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Baby, It's in Your Smile: Right Hemiface Bias in Infant Emotional Expressions

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Adult facial expressions are more intense on the left hemiface, suggesting right hemisphere emotional specialization. In this research, adult judgments of mirror-image chimeras indicated that infant expressions are more intense on the right hemiface, which is not predicted by current models of adult cerebral asymmetries. The rightward bias was stronger when judgments were restricted to the central facial features in computer-digitized images of the chimeric faces. Because the mouth and eye regions receive contralateral versus bilateral cortical input, respectively, separate judgments of the mouth and eyes/brows were obtained. Only the mouths showed a significant rightward bias, implicating cortical rather than lower-level mechanisms. The results were replicated with a second set of infants. The findings are interpreted as support for a right-to-left gradient in development of cortical inhibition over subcortical influences on facial expressions.

Human communication depends on emotional displays that help regulate interactions (Buck, 1986; Darwin, 1872/1965; Tomkins, 1962, 1963), particularly in the case of preverbal infants. Expressions of the primary categories of emotion (Tomkins, 1962, 1963) show notable regularities across disparate cultures, suggesting a biological basis for the emotional signal system (Eibl-Eibesfeldt, 1972; Ekman, 1973), along with observations that certain emotional signals such as the distress cry appear shortly after birth and others emerge according to universal milestones during the first year (e.g., Bowlby, 1969; Izard, 1978).

Moreover, there is direct evidence of neural specialization for human emotional behavior at even the highest levels of the nervous system. Neocortical control is involved in both deliberate, posed expressions, largely by means of frontal lobe inputs to the pyramidal tract, and in so-called spontaneous emotional expressions, by means of temporal lobe inputs to the extrapyramidal system (Ekman, 1980; Kahn, 1964; Monrad-Krohn, 1924; Remillard, Andermann, Rhi-Sausi, & Robbins, 1977; Rinn, 1984). Cortical representation on the frontal motor strip is substantially greater for the lower than for the upper portion of the face, and descending inputs to the lower division of the facial nerve on each side arise predominantly from the contralateral cortex, whereas those to the upper division arise bilaterally (Gatz, 1970; Kuypers, 1958; Rinn, 1984). Furthermore, studies of unilateral brain-damaged patients indicate a right hemisphere superiority for the expression of emotions (Borod, Koff, Lorch, & Nicholas, 1986; Bruyer, 1981; Buck & Duffy, 1980; Kolb & Milner, 1981a, 1981b). Consistent with these clinical findings, normal adults show a left hemiface bias in the intensity of posed expressions (Borod & Koff, 1983; Campbell, 1978; Koff, Borod, & White, 1981; Sackeim & Gur, 1978; Sackeim, Gur, & Saucy, 1978), implying greater involvement of the contralateral right hemisphere (Crockett & Estridge, 1951; Peele, 1961; Zollinger, 1935).

Little is currently known, however, about the ontogenetic origins of asymmetries in emotional expression, which could illuminate several unresolved controversies in the adult literature. First, whereas some claim that asymmetrical cortical involvement is restricted to posed facial expressions (Ekman, 1980; Ekman, Hager, & Friesen, 1981; Hager & Ekman, 1985), others argue that it also extends to spontaneous expressions (Borod, Koff, & White, 1983; Cacioppo & Petty, 1981; Dopson, Beckwith, Tucker, & Bullard-Bates, 1984; Moscovitch & Olds, 1982). Second, whereas some claim that the right hemisphere is specialized for production of all emotions, regardless of their hedonic valence or motivational significance (e.g., Campbell, 1978; Sackeim, Gur, & Saucy, 1978), others argue that it is specialized only for negative or avoidance-related emotions and that the left hemisphere is specialized for positive or approach-related emotions (Ahern & Schwartz, 1979; Davidson, 1984; Sackeim & Gur, 1978; Sackeim et al., 1982; Schwartz, Ahern, & Brown, 1979). Third, expressive asymmetries may result from

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cortically mediated right hemisphere activation of left hemiface movements, from left hemisphere inhibition of subcortically mediated right hemiface movements, or from some combined influence (Buck, 1986; Gainotti, 1984; Rinn, 1984; Tucker, 1986; Tucker & Frederick, in press).

Infants' expressive asymmetries are of particular interest for several reasons. Emotional displays are the primary means of communication for preverbal infants and are central to parent–infant relationships, personality development, and early language acquisition (e.g., Kaye, 1982; Stern, 1974; Tronick, Als, & Adamson, 1979; Tronick, Ricks, & Cohn, 1982). In addition, infant expressions are spontaneous rather than voluntary or posed. Deliberate simulation and masking of emotions are generally thought to appear only during the second year of life (Campos, Barrett, Lamb, Goldsmith, & Stenberg, 1983; Oster, & Ekman, 1978; Rothbart & Posner, 1985; Sroufe, 1979). In contrast, in social situations even spontaneous adult expressions are influenced by social conditioning and cultural display rules (Buck, 1986; Ekman, 1972). Finally, theory and research indicate that the gradual functional maturation of the neocortex during infancy is initially manifested as *inhibition* of the subcortically mediated reflexive and spontaneous behaviors seen in neonates; this inhibitory function may precede the appearance of true voluntary cortical control (i.e., cortical *activation* of behavior), often by several months (Brodal, 1969; Clifton, Morrongiello, Kulig, & Dowd, 1981; McGraw, 1943).

Current models of adult emotional asymmetries would predict one of the following patterns for infant expressions: either a left hemiface bias across both negative and positive emotions (e.g., Borod & Koff, 1983; Borod, Koff, & White, 1983; Campbell, 1978) or a left hemiface bias for negative emotion only (e.g., Ahern & Schwartz, 1979; Davidson, 1984; Sackeim & Gur, 1978; Schwartz, Ahern, & Brown, 1979). In support of the latter prediction, Davidson and Fox (1982) and Fox and Davidson (1987) found asymmetrical electroencephalographic (EEG) responses in 10-month-olds who were viewing or participating in emotional situations, which suggested that left frontal activation is greater during presentation of positive than of negative emotional stimuli. Similarly, Fox and Davidson (1986) found greater overall left hemisphere activation in newborns during positive reactions to the taste of sucrose than during negative reactions to citric acid.

Asymmetries in infant expressions, however, may not be directly predictable from adult patterns. Infants' emotional processes or cortical function (or both) may be relatively immature, resulting in a lack of any asymmetry, which cannot be observed for a function that has not yet developed (e.g., Witelson, 1985). Alternatively, infants and adults may show different patterns of expressive asymmetries because of the initially inhibitory influence of the maturing cortex on subcortically mediated behaviors and the possibility that the two hemispheres may mature asynchronously. Several researchers have proposed either a left-to-right gradient in the early maturation of the hemispheres (Bever, 1978; Broca, 1865; Corballis & Morgan, 1978) or a right-to-left gradient (Best, 1988; Chi, Dooling, & Gilles, 1977; Crowell, Jones, Kapuniai, & Nakagawa, 1973; Tucker, 1986; Whitaker, 1978). Earlier maturation of the left hemisphere, combined with the initially inhibitory influence of the maturing cortex, should lead to inhibition of subcortically mediated right hemiface movements and, thus, to an extreme left hemiface bias in infant expressions. Conversely, earlier maturation of the right hemisphere should lead to inhibition of subcortically mediated left hemiface movements and, hence, to a right hemiface bias.

To examine these possibilities, we conducted a series of experiments on asymmetries in infants' emotional expressions. For each study, we obtained adult judgments about the relative intensity of emotional expressions for mirror-image composites of the left versus the right hemiface of infants' smiling or crying expressions. We progressively restricted the observers' focus on specific facial features to determine the source of the expressive asymmetries. The first experiment was designed to determine whether infant expressions show the same pattern of asymmetries found in adult expressions. Next, to test whether the asymmetries occurred in the actual expressive patterning of the facial features, the faces were computer-digitized and edited in Experiment 2 to remove all details other than mouth, eyes, brows, and nose. In Experiment 3, we addressed the role of cerebral, as opposed to lower-level, influences by determining whether the asymmetries were larger for the contralaterally innervated mouth than for the bilaterally innervated eye region. Finally, Experiment 4 replicated the second and third experiments with an additional group of 12 smiling infants.

Experiment 1

Method

Subjects. The judges were 46 university students (23 women and 23 men). The sample was restricted to familial right-handers, because research has shown them to be more consistent and more strongly lateralized than nonright-handers for various hemispherically specialized functions, including the perception and production of emotional expressions (Chaurasia & Goswami, 1975; Heller & Levy, 1981; Moscovitch & Olds, 1982). Handedness was assessed using a checklist on strength of hand preference for 10 common unimanual activities (including writing) in which people usually use the writing-dominant hand as well as by a series of questions about the hand preference of immediate family members. To be considered strongly right-handed, judges had to check *strong* to *moderate* right-hand preference for all items and they had to indicate that they had not switched from an early tendency toward left-handedness and that both of their parents were right-handed writers. Four additional judges were eliminated on the basis of their answers on the handedness inventory. All judges had normal or corrected vision. They received $4 for their participation in the 40-min test session.

The infant posers were normal, full-term 7- to 13-month-old infants, of whom a set of portrait photographs had been taken by a professional photographer for a series of previous studies on adult judgments of infant attractiveness (Hildebrandt, 1983; Hildebrandt & Fitzgerald, 1978, 1979, 1981). The photographs of these infants were selected from a sample taken of 60 infants (made available by Hildebrandt). Our selection criteria were as follows:

1. There had to be one still photograph of either a clearly negative (i.e., crying) or a clearly positive (i.e., smiling) expression for each infant. Our choices were made according to independent ratings of the infants' emotional expressions (Hildebrandt, 1983). None of the infants provided both a negative and a positive expression in the still photographs taken during their photography session (Hildebrandt, personal communication, January 1985); thus, our research design was restricted to between-subject comparisons on the emotional valence variable.

2. Because we also used the photographs in a separate series of studies on perceptual asymmetries in adults' responses to infant emotional expressions, which employed mixed-expression composites (half-neutral and half-emotional) of individual infants, there also had to be a photograph with a neutral expression for each infant poser. The neutral photographs were not used, however, in the studies reported here.

3. In order to construct mirror-image composites of the right and the left hemiface of each infant poser (see the Stimuli section below) for our assessments of expressive asymmetries, we selected only those infants who provided full-frontal facial views in their photographs (determined by consensus among the research assistants for Experiment 1).

Only 10 infants (5 girls and 5 boys) met all three criteria. Of these, 4 had crying expressions, and the other 6 had smiling expressions. Although the sample size is somewhat small, it is consistent with those in some published studies of adult expressive asymmetries (Cacioppo & Petty, 1981, used 4 posers; Campbell, 1978, and Heller & Levy, 1981, used 9 posers; Sackeim & Gur, 1978, used 14 posers).

Stimuli. Two black-and-white 5 × 7 in. prints were made of each smiling and crying infant photograph selected for the study. One print was made in normal orientation; the other was a mirror-reversal. These were used to construct mirror-image composites of each hemiface for each infant. Each print of a given infant was carefully cut down the exact facial midline, defined as the line connecting the point midway between the internal canthi of the eyes and the point in the center of the philtrum just above the upper lip. The left hemiface mirror-image composite was made by joining the left half of the mirror-reversed print and the right half of the normal print, both representing the left half of the infant's face, following the general procedure used to test for adult expressive asymmetries (e.g., Sackeim & Gur, 1978; Sackeim et al., 1978). The two left hemifaces were aligned exactly down the midline and glued to a backing sheet, producing an exactly symmetrical facial composite. The right hemiface composite was similarly constructed by joining the right half of the mirror-reversed print and the left half of the normal print. Each composite was centered behind an oval-shaped mattboard opening that was the size of the average photographed face in order to screen out variations in facial outline among infants. Copies of these were then made, one per page, on a high-quality Kodak photocopier, using a gray-scale correction template that produces good resolution of photographic images. Test booklets were constructed from these, containing one copy of each of the resulting mirror-image composites—that is, a left hemiface composite and a right hemiface composite for each of the 10 infant posers, or 20 composites altogether. The pages were ordered pseudorandomly, with the constraints that there be no more than three consecutive smiling pictures or three consecutive crying pictures and that there be no consecutive presentations of the same poser.

Procedure. Judges were tested in groups of 5 to 15 in a quiet testing room. Each judge received a copy of the test booklet, with a cover sheet that instructed him or her to indicate on an answer sheet how intense the emotional expression was for each mirror-image composite, using a 1 to 7 Likert-type scale, where 1 indicated *neutral* and 7 indicated *extremely intense* (Sackeim et al., 1978).[1] The judges proceeded at their own pace through the booklet, one page at a time without turning back or directly comparing pictures.

Results

In an important sense, both judges and infants could be considered the "subject" factor of the experimental design, and indeed the hypotheses of the study made it necessary to determine whether the results would generalize to both populations.[2] Therefore, we conducted two separate analyses of variance (ANOVAs). In the first, adult judges were treated as the "subject" factor (random effect), and the data for each judge were summarized across the infant posers within each of the two types of emotional expressions (smile vs. cry). In the second, infant posers were treated as the subject factor (random effect), and the data on each infant were summarized across adult judges. The relatively small number of infant posers makes the latter analysis quite conservative. Therefore, any significant findings in the infants analysis would indicate large effects or low variability (or both) among infants.

The significant Emotion effect indicated that crying expressions were more intense than smiling expressions, according to both the Judges ANOVA, $F(1, 44) = 99.94$, $p = .0000$, and the Infants ANOVA, $F(1, 8) = 17.14$, $p = .003$. The Hemiface effect indicated that the infants' right hemiface expressions were significantly more intense than the left hemiface expressions according to the Judges analysis, $F(1, 44) = 4.81$, $p = .034$, but this failed to reach significance in the Infants analysis. The Emotion × Hemiface interaction was significant in the Judges analysis, $F(1, 44) = 23.41$, $p = .0000$, and of borderline significance in the Infants analysis, $F(1, 8) = 4.90$, $p = .058$, so that a right hemiface bias in expressive intensity was reliably associated with smiling but not crying expressions (see Table 1).

We confirmed this pattern using a *t*-test analysis of the strength of hemiface asymmetries in individual infants (see Table 2, Column 1). All 6 of the smiling infants, but only 1 of the 4 crying infants, showed a significant individual right hemiface

[1] A judgment technique was chosen over detailed coding of expressive facial movements (e.g., FACS: Ekman & Friesen, 1978; MAX: Izard, 1979) for several reasons: Adult expressive asymmetries have often been measured by viewers' judgments about mirror-image composites. More generally, the use of viewer judgments is well established in emotion research and has greater ecological validity with respect to the potential *communicative* function of emotional asymmetries in infant–adult interactions. The construct validity of the coding schemes ultimately depends on such judgments, anyway, particularly in the case of infants who cannot verbally indicate their emotional state. Moreover, scores of emotion categories by trained coders are highly correlated with global judgments of the same photographs by untrained judges (Izard & Dougherty, 1982). Finally, existing coding schemes were not designed to detect gradations in intensity of expression in each hemiface. Appropriate modification of the coding would require extensive investigation, which might be warranted to resolve weak or equivocal judgment data. However, our judgment data yielded strong and reliable evidence of expressive asymmetries.

[2] Testing for statistical reliability across stimulus materials, and not only across traditionally defined subjects, has concerned language researchers (e.g., Clark, 1973; Coleman, 1964; Forster & Dickinson, 1976) as well as researchers in other fields such as psychophysics (e.g., Santa, Miller, & Shaw, 1979) for over two decades. The single analysis of variance (ANOVA) conducted with traditionally defined subjects as a random factor is susceptible to alpha inflation (Type I error) because of stimulus variation that is not figured into the error term. In response to this problem, alternatives to the standard F ratio have been proposed (Clark, 1973; Santa et al., 1979), which take stimulus variability as well as subject variability into account. However, computer simulations have shown these to be unnecessarily conservative, increasing Type II error (e.g., Forster & Dickinson, 1976). The most common solution has been to conduct two separate ANOVAs, one with subjects as the random factor and the other with stimuli as the random factor, and to require that significance be reached on both tests (e.g., Bock, 1986, 1987; Fowler & Housum, 1987).

Table 1
Experiment 1: Mean Intensity Ratings of Mirror-Image Hemiface Composite

Emotional expression	Hemiface Right	Hemiface Left
Smile		
M	4.41[a]	3.91
SD	.15	.12
Cry		
M	5.13	5.34
SD	.12	.12
M	4.77	4.62

[a] The emotional intensity rating scale ranged between 1 and 7 (1 = *neutral* and 7 = *extremely intense*).

bias in expressiveness. The other 3 criers showed a left hemiface bias, which was significant in two cases.

Discussion

The greater rated intensity of crying than of smiling expressions deserves comment, although intensity differences between emotions were not central to our a priori hypotheses about asymmetries in expressiveness. The greater intensity of negative expressions is consistent with reports about the relative intensity of spontaneous negative, compared with positive, expressions in adults. Moreover, ethological considerations predict that negative emotional displays should be very compelling, because such displays must influence caregivers to act quickly to remove infants from distressing situations or to reduce noxious or painful stimuli. Finally, although the display rules of our society tend to sanction against the public display of strong negative emotions by adults and older children, infants under about 1 year of age seem to be relatively uninfluenced by, or unresponsive to, such proscriptions.

The suggestion of an overall right hemiface bias in expressiveness was of more particular interest to the topic of infant emotional asymmetries. The direction of bias was exactly the opposite of that found consistently in adults (e.g., Campbell, 1978; Sackeim et al., 1978) and even children (Rubin & Rubin, 1980). Although the difference is intriguing, the right hemiface bias was significant only for judges and failed to reach significance for infants, owing to the interaction between the Emotion and Hemiface factors and probably to the small number of infant posers.

The pattern of the interaction, which was significant in both analyses, was at one level consistent with reports of valence effects on emotional asymmetries in the adult literature. That is, both for these infants and in some reports on adults, there is a greater association between expression of negative emotions and the left rather than the right hemiface, whereas there is a greater association between positive emotions and the right hemiface. The details of the interaction, however, differ between infants and adults because of their differences in overall direc-

Table 2
Hemiface Asymmetries in Individual Infants for Each Experiment

Infants	Experiment 1[a]	Experiment 2[a] (Rating test)	Experiment 2[b] (Paired choices)	Experiment 3[b] (Mouth)	Experiment 3[b] (Eyes)
Smilers					
9F2	.43**	1.81†††	.84††	.91†††	.11
9F4	.11	1.24†††	.63††	.54†	−.33†
9M4	.59***	1.09†††	.81††	.85†††	.41†
11M7	.37**	−.93†††	−.46†	−.17	−.31***
13M1	.78††	1.03†††	.75††	.19*	.15
13M4	.72***	1.81†††	.87†††	.89†††	−.04
Criers					
7F6	−1.00††	−.72††	−.30***	.30***	−.09
11M2	.87†††	.98†††	.57††	.61††	.93†††
13F5	−.09	1.88†††	.77††	.35††	−.37†
13F6	−.67†	1.26†††	.71††	.48††	.35†
RHF/N[c]	6/10	8/10**	8/10**	9/10***	3/10

Note. In the infant identification codes, the first numeral indicates age in months, and M or F indicates sex.
[a] For the intensity ratings of each mirror-image hemiface composite (Experiment 1 and Experiment 2: Rating Test), *t* tests compared ratings of the right and the left hemiface for each infant. Listed values are the difference in mean intensity between the hemiface composites for each infant (right−left); the possible range was from −6.0 to 6.0 (absolute leftward bias vs. absolute rightward bias, respectively). [b] Chi-square tests were applied for the paired-comparison choices between hemiface composites of each infant (Experiment 2: paired-choice test and Experiment 3). Values listed are the computed laterality ratios for each infant [(right − left)/(right + left)]; the range was −1.0 to 1.0 (absolute leftward bias vs. absolute rightward bias, respectively). [c] This row shows the ratio of infants with significant right hemiface bias to the total number of subjects (10), with binomial probability levels indicated.
* $p = .056$. ** $p \leq .05$. *** $p \leq .01$. † $p \leq .005$. †† $p \leq .001$. ††† $p = .0000$.

tional bias of expressive asymmetries—leftward, especially for negative expressions, in adults, but rightward, especially for smiling expressions, in infants.

Because the findings were not completely predictable from established findings with adults, and because the right hemiface bias was significant in only one analysis, we examined the infant expressive asymmetries further in a second experiment. Specifically, we wished to learn which aspects of the infant face stimuli might be primarily responsible for the effects observed in Experiment 1, and whether confining judgments of emotional expressiveness to a subset of the stimulus details might clarify the overall directional bias found in the Judges analysis or the Emotion × Hemiface interaction (or in both) found in both analyses.

Experiment 2

The aspect of expressive influence that we examined in the second experiment was the configuration of the central facial features: eyes/brows, mouth, and nose. The categorization of emotional expressions using both formal coding systems and naive observers depends heavily on differences or changes in the muscular patterning of those features as opposed to more peripheral characteristics such as face outline or hemiface width (Ekman & Friesen, 1978; Izard, 1979; Izard, Huebner, Risser, McGinnes, & Dougherty, 1980). The muscular control of the central facial features is also strongly affected by descending cortical influences (e.g., Kahn, 1964; Rinn, 1984). Thus, the configuration of these facial features is the most likely source of cerebral asymmetries effects on emotional expressions.

In order to restrict the judges' attention to the eyes/brows, mouth, and nose, we modified the original stimuli by optically digitizing them and editing out the unwanted details (e.g., face outline, hair, and cheeks) by means of computer. Because we were concerned about the potential confounding influence that the overall intensity difference between crying and smiling might have on judgments of expressive asymmetry, we included a second measure of expressive asymmetry in this experiment. A new group of adult judges rated the intensity of emotional expression for each individual mirror-image hemiface composite of the edited images, but, in addition, these judges and another new group also completed a second booklet in which the right and left hemiface composites of each infant were presented together for forced choice of the more expressive composite (happier or sadder) in each pair.

Method

Subjects. A new group of 58 familial right-handed university students (29 women and 29 men) served as judges in both tests of Experiment 2. They each received $4 for their participation in a 45-min session. An additional group of 39 high-school seniors (22 girls and 17 boys) completed only the paired-comparison test as unpaid volunteers. All had normal or corrected vision. The posers were the same 6 smiling and 4 crying infants studied in Experiment 1.

Stimuli. High-quality photocopies of the original, normal orientation photographs from Experiment 1 were digitized using an Apple Macintosh 512+ computer, using the Thunderscan optical scanner and software package. Portions of the resulting images were first manipulated with the Thunderscan program to adjust the contrast and brightness of the central facial features of each hemiface of all the infants to equivalent levels. Next, the Superpaint graphics program was used to remove the visual details of the cheeks, ears, chin, hair, and face outline. The edited image files were printed on an Apple Imagewriter printer in both normal and mirror-reversed orientation. These prints were then used to generate mirror-image composites of the left and right hemiface of each infant (see the examples in Figure 1), following the procedure described in Experiment 1. The composites were assembled into two master booklets. The intensity rating booklet was designed as in Experiment 1. Each page of the paired-comparison booklet instead contained the pair of hemiface composites for a given infant, presented one above the other with the question "Which face looks happier (sadder)?" printed across the top of the page. Thus, there were 10 pages in the paired-comparison booklet; the position of the right versus left hemiface composites on the page was counterbalanced across infant posers. A high-quality photocopier was again used to make multiple copies of each booklet.

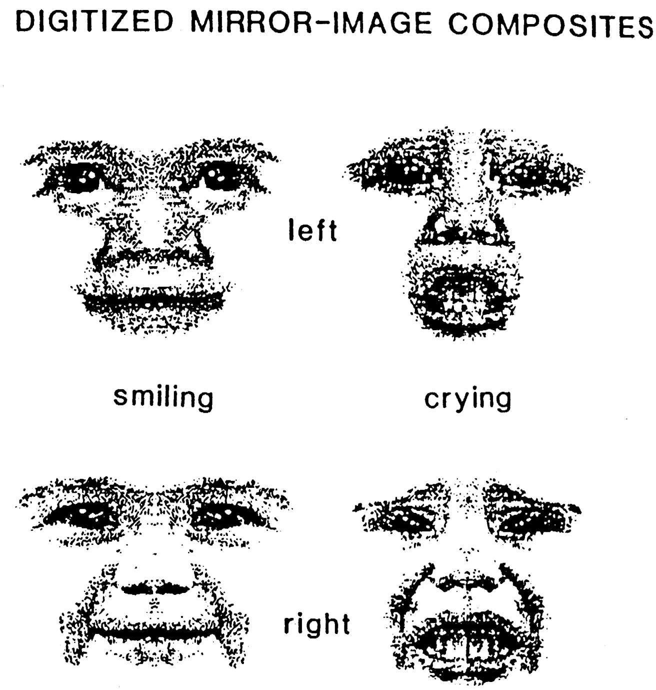

Figure 1. Examples of digitized left and right mirror-image hemiface composites of a smiling and a crying infant (Experiment 2).

Procedure. Judges were tested as in Experiment 1. The university-level judges completed the intensity rating test prior to the paired-comparison test. The high-school judges completed only the paired-comparison test.

Results

We analyzed the data for the intensity rating test as in Experiment 1. The Emotion effect was again significant. Crying expressions were more intense than smiling expressions according to both the Judges ANOVA, $F(1, 56) = 197.07$, $p = .0000$, and the Infants ANOVA, $F(1, 8) = 6.39$, $p < .04$. This time, the Hemiface effect indicated that the right hemiface bias in expressiveness was significant in both the Judges analysis, $F(1, 56) = 200.17$, $p = 0000$, and the Infants analysis, $F(1, 8) = 7.45$, $p < .026$. However, the Emotion × Hemiface interaction failed to reach

Table 3
Experiment 2: Mean Intensity Ratings of Mirror-Image Hemiface Composites

Emotional expression	Hemiface Right	Hemiface Left
Smile		
M	3.12[a]	1.77
SD	.11	.11
Cry		
M	4.66	3.50
SD	.12	.11
M	3.89	2.64

[a] Emotional intensity rating scale ranged between 1 and 7 (1 = *neutral* and 7 = *extremely intense*).

significance in either analysis of the intensity rating data in Experiment 2. The means are shown in Table 3, and the asymmetry scores for individual infants are shown in Column 2 of Table 2. This time, 3 of the 4 crying infants (all except 7F6) and 5 of the 6 smiling infants (all except 11M7) showed a significant right hemiface bias in expressiveness, for a total of 8 out of 10 of the sample, which differs significantly from the prediction of a left hemiface bias, as found in adults, according to binomial test ($p < .05$, one-tailed).

The data from the paired-comparison test allowed for assessment of *relative* degrees of expressive asymmetry in each infant poser, presumably unconfounded by overall differences in intensity of expressions between emotions and among infants. Mean laterality ratios were computed from these data according to the following formula: $[(R - L)/(R + L)]$, where R is the percentage of choices of the right hemiface as more emotional, L is the percentage of left hemiface choices, and R + L represents 100%.[3] Possible values range from -1.0 to 1.0 (absolute left vs. absolute right hemiface bias, respectively). These laterality ratios were averaged across infant posers within each emotion category for each judge in order to conduct the Judges ANOVA, but they were reaveraged across judges for each infant poser in order to conduct the Infants ANOVA. The Emotion effect, which indicated larger laterality ratios (greater right hemiface bias) for smiling expressions (.58) than for crying expressions (.44), was significant in the Judges analysis, $F(1, 95) = 7.96$, $p = .006$, but not in the Infants analysis. Because the laterality ratio reflects hemiface differences as a single score, these ANOVAs did not contain a Hemiface factor. Therefore, the direction and degree of hemiface asymmetry were assessed using *t* tests of the actual laterality ratios against the null hypothesis of no asymmetry (laterality ratio = 0). There was a significant right hemiface bias, according to both the Judges analysis, $t(96) = 16.86$, $p = .0000$, and the Infants analysis, $t(9) = 3.39$, $p < .008$.

The mean laterality scores for the individual infants are shown in Column 3 of Table 2. The statistical reliability of these individual scores was tested using chi-square analyses, which yielded exactly the same pattern as had been found in the *t*-test analyses of individual infants' asymmetries in intensity ratings.

To determine whether the pairwise "happier/sadder" judgments were influenced by stimulus variations in overall expressive intensity, the laterality ratios for each infant poser from the paired-comparison test were correlated with the mean of the intensity ratings of the two hemifaces for each infant from the intensity rating test. The relation was nonsignificant ($r = .26$). Because asymmetries in hemiface width might also affect expressive asymmetries by means of hemiface differences in muscle mass or extent of possible facial feature movement (Ekman, 1980; Nelson & Horowitz, 1980; but cf. Borod & Koff, 1983; Borod et al., 1983; Sackeim & Gur, 1980), we also assessed hemiface width in the original photographs from Experiment 1 by measuring the distance from the point midway between the internal canthi of the eyes to the point on each temple where the top of the ear connects. Although there was a nonsignificant trend for a wider right than left hemiface in the infants, $t(9) = 1.176$, $p > .10$, consistent with the significant rightward bias in hemiface width found among adults (e.g., Koff et al., 1981), the infants' hemiface width differences did not correlate significantly with their laterality ratios ($r = .45$). Finally, to assess whether brightness differences between the right and left hemifaces may have influenced the laterality ratio, we asked 10 additional adult subjects (3 women and 7 men) to choose the brighter-appearing composite of each pair from the paired-comparison test and to rate the degree of difference in brightness on a 5-point scale between *slight* and *extreme*. Although the right hemiface was rated to be *somewhat* to *moderately* brighter than the left, $t(9) = 10.81$, $p < .001$, brightness differences did not correlate significantly with laterality ratios ($r = -.19$). Composite scores were also computed as the mean of the *z* scores for the intensity, width, and brightness measures; again, these failed to correlate significantly with the laterality ratios ($r = -.37$).

Discussion

The removal of facial information other than the central features in Experiment 2 had several important effects on the pattern of expressive asymmetries detected in the infants. First, the overall right hemiface bias in intensity of expression was strengthened, now reaching significance on both the analyses conducted with judges and those with infants treated as subjects. This rightward bias emerged both in the data on absolute intensity ratings of the composites and in the paired-comparison judgments of relative expressiveness of the hemifaces in each infant. Second, the influence of emotional valence (smile or cry) on expressive asymmetry was attenuated and only reached significance for the Judges analysis of the paired-comparison data. Thus, the findings of Experiment 2 suggest that the right hemiface bias is attributable to the expressive patterning of the central facial features themselves rather than to other, more peripheral characteristics of the faces, such as facial outline or asymmetries in hemiface width. This interpretation is strengthened by the lack of significant correlation between laterality ratios in the paired-comparison test and various mea-

[3] Performance level corrections such as the Phi coefficient (Kuhn, 1973) or lambda (Bryden & Sprott, 1981) do not apply to binary forced-choice data such as these.

sures of other, potentially confounding facial properties (differences in overall emotional intensity and asymmetries in hemiface width or brightness).

A comparison of the results from Experiments 1 and 2 also suggests that the influence of emotional valence on expressive asymmetry that was found in the former study is not reliably associated with the configuration of the facial features, but may instead be traceable to aspects of the peripheral facial information that were eliminated in the digitized, edited versions of the faces. Indeed, the stimulus manipulations for Experiment 2 appear to have reduced the perceived intensity of the emotional expressions overall (compare, for example, the mean intensity ratings shown in Tables 1 and 3). However, it should be recalled that there were only 4 crying and 6 smiling infants, providing a very conservative test of generalizability to the infant population in the infants-as-subjects analyses. Although this consideration underscores the strength of the significant right hemiface bias, it may well have obscured a real influence of emotional valence on the degree of expressive asymmetry. A larger sample, particularly in a within-subjects design, might yield a reliable Emotion × Hemiface interaction.

Although restricting judgments of emotional intensity to the central facial features clarified the direction and strength of the infants' expressive asymmetry and indicated that it was not associated with peripheral characteristics of the faces, the source of the effect within the nervous system remained unclear. Experiment 3 addressed this issue by taking advantage of differences in the pattern of ipsilateral versus contralateral cortical influences on movements of the muscles of facial expression in the upper and lower portions of the face.

Experiment 3

The facial nerve, which is the final common pathway for control of the facial expressive muscles, has two major divisions on each side of the face. The temporofacial division serves the upper part of the face, including the muscles around the eyelids, the eyebrows, and the forehead. The cervicofacial division serves the lower face, including the muscles around the mouth, the chin, and the lower cheeks (Rinn, 1984). The lower part of the face is more heavily represented on the motor strip in the frontal cortex than is the upper face and shows a greater degree of fine motor control, including greater bilateral independence of movements. Differences in the pattern of descending cortical influence on the upper and lower divisions of the facial nerve were of particular interest in Experiment 3. The cortical input to the lower division is contralateral, whereas the input to the upper division is bilateral, arising from both cerebral hemispheres. Therefore, if lateralized cortical contributions are responsible for the right hemiface bias, the lower face should display a more consistent expressive asymmetry than does the upper face. To test this hypothesis, we made further modifications of the digitized images of the infant faces, which were used to develop an "upper face" test and a "lower face" test similar to the paired-comparison test of Experiment 2.

Method

Subjects. A new group of 54 familial right-handed university students (27 women and 27 men) served as judges. They received $4 for participating in a 45-min session.

Stimuli. The digitized, edited faces developed for Experiment 2 were further revised for the present study. For the upper-face test, all facial features other than the eyes, brows, and bridge of the nose were removed from the digitized faces. For the lower-face test, all features except the mouth and the tip of the nose were eliminated (see Figure 2). Separate mirror-image composites were generated for the eyes/brows and for the mouth, following the procedures described in the first two experiments (eyes/brows and mouth regions were not physically separated until after the faces had been cut down the exact midline). Two master paired-comparison test booklets were constructed, each designed as in the second test of Experiment 2. As before, high-quality photocopies of these booklets were made for the judges.

Procedure. The judges were tested as in the first two experiments; each judge completed both booklets. All judges completed the lower-face test first and the upper-face test second, because pilot testing had indicated that forced-choice judgments about the eyes/brows would be more difficult. This order allowed greater practice with the procedure prior to the more difficult test. Thus, it would most likely have biased *against* the predicted pattern of greater asymmetry for the mouth than for the eye region, because the judges would have become more sensitized to any available expressive intensity differences between paired images during the second test than during the first. As in the paired-comparison test of Experiment 2, the judges indicated which member of each pair of composites was happier or sadder.

Results

The data were converted to laterality ratios and analyzed as in the second test of Experiment 2. As predicted, the significant Face Part effect indicated that there was a stronger rightward bias in expressiveness for the mouth region than for the eyes/brows of the faces in both the Judges analysis, $F(1, 52) = 74.94$, $p = .0000$, and the Infants analysis, $F(1, 8) = 8.38$, $p < .02$. In fact, in the t tests that were conducted to determine whether the laterality ratio across the 10 infants was different from zero, a significant rightward bias was found only for the mouth region, $t(9) = 4.67$, $p < .0012$ (see Table 4). The Emotion effect, which indicated that there was a larger rightward bias for smiling than for crying expressions, was significant only in the Judges analysis, $F(1, 52) = 13.07$, $p = .0007$.

The mean laterality ratios and chi-square tests for the individual infants are shown in Columns 4 and 5 of Table 2. Note that, whereas only 3 out of 10 infants showed a significant right hemiface bias in the eyes/brows region, 9 out of 10 showed a rightward bias in the mouth region; the data for the mouth region differ significantly from the adult-based prediction of leftward bias according to binomial test ($p < .01$, one-tailed). The one crying infant (7F6) who had shown a leftward bias on previous tests instead showed a rightward bias on the mouth test, and the one smiling infant (11M7) who had shown significant leftward bias previously now showed a nonsignificant leftward bias on the mouth test.

Discussion

Because of the difference in contralateral versus bilateral innervation of the lower and upper face, respectively, the results of Experiment 3 suggest that the right hemiface bias in infant expressiveness is attributable to asymmetrical cortical influences. It appears not to be accounted for simply by subcortical or peripheral factors. Moreover, it is noteworthy that the num-

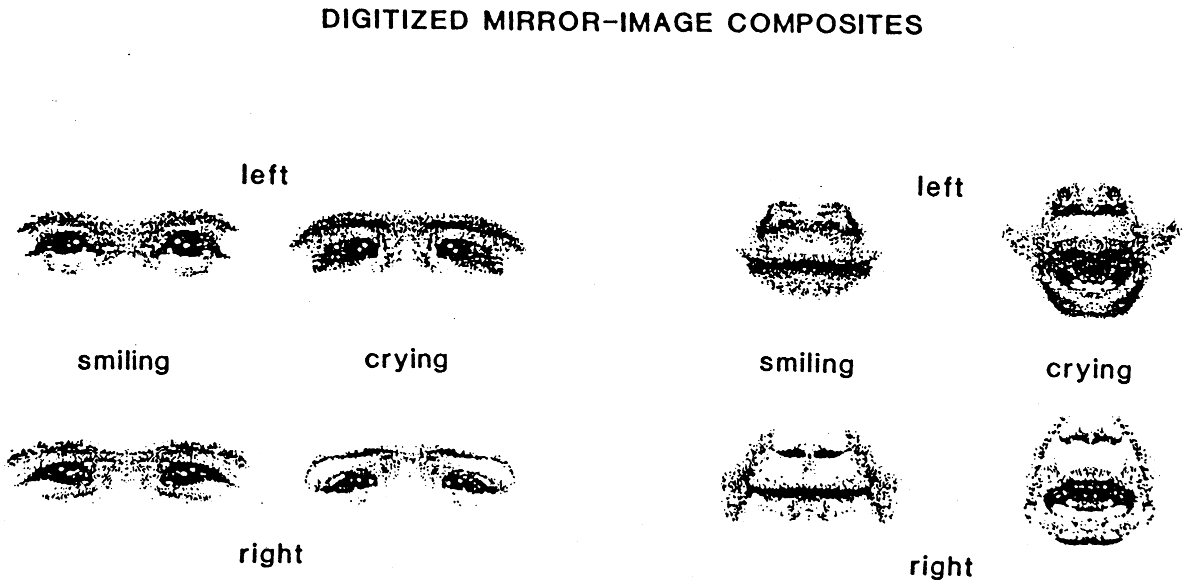

Figure 2. Examples of digitized left and right mirror-image hemiface composites of the mouth region and the eye region of a smiling and a crying infant (Experiment 3).

ber of individual infants who showed a significant rightward bias was larger for the mouth test than for any previous tests with the same infants (see Table 2). As the focus on specific regions of facial information was progressively narrowed across the three experiments, the number of infants showing a significant right hemiface bias increased. Thus, the effect seems to reside in the actual expressive patterning of the facial features, especially the mouth, rather than in more peripheral influences.

In order to generalize the findings, given our relatively small sample of infant posers, we replicated Experiments 3 and 4 with a new group of 12 smiling infants photographed under the same conditions as before.

Experiment 4

In this final study, judges were asked to complete the following three separate tests with the new set of infant smiling expressions: (a) pairwise comparisons of mirror-image hemiface composites of the full faces, (b) mirror-image composites of the eye regions of those faces, and (c) mirror-image composites of the mouth regions. The photographs for this experiment were taken from an expanded set of infants ranging between 3 and 13 months of age (again provided by Hildebrandt) and were selected using the same criteria as used for the original posers (except the requirement for a neutral-expression photograph). We selected only smiling infants for the final study because there were no additional crying infant photographs in Hildebrandt's collection and because we had found no reliable valence effect on expressive asymmetries among the individual infants. Note that 6 of the infants who met the selection requirements for this replication were younger than the youngest infant in Experiments 1 to 3. Restricting the age range to 7 to 13 months, as before, would have resulted in an unsatisfactorily small sample for the replication.

Table 4
Experiment 3: Laterality Ratios for Paired-Comparison Choices of Mirror-Image Hemiface Composites of Mouth Versus Eye Regions

Emotional expression	Mouth	Eyes/brows
Smile		
M	.53[a]	−.009
SD	.033	−.033
Cry		
M	.44*	.22*
SD	.052	.044
M	.106	.485*

[a] Laterality ratio = (right − left)/(right + left).
* $p = .0000$.

Method

Subjects. A new group of 20 right-handed university students (8 men and 12 women) served as judges. They received $4 for participation in a 30-min session.

Stimuli. The new set of 12 infant smiling expressions was digitized and edited as in Experiment 2. The resulting images were used to construct mirror-image composites for the full-face test as before. The images were then further revised as in Experiment 3 for the upper-face and lower-face tests. Mirror-image composites were also constructed for these last two tests.

Procedure. The judges were tested as in Experiments 2 and 3. All judges completed the full-face, upper-face, and lower-face tests in a single booklet. However, test order was counterbalanced across judges in three test booklets differing in order of presentation of the individual tests.

Results and Discussion

The data were converted to laterality ratios as in the second test of Experiment 2 and in Experiment 3. For the Infants analyses, the new data were tested alone to assess replication of the previous findings. They were also added to the data from the original 6 smiling infant posers and reanalyzed to assess the generalizability of results from the entire sample of smiling infants ($N = 18$).

Judges: Full-face test. Because there were only smiling expressions in this experiment, the only statistical test needed was a t test of whether the laterality ratios for the judgments of the new infants were significantly different from zero. As in the previous experiments, there was a significant right hemiface bias in the new smiling expressions, $t(19) = 3.09, p < .003$.

Judges: Comparison of upper- and lower-face tests. A paired-comparison t test on laterality ratios for the upper- and the lower-face tests indicated that the rightward bias was significantly stronger for the mouth region than for the eye region, as in Experiment 3, $t(19) = -3.332, p < .002$. The laterality ratios showed a significant right hemiface bias for both the upper-face test, $t(19) = 2.37, p < .02$, and for the lower-face test, $t(19) = 7.122, p < .0001$.

Infants: Full-face test. The rightward bias for the total sample of 18 smiling infants was significant, $t(17) = 2.832, p = <.006$; this effect was marginal for the new sample of infants alone, $t(11) = 1.618, p < .067$. Of the new posers, 8 out of 12 showed a rightward bias; in the previous sample, 5 out of 6 of the smiling infants had shown a rightward bias. The weaker effect in the new sample may be associated with infants who were 7 months or younger. Whereas none of the smiling infants from the original sample were under 9 months of age, the new sample included 8 infants between 3 and 7 months of age. Only 5 out of 8 of these younger infants showed a rightward bias in expressiveness. This young subgroup failed to show a significant rightward bias overall according to a t test. Four infants from the new sample were older than 7 months, and 3 of these showed a right hemiface bias. This older subgroup from the new sample also failed to show a significant rightward bias in a t test, but this is not surprising given the small sample size. When all smiling infants over 7 months of age were considered across both samples, 8 out of 10 showed a rightward bias in expressiveness. The rightward bias in older infants from both samples was significant in a t test, $t(9) = 2.83, p < .02$.

Infants: Comparison of upper- and lower-face tests. Only the lower-face test yielded a significant right hemiface bias in expressiveness in the total sample, $t(17) = 2.862, p < .006$, as well as the new sample, $t(11) = 2.27, p < .02$. Paired-comparison tests of the difference in laterality ratios between the upper and the lower face revealed that the rightward bias was significantly larger for the mouth than for the eye region in the total sample, $t(17) = 2.528, p < .01$, and in the new sample alone, $t(11) = 1.883, p < .04$.

Thus, the results of this experiment extended the findings of Experiments 2 and 3 with a new set of smiling infants. The right hemiface bias in infant expressiveness, particularly for the lower portion of the face, was corroborated, especially by infants over 7 months of age. The lower rate of occurrence of rightward bias among younger infants suggests the possibility that the factors responsible for the expressive bias do not exert their full influence until sometime after 7 months.

General Discussion

The experiments revealed a pattern of infant hemiface expressive asymmetry that is seemingly at odds with predictions from current adult-based models of emotional asymmetries. The infants' right hemiface bias resides in the actual expressive configuration of the central facial features, rather than in more peripheral aspects of the face. It most likely reflects asymmetrical cortical control of the facial features, given that it was significant only for the contralaterally innervated lower portion of the face and that the degree of asymmetry failed to correlate with other potentially influential properties of the digitized composites used in Experiment 2. This finding of rightward bias appears to be quite robust. It was significant in the Infants analyses of Experiments 1 through 3 even though only 10 infants were used. Eight of those infants showed a significant individual right hemiface bias in the patterning of their central facial features (Experiment 2), and 9 showed the rightward bias in their mouth region (Experiment 3). Moreover, the pattern was corroborated using an additional sample of smiling infants in Experiment 4, particularly by those infants who were older than 7 months.

It is conceivable, although unlikely, that the generality of these results may be restricted to relatively emotionally labile infants, because our selection criteria for the stimuli used in Experiments 1 to 3 required that infant posers provide both an emotional and a neutral expression during a single photography session. These infants probably do not represent extreme lability, however, because none of them produced the full gamut of negative to positive expressions during the photography session (Hildebrandt, personal communication, January 1985). Indeed, normal 7- to 13-month-old infants (the age range tested in the first three studies) often do show fairly rapid shifts in mood during a short time span; they do not typically show long, deliberately sustained emotional states (Sroufe, 1979). Furthermore, the independent ratings of positive or negative expressions (Hildebrandt, 1983) that we used in choosing our infant posers are unlikely to have artifactually selected for *right* hemiface bias. Rather, the well-established left-visual-field advantage in adults' perception of emotional expressions (Heller & Levy, 1981; Levy, Heller, Banich, & Burton, 1983) should lead to the opposite bias. Because the infant poser's left hemiface would fall in the viewer's less sensitive right visual field, the left hemiface expressions would have to be physically more intense than those of the right hemiface in order to be *perceived* as equally intense. Such concerns about sampling bias are further mitigated by the results of Experiment 4, in which the posers were required to provide only a smiling expression, and by a recent independent corroboration of the right hemiface effect in a sample of 59 infants videotaped at 6.5, 10.5, and 13.5 months of age (Rothbart, Taylor, & Tucker, in press). In that study, coders first identified all asymmetrical smiles and distress expressions on the videotapes, and then trained observers recoded each of those expressions as to the direction of asymmetrical bias. Similarly, a right hemiface bias was also found in unpublished dissertation research using the mirror-image composite technique with positive and negative expressions of newborns and 3-month-olds (Weber, 1983).

It should also be noted that, although we did not observe reliable valence effects in hemiface expressive bias, some views about the influence of emotional valence predict that the pattern of observed asymmetries should be affected by the properties of the negative and positive expressions tested (e.g., Davidson, 1984; Fox & Davidson, 1987). If, as Davidson (1984) proposed, the left hemisphere is specialized for approach responses and the right for withdrawal, we would expect differences in expressive asymmetries for smiles or cries that reflect different balances of approach–avoidance. For example, Fox and Davidson (1988) found opposite patterns of EEG asymmetry in infants displaying genuine or "felt" smiles and cries, as compared with those showing masked or "unfelt" smiles and cries. According to the Fox and Davidson criteria, all four cries and 14 of the 18 smiles from the total sample used in Experiments 1 to 4 were "felt." We found no obvious relationship between these ratings and the laterality ratios for the facial expressions, but this may be because of the very small number of "unfelt" smiles (4 subjects) and cries (no subjects) in our sample. The issues raised by Fox and Davidson are interesting and important, nevertheless, and deserve systematic study with respect to expressive asymmetries in future research.

As for the present findings, two explanations of the infant right hemiface bias can be offered, although we believe one to be more promising than the other. On the one hand, the direction of the asymmetry may suggest greater left than right hemisphere activation during infants' facial expressions, in line with proposals for a left-to-right gradient in the development of cortical maturation (e.g., Corballis & Morgan, 1978). However, recent anatomical, physiological, and behavioral data argue instead for a right-to-left developmental gradient (Best, 1988; Crowell et al., 1973; Chi et al., 1977; Tucker, 1986; Whitaker, 1978). More important, given the clinical and normative evidence of greater right hemisphere involvement in adults' expressions, a left hemisphere activational bias in infants' expressions would require a developmental shift of control from the left to the right hemisphere at some point between infancy and adulthood. Although asymmetries may be lacking in some higher cognitive abilities until those abilities become functional ontogenetically (Levine, 1985; Witelson, 1985), no reversals in hemispheric superiority for any given ability during normal development have been proposed or observed.

We propose an alternative explanation, drawing from research and theory on neurobehavioral development during infancy: The infant right hemiface bias actually reflects inhibition of subcortically mediated influences on the left hemiface. According to McGraw's (1943) well-known model of the gradual corticalization of motoric behavior during infancy, subcortical mechanisms are responsible for the reflexive and spontaneous behaviors typically observed in newborns, such as the stepping, Babinski, and Moro reflexes, as well as the spontaneous facial movements and postural biases that are observed in awake newborns. McGraw proposed that as the neocortex begins to mature functionally, its initial influence is to inhibit lower neural centers, hence the disappearance of neonatal reflexive and spontaneous behavior patterns. For example, the neonatal reflexive head-turn toward a continuous laterally placed sound disappears by about the second month (Clifton et al., 1981). Only later does the cortex mature sufficiently to actively guide voluntary behavior. In the example of sound-elicited head-turns, voluntary head-turning toward sounds (now including brief-duration sounds) reappears around 5 months of age.

Our novel proposal, then, is that there is earlier maturation of right hemisphere inhibition over subcortically mediated emotional expressions in infancy, once cortical influences over this behavior come into play. Our findings from Experiment 4 suggest that this cortical inhibitory influence may be particularly evident after 7 months of age. Indeed, there should be an earlier-appearing right hemisphere inhibition of reflexive and nonvoluntary spontaneous left-sided movements in general. This proposal is compatible with widespread observations of rightward biases in neonatal motoric behaviors, such as the stepping reflex (Peters & Petrie, 1979), reflexive tongue movements (Weiffenbach, 1972), spontaneous and reflexive manual behaviors (Caplan & Kinsbourne, 1976; Cobb, Goodwin, & Saelens, 1966), and spontaneous postural asymmetries (Michel & Goodwin, 1979; Turkewitz & Creighton, 1974), that may be related to the development of hand preferences (Coryell & Michel, 1978; Liederman & Coryell, 1981; Liederman & Kinsbourne, 1980), as well as with observations of rightward biases in responsiveness to sensory stimulation (Hammer & Turkewitz, 1974; Harris & MacFarlane, 1974; Reiser, Yonas, & Wikner, 1976; Turkewitz, Birch, Moreau, Levy, & Cornwell, 1966). We suggest that these rightward-biased behaviors indicate greater inhibition, by the more mature right hemisphere, of the subcortically mediated movement patterns on the left side of the body, although it has sometimes been inferred that those behavioral asymmetries may reflect *left* hemisphere specialization. A right-to-left gradient in corticalization should also imply earlier appearance of certain more mature or voluntary forms of behavior on the left than on the right side, under right hemisphere *activation*, which has indeed been shown by McDonnell, Anderson, and Abraham (1983) for young infants' hand movements in response to visual targets. Those authors found that 3- to 8-week-old infants' left-hand movements were more frequent, more appropriately oriented, and farther extended toward the target than were their right-hand movements.

The timing of developing cortical influence over various behaviors would depend, of course, on the differential maturation of specific brain areas, including the commissural pathways. The frontal cortex, the substrate for voluntary control of facial expressions (Kahn, 1964; Monrad-Krohn, 1924; Rinn, 1984), begins to mature functionally during the last quarter of the first year, an age range covered in the present research. Growing frontal influence should initially inhibit contralateral subcortical extrapyramidally mediated (i.e., limbic system) spontaneous expressions. The maturing corpus callosum would also allow for inhibition between the hemispheres. These suggestions are congruous with proposals that asymmetries in adult emotional expressions may reflect not only right hemisphere voluntary control of the left hemiface, but also *left* frontal inhibition of the right hemiface (Gainotti, 1984; Rinn, 1984; Tucker, 1986; Tucker & Frederick, in press), which according to the proposal offered here is a vestige of the developmental right-to-left gradient in maturation of cortical control.

Further research could determine the ontogenetic pattern of the transition from inhibition of spontaneous expressions to active, voluntary production of expressions, which should coincide with a gradual shift from a right to a left hemiface bias. This shift should be related to the emergence of deliberate simulation and masking of emotions during the preschool years and should correspond to the fuller maturation of the frontal cortex and the corpus callosum that is taking place during that time

(Brodal, 1969; McGraw, 1943). The left hemiface bias appears to be present by 6 to 8 years of age (Rubin & Rubin, 1980), but there may be an inconsistent right hemiface bias at 2 to 3 years (Moscovitch, Strauss, & Olds, 1980), supporting the possibility that the preschool years are the period of transition in direction of hemiface asymmetry.

Finally, the infants' right hemiface bias, in combination with adults' *left* visual field superiority for perception of emotions (Heller & Levy, 1981; Levy et al., 1983), may contribute to ethological observations that adults show greater emotional responsiveness to pictures of infant facial expressions than to those of unknown adults (e.g., Lorenz, 1935). In *en face* interactions, the right hemiface falls in the viewer's more sensitive left visual field. Whereas the right hemiface is less expressive in adults, it is the more expressive side in infants. The hemiface–hemifield convergence during social interactions with infants should accentuate the viewer's empathic response toward infants relative to their response toward other adults.

References

Ahern, G. L., & Schwartz, G. E. (1979). Differential lateralization for positive versus negative emotion. *Neuropsychologia, 17,* 693–698.

Best, C. T. (1988). The emergence of cerebral asymmetries in early human development: A literature review and a neuroembryological model. In S. Segalowitz, & D. L. Molfese (Eds.), *Developmental implications of brain lateralization* (pp. 5–34). New York: Guilford Press.

Bever, T. G. (1978). Broca and Lashley were right: Cerebral dominance is an accident of growth. In D. Caplan (Ed.), *Biological studies of mental processes* (pp. 186–230). Cambridge, MA: MIT Press.

Bock, J. K. (1986). Syntactic persistence in language production. *Cognitive Psychology, 18,* 355–387.

Bock, J. K. (1987). An effect of the accessibility of word forms on sentence structures. *Journal of Memory and Language, 26,* 119–137.

Borod, J. C., & Koff, E. (1983). Hemiface mobility and facial expression asymmetry. *Cortex, 19,* 327–332.

Borod, J. C., Koff, E., Lorch, M. P., & Nicholas, M. (1986). The expression and perception of facial emotion in brain-damaged patients. *Neuropsychologia, 24,* 169–180.

Borod, J. C., Koff, E., & White, B. (1983). Facial asymmetry in posed and spontaneous expressions of emotion. *Brain and Cognition, 2,* 165–175.

Bowlby, J. (1969). *Attachment and loss* (Vol. 1). New York: Basic Books.

Broca, P. (1865). Sur la faculté du langage articulé [Concerning the faculty of articulated language]. *Bulletin of Social Anthropology, 6,* 493–494.

Brodal, A. (1969). *Neurological anatomy: In relation to clinical medicine.* New York: Oxford University Press.

Bruyer, R. (1981). Asymmetry of facial expression in brain-damaged subjects. *Neuropsychologia, 19,* 615–624.

Bryden, M. P., & Sprott, D. A. (1981). Statistical determination of degree of laterality. *Neuropsychologia, 19,* 571–581.

Buck, R. (1986). The psychology of emotion. In J. E. LeDoux & W. Hirst (Eds.), *Mind and brain: Dialogues in cognitive neuroscience* (pp. 275–300). London: Cambridge University Press.

Buck, R., & Duffy, J. (1980). Nonverbal communication of affect in brain-damaged patients. *Cortex, 16,* 351–362.

Cacioppo, J. T., & Petty, R. E. (1981). Lateral asymmetry in the expression of cognition and emotion. *Journal of Experimental Psychology: Human Perception and Performance, 7,* 333–342.

Campbell, R. (1978). Asymmetries in interpreting and expressing a posed facial expression. *Cortex, 19,* 327–342.

Campos, J. J., Barrett, K. C., Lamb, M. E., Goldsmith, H. H., & Stenberg, C. (1983). Socioemotional development. In P. H. Mussen (Series Ed.), M. M. Haith & J. J. Campos (Vol. Eds.), *Handbook of child development: Vol. 2. Infancy and developmental psychobiology* (pp. 784–915). New York: Wiley.

Caplan, P. J., & Kinsbourne, M. (1976). Baby drops the rattle: Asymmetry of grasp duration by infants. *Child Development, 47,* 532–534.

Chaurasia, B. D., & Goswami, H. K. (1975). Functional asymmetry in the face. *Acta Anatomica, 91,* 154–160.

Chi, F. G., Dooling, E. C., & Gilles, F. H. (1977). Left–right asymmetries of the temporal speech areas of the human fetus. *Archives of Neurology, 34,* 346–348.

Clark, H. (1973). The language-as-fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior, 12,* 335–359.

Clifton, R. K., Morrongiello, B. A., Kulig, J. W., & Dowd, J. M. (1981). Developmental changes in auditory localization in infancy. In R. N. Aslin, J. R. Alberts, & M. R. Peterson (Eds.), *Development of perception: Psychobiological perspectives* (Vol. 1, pp. 141–160). New York: Academic Press.

Cobb, K., Goodwin, R., & Saelens, E. (1966). Spontaneous hand positions of newborn infants. *Journal of Genetic Psychology, 108,* 225–237.

Coleman, E. B. (1964). Generalizing to a language population. *Psychological Reports, 14,* 219–226.

Corballis, M. C., & Morgan, M. J. (1978). On the biological basis of human laterality: I. Evidence for a maturational left–right gradient. *Behavioral and Brain Sciences, 2,* 261–267.

Coryell, J., & Michel, G. (1978). How supine postural preferences in infants can contribute to the development of handedness. *Infant Behavior and Development, 1,* 245–257.

Crockett, H. G., & Estridge, N. M. (1951). Cerebral hemispherectomy. *Bulletin of the Los Angeles Neurological Society, 16,* 71–87.

Crowell, D. H., Jones, R. H., Kapuniai, L. E., & Nakagawa, J. K. (1973). Unilateral cortical activity in human newborns: An index of early cerebral dominance? *Science, 180,* 205–208.

Darwin, C. R. (1965). *Expression of the emotions in man and animals.* Chicago: University of Chicago Press. (Original work published 1872)

Davidson, R. J. (1984). Affect, cognition, and hemispheric specialization. In C. E. Izard, J. Kagan, & R. Zajonc (Eds.), *Emotion, cognition and behavior* (pp. 320–365). New York: Cambridge University Press.

Davidson, R. J., & Fox, N. A. (1982). Asymmetrical brain activity discriminates between positive and negative affective stimuli in human infants. *Science, 218,* 1235–1237.

Dopson, W. G., Beckwith, B. E., Tucker, D. M., & Bullard-Bates, P. C. (1984). Asymmetry of facial expression in spontaneous emotion. *Cortex, 20,* 243–251.

Eibl-Eibesfeldt, I. (1972). Similarities and differences between cultures in expressive movements. In R. A. Hinde (Ed.), *Nonverbal communication* (pp. 297–312). Cambridge, England: Cambridge University Press.

Ekman, P. (1972). Universals and cultural differences in facial expressions of emotion. *Nebraska Symposium on Motivation* (pp. 207–283). Lincoln: University of Nebraska Press.

Ekman, P. (1973). Cross-cultural studies of facial expression. In P. Ekman (Ed.), *Darwin and facial expression* (pp. 169–229). New York: Academic Press.

Ekman, P. (1980). Asymmetry in facial expression. *Science, 209,* 833–834.

Ekman, P., & Freisen, W. V. (1978). *Facial action coding system.* Palo Alto, CA: Consulting Psychologists Press.

Ekman, P., Hager, J. C., & Friesen, W. V. (1981). Symmetry and the nature of facial action. *Psychophysiology, 18,* 101–106.

Forster, K. I., & Dickinson, R. G. (1976). More on the language-as-fixed-effect fallacy: Monte Carlo estimates of error rates for F_1, F_2, and min F'. *Journal of Verbal Learning and Verbal Behavior, 15*, 135–142.

Fowler, C. A., & Housum, J. (1987). Talkers' signaling of "new" and "old" words in speech and listeners' perception and use of the distinction. *Journal of Memory and Language, 26*, 489–504.

Fox, N. A., & Davidson, R. J. (1986). Taste-elicited changes in facial signs of emotion and the asymmetry of brain electrical activity in newborn infants. *Neuropsychologia, 24*, 417–422.

Fox, N. A., & Davidson, R. J. (1987). Electroencephalogram asymmetry in response to the approach of a stranger and maternal separation in 10-month-old infants. *Developmental Psychology, 23*, 233–240.

Fox, N. A., & Davidson, R. J. (1988). Patterns of brain electrical activity during facial signs of emotion in 10-month-old infants. *Developmental Psychology, 24*, 230–236.

Gainotti, G. (1984). Some methodological problems in the study of the relationships between emotions and cerebral dominance. *Journal of Clinical Neuropsychology, 6*, 111–121.

Gatz, A. J. (1970). *Manter's essentials of clinical neuroanatomy and neurophysiology.* Philadelphia: Davis.

Hager, J. C., & Ekman, P. (1985). The asymmetry of facial actions is inconsistent with models of hemispheric specialization. *Psychophysiology, 22*, 307–318.

Hammer, M., & Turkewitz, G. (1974). A sensory basis for lateral difference in the newborn infant's response to somesthetic stimulation. *Journal of Experimental Child Psychology, 18*, 304–312.

Harris, P., & McFarlane, A. (1974). The growth of the effective visual field from birth to seven weeks. *Journal of Experimental Child Psychology, 18*, 340–349.

Heller, W., & Levy, J. (1981). Perception and expression of emotion in right-handers and left-handers. *Neuropsychologia, 19*, 263–272.

Hildebrandt, K. A. (1983). Effect of facial expression variations on ratings of infants' physical attractiveness. *Developmental Psychology, 19*, 414–417.

Hildebrandt, K. A., & Fitzgerald, H. E. (1978). Adults' responses to infants varying in perceived cuteness. *Behavioural Processes, 3*, 159–172.

Hildebrandt, K. A., & Fitzgerald, H. E. (1979). Adults' perceptions of infant sex and cuteness. *Sex Roles, 5*, 471–481.

Hildebrandt, K. A., & Fitzgerald, H. E. (1981). Mothers' responses to infant physical appearance. *Infant Mental Health Journal, 2*, 56–61.

Izard, C. (1978). On the ontogenesis of emotions and emotion-cognition relationships in infancy. In M. Lewis & L. A. Rosenblum (Eds.), *The development of affect* (pp. 389–413). New York: Plenum Press.

Izard, C. (1979). *The maximally discriminative facial movement coding system.* Newark: University of Delaware Press.

Izard, C., & Dougherty, L. M. (1982). Two complementary systems for measuring facial expressions in infants and children. In C. E. Izard (Ed.), *Measuring emotion in infants and children* (pp. 97–126). Cambridge, England: Cambridge University Press.

Izard, C., Huebner, R. R., Risser, D., McGinnes, G. C., & Dougherty, L. M. (1980). The young infant's ability to produce discrete emotional expressions. *Developmental Psychology, 16*, 132–140.

Kahn, E. A. (1964). On facial expression. In *Clinical neurosurgery: Proceedings of the Congress of Neurological Surgeons* (pp. 9–22). Baltimore, MD: Williams & Wilkins.

Kaye, K. (1982). *The mental and social life of babies.* Chicago: University of Chicago Press.

Koff, E., Borod, J. C., & White, B. (1981). Asymmetries for hemiface size and mobility. *Neuropsychologia, 19*, 825–830.

Kolb, B., & Milner, B. (1981a). Performance of complex arm and facial movements after focal brain lesions. *Neuropsychologia, 19*, 491–501.

Kolb, B., & Milner, B. (1981b). Observations of spontaneous facial expression after focal cerebral excisions and after intracarotid injection of sodium amytal. *Neuropsychologia, 19*, 505–514.

Kuhn, G. M. (1973). The Phi coefficient as an index of ear differences in dichotic listening. *Cortex, 9*, 447–457.

Kuypers, H. G. J. M. (1958). Cortico bulbar connections to the pons and lower brain stem in man. *Brain, 81*, 364–388.

Levine, S. C. (1985). Developmental changes in right hemisphere involvement in face perception. In C. T. Best (Ed.), *Hemispheric function and collaboration in the child* (pp. 157–191). New York: Academic Press.

Levy, J., Heller, W., Banich, M. T., & Burton, L. A. (1983). Asymmetry of perception in free viewing of chimeric faces. *Brain and Cognition, 2*, 404–419.

Liederman, J., & Coryell, J. (1981). How right-hand preference may be facilitated by rightward turning biases during infancy. *Developmental Psychobiology, 14*, 439–450.

Liederman, J., & Kinsbourne, M. (1980). Rightward bias in neonates depends upon parental right-handedness. *Neuropsychologia, 18*, 579–584.

Lorenz, K. (1935). *Studies in animal and human behavior* (Vol. 1). Cambridge, MA: Harvard University Press.

McDonnell, P. M., Anderson, V. E., & Abraham, W. C. (1983). Asymmetry and orientation of arm movements in three- to eight-week-old infants. *Infant Behavior and Development, 6*, 287–298.

McGraw, M. (1943). *The neuromuscular maturation of the human infant.* New York: Columbia University Press.

Michel, G., & Goodwin, R. (1979). Intrauterine birth position predicts newborn supine head position preferences. *Infant Behavior and Development, 2*, 29–38.

Monrad-Krohn, G. H. (1924). On the dissociation of voluntary and emotional innervation in facial paralysis of central origin. *Brain, 47*, 22–35.

Moscovitch, M., & Olds, J. (1982). Asymmetries in spontaneous facial expressions and their possible relation to hemispheric specialization. *Neuropsychologia, 20*, 71–81.

Moscovitch, M., Strauss, E., & Olds, J. (1980, June). *Children's productions of facial expressions.* Paper presented at the meeting of the International Neuropsychology Society, Italy.

Nelson, C. A., & Horowitz, F. D. (1980). Asymmetry in facial expression. *Science, 209*, 834.

Oster, H., & Ekman, P. (1978). Facial behavior in child development. In W. A. Collins (Ed.), *Minnesota Symposium on Child Psychology* (Vol. 2, pp. 231–276). Hillsdale, NJ: Erlbaum.

Peele, T. L. (1961). *The neuroanatomic basis for clinical neurology.* New York: McGraw-Hill.

Peters, M., & Petrie, B. F. (1979). Functional asymmetries in the stepping reflex of the human newborn. *Canadian Journal of Psychology, 33*, 198–200.

Reiser, J., Yonas, A., & Wikner, K. (1976). Radial localization of odors by human newborns. *Child Development, 47*, 856–859.

Remillard, G. M., Andermann, F., Rhi-Sausi, A., & Robbins, N. M. (1977). Facial asymmetry in patients with temporal lobe epilepsy: A clinical sign useful in the lateralization of temporal epileptic foci. *Neurology, 27*, 109–114.

Rinn, W. E. (1984). The neuropsychology of facial expression: A review of the neurological and psychological mechanisms for producing facial expressions. *Psychological Bulletin, 95*, 52–77.

Rothbart, M. K., & Posner, M. I. (1985). Temperament and the development of self-regulation. In L. C. Hartlage & F. C. Telzrow (Eds.), *The neuropsychology of individual differences: A developmental perspective* (pp. 93–123). New York: Plenum Press.

Rothbart, M. K., Taylor, S. B., & Tucker, D. M. (in press). Right-sided facial asymmetry in infant emotional expression. *Neuropsychologia.*

Rubin, D. A., & Rubin, R. T. (1980). Differences in asymmetry of facial expression between left- and right-handed children. *Neuropsychologia, 18*, 373–377.

Sackeim, H. A., Greenberg, M. S., Weiman, A. L., Gur, R. C., Hungerbuhler, J. P., & Geschwind, N. (1982). Hemispheric asymmetry in the expression of positive and negative emotions. *Archives of Neurology, 39*, 210–218.

Sackeim, H. A., & Gur, R. C. (1978). Lateral asymmetry in intensity of emotional expression. *Neuropsychologia, 16*, 473–481.

Sackeim, H. A., & Gur, R. C. (1980). Asymmetry in facial expression. *Science, 209*, 834–836.

Sackeim, H. A., Gur, R. C., & Saucy, M. C. (1978). Emotions are expressed more intensely on the left side of the face. *Science, 202*, 434–436.

Santa, J. L., Miller, J. J., & Shaw, M. L. (1979). Using Quasi *F* to prevent alpha inflation due to stimulus variation. *Psychological Bulletin, 86*, 37–46.

Schwartz, G. E., Ahern, G. L., & Brown, S. L. (1979). Lateralized facial muscle response to positive and negative emotional stimuli. *Psychophysiology, 16*, 561–571.

Sroufe, L. A. (1979). Socioemotional development. In J. Osofsky (Ed.), *Handbook of infant development*. New York: Wiley.

Stern, D. (1974). Mother and infant at play: The dyadic interaction involving facial, vocal, and gaze behaviors. In M. Lewis & L. Rosenblum (Eds.), *The effect of the infant on its caregiver*. New York: Wiley.

Tomkins, S. S. (1962). *Affect, imagery, consciousness: Vol. 1. The positive emotions*. New York: Springer.

Tomkins, S. S. (1963). *Affect, imagery, consciousness: Vol. 1. The negative affects*. New York: Springer.

Tronick, E. Z., Als, H., & Adamson, L. (1979). Structure of early face-to-face interactions. In M. Bullowa (Ed.), *Before speech: The beginnings of interpersonal communication*. Cambridge, England: Cambridge University Press.

Tronick, E. Z., Ricks, M., & Cohn, J. F. (1982). Maternal and infant affective exchange: Patterns of adaptation. In T. Field & A. Fogel (Eds.), *Emotion and early interaction: Normal and high-risk infants* (pp. 83–100). Hillsdale, NJ: Erlbaum.

Tucker, D. M. (1986). Neural control of emotional communication. In P. Blanck, R. Buck, & R. Rosenthal (Eds.), *Nonverbal communication in the clinical context* (pp. 258–307). University Park: Pennsylvania State University Press.

Tucker, D. M., & Frederick, S. L. (in press). Emotion and brain lateralization. In H. Wagner & T. Manstead (Eds.), *Handbook of psychophysiology: Emotion and social behavior*. New York: Wiley.

Turkewitz, G., Birch, H., Moreau, T., Levy, L., & Cornwell, H. (1966). Effect of intensity of auditory stimulation on directional eye movements in the human newborn. *Animal Behavior, 14*, 93–101.

Turkewitz, G., & Creighton, S. (1974). Changes in lateral differentiation of head posture in the human neonate. *Developmental Psychobiology, 8*, 84–89.

Weber, S. L. (1983). *Facial asymmetry in the expression of emotion in infants*. Unpublished doctoral dissertation, New York University, New York.

Weiffenbach, J. M. (1972). Discrete elicited movements of the newborn's tongue. In J. F. Bosma (Ed.), *Third symposium on oral sensation and perception* (pp. 391–399). Springfield, IL: Charles C. Thomas.

Whitaker, H. A. (1978). Is the right leftover? Commentary on Corballis & Morgan, "On the biological basis of human laterality." *Behavioral and Brain Sciences, 1*, 323–324.

Witelson, S. F. (1985). Hemisphere specialization from birth: Mark II. In C. T. Best (Ed.), *Hemispheric function and collaboration in the child* (pp. 33–85). New York: Academic Press.

Zollinger, R. (1935). Removal of left cerebral hemisphere. *Archives of Neurological Psychiatry, 34*, 1055–1064.

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