemisphere of the mother. If this is the case, then we may expect a similar relationship between eye asymmetry and LCT.

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