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The Temporal Structure of Face-to-Face Communication Between Mothers and Infants

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Thirty-seven infants were videotaped in face-to-face play with their mothers at 6, 13, and 26 weeks of age. Analysis proceeded at three levels: (a) The infants' periods of attention toward the mothers significantly overlapped with the mothers' facially expressive behavior. This was increasingly true as the infants grew older: Whereas the total proportion of time looking at the mothers decreased, the time looking at them while they were *on* did not decrease. (b) The infants' Vocalizations, Smiles, and Mouth Openings clustered into "runs" as described by previous investigators, but at 6 weeks these occurred only when the mothers were *on*. By 26 weeks of age, the infants' clusters of expression had become autonomous turns in a dialoguelike exchange. (c) Analysis of contingent sequences following the onset of infant *attention* showed that with infants 6 weeks old, mothers' facial *greetings*—Nodding, Smiling, and so forth—were only rarely effective in eliciting expressive *greetings* from the infants, but without the mothers' *greetings* the infants almost never made such responses. With 13-week-old infants, mothers more easily elicited *greetings*, and some spontaneous (unelicited) *greetings* by the infants could also be seen. With 26-week-old infants, the spontaneous *greetings* had become as frequent as those elicited by the mothers.

Cognitive development demands a widening of the infant's horizons beyond the mother's face to include other animate objects and their actions as well as inanimate objects and their motions. Thus, infants' preferences change over the first 6 months so that faces, especially mothers' faces, occupy a declining share of their attention (Schaffer, 1977).

Maternal behavior might be expected to change in response to this shift in infant preferences. Mothers might use more varied and exaggerated expressions (Brazelton, Koslowski, & Main, 1974; Stern, Beebe, Jaffe, & Bennett, 1977) to compete against other objects for infants' attention, for the periods of involvement with the parent must not be allowed to wane. In fact, they must intensify, must change from a matter of "obligatory" observation of an interesting stimulus (Stechler & Latz, 1966) to the purposive, rule-governed, reciprocal turn taking so fundamental to human discourse (Kaye, 1979; Terrace, Petitto, Sanders, & Bever, 1979).

Fogel's (1977) study of an infant from 5 to 13 weeks of age and his mother provided some hints about how a balance can be achieved between involvement with the mother and disengagement from her. He found that the mother's exaggerated displays were not effective in attracting the infant's attention. She was more effective when she simply gazed at him with her face at rest. Once the baby had met her gaze, if she then shifted into a series of exaggerated facial expressions (eyebrows raised, mouth wide open or smiling, head nodding, etc.) she was able to hold his attention longer and elicit bursts of vocalization and wide mouth opening. The mother first pro-

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vided an attentive frame within which the infant's attention cycled to and from her face (while she continued to watch him); she could then use facial expressions, head movements, vocalization, and so forth, within his periods of attention, to maintain and intensify his involvement.

The relevant units of maternal behavior in Fogel's study can be seen as alternating *on* and *off* phases that seemed to overlap with the *on* and *off* phases of infant attention (Brazelton et al., 1974; Trevarthen, 1977). Alternatively, they could be analyzed as discrete events having different rates depending on the infant's state of attention. Then there were the infant's vocalizations and facial expressions, discrete events that appeared to cluster into "runs" within the mother's *on* phases.

The first concern of the present study was whether the foregoing descriptions would apply generally across a large sample of mothers and babies. Second, we hoped to explore some of the mechanisms that might produce such temporal structure. Can each partner's behavior be understood as responses to stimuli produced by the other or do they constitute a "system" in the sense of a controlling organization greater than the sum of its parts?

Method

Sample

Our initial sample of 52 mothers was recruited at the time of their infants' birth for a longitudinal study that included neonatal assessments, observation of feeding interactions in the first month, imitation and instruction at age 6 months, and a study of mother–child dialogues and play in the third year. Face-to-face play was videotaped in the subjects' homes when the infants were 6, 13, and 26 weeks of age.

All mothers were English speaking, white and United States born, who carried their babies to full term without major complications. Only 17% were college graduates, and 25% had not graduated from high school. About 10% were unmarried at the time of the infant's birth. In short, the sample consisted of a representative range of working-class families from many different ethnic backgrounds (except that 63% happened to be Catholic and all the rest Protestant).

Procedure

The face-to-face paradigm has been studied by many investigators in recent years (e.g., Brazelton et al., 1974; Stern et al., 1977; Trevarthen, 1977). It introduces a degree of simplification and standardization into our observations without artificially reducing the complexity of behavioral organization and interaction in real time.

Each mother sat in a straight chair holding her infant freely in her lap. She was asked to "see if you can get his/her attention and play with him/her as you normally do." The one constraint, their sitting up rather than playing on the floor or a bed, was explained as being necessary so as to observe different babies in the same situation. Sessions lasted 4–7 min ($M = 300$ sec). Some sessions that had to be curtailed because of prolonged or intense crying were replaced by more satisfactory ones 1 or 2 hours later, after a feeding or a nap; however, less extreme fussiness was considered a normal part of the interaction, occurring at least briefly in about half of the sessions at each age.

The sessions were videotaped with SONY 3400 portable equipment, which limited us to a single camera. The camera was located about 3 m to the mother's right, 5°–15° above the horizontal plane through her face and the baby's, and about 85° off the mother's line of regard, so that when they were in direct eye-to-eye contact we could see somewhat more than the infant's profile and somewhat less than the mother's. If a mother's hair obscured her face from the camera's view, she was given bobby pins or a rubber band to pull it back.

Coding

Table 1 presents brief definitions of the coding and recoding categories.[1] Roman type, capitalized, denotes event categories as originally coded; subsequently defined states and higher order groupings are italicized.

The most important aspect of our method was the independent coding of the seven modes of behavior. Whenever possible, the mother's image was covered while the infant was being coded, sound was turned off while head and eye direction were coded, and so forth. Each of the seven modes was coded in a single full speed pass through the videotape by depressing buttons on an electronic device (Datamyte, Electro/General Co.) that recorded the time of occurrence and the category. These digital codings were associated with labels, intercalated, synchronized, and later recoded as indicated in Table 1, by a software system called CRESCAT (Kaye, 1978), which also provided a language for pattern searching, sequential analysis, and extraction of variables by subject and session.

Coding the videotapes without resorting to slow motion or stop-frame transcription means that we made some sacrifices in response latency, observer error, and number of possible categories for the sake of being able to code a large number of sessions. Any errors that occurred, however, must have been un-

[1] Table 1 omits categories not used in this analysis (e.g., baby's head direction Down was subsumed into Away).

systematic and unbiased at least regarding the relationship between the independently coded modes. The only behavioral relations reported are between modes, not within modes.

Reliability

Two or three coders were assigned to each mode. During the training period, they observed one another coding a number of sessions and stopped the videotape to discuss each questionable event. When no further questions arose, they checked to see that all distinctions (category boundaries) as well as the hit rate (vs. misses and false alarms) were reliable at the 85% level or better, based on mean agreement between two codings (agreements divided by number of events seen, category by category). A "match" between two coders was counted so long as they recorded the same event with a maximum lag of 3 sec; however, the vast majority of lags between coders for agreed-on events were less than 1 sec. The 133 codable videotapes were then randomly divided among

Table 1
Brief Definitions of Coding and Recoding Categories

Mode/coding category	Definition
	Infant behavior
1. Head orientation	
C Toward	A straight line from baby's nose would hit mother's face.
C Peripheral	The line would miss mother's face by <90°.
C Away	The line would miss mother's face by >90°.
2. Eye quality	
C Closed	Eyeball not visible.
C Dull	Eyes glazed or eyelids drooping.
C Alert	Not Dull or Closed.
3. Facial expressions	
C Cry	Continual state of fussy sounds and/or cry face.
D Smile	Based on mouth only (eyes could be closed).
D Wide	Mouth open to at least the width of a spoon.
D Vocalization	"Human" vocalizations, except cries, whimpers, and laughs.
D Laugh	Laugh.
Combinations	
R *Attention* (*attending*)	Toward and Alert.
R *Expression*	Smile, Wide, Vocalization or Laugh.
R *Greeting*	First *expression* following onset of *attention*.
	Mother behavior
4. Head movements	
C Head	Bobbing head up and down or side to side.
C At Baby	Looking at baby.
C Away	Clearly directed elsewhere.
5. Facial expressions	
C Smile	Big smile.
C Exaggeration	Exaggerated expression (raised eyebrows, clownface, astonishment, frown, etc.).
C Normal	Each mother's baseline or "resting" face.
6. Touching	
D Touch	Any touch, stroke, poke, or jiggle.
R *Touching*	Bursts of Touches < 2 sec apart.
7. Changing baby's position	
D Posture Changing	Moving infant from 1 of 32 zones (8 support positions × 4 compass directions) into any other zone.
D Bounce	Movement in any direction within a zone.
R *Bouncing*	Bursts of Bounces < 2 sec apart.
Combinations	
R *On*	Smile, Exaggeration, or Head.
R *Greeting*	Change to *on* following onset of infant *attention*.

Note. C = Continual events, coded at onset and offset, or mutually exclusive states. D = Events coded as discrete or at onset only. R = Categories defined and recoded in the computer. Italics indicate states and higher order groupings defined subsequent to the categories originally coded, which appear in roman type.

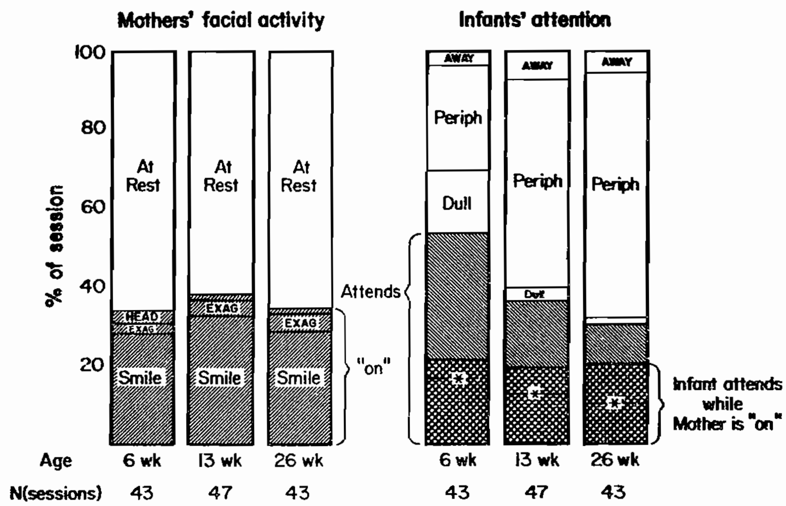

Figure 1. Proportional distribution of principal states of mothers' and infants' facial expressions. (EXAG = wide-open mouth, raised eyebrows, mock frown or pout, etc. HEAD = bobbing head with face otherwise at rest (additional head bobbing also occurred during EXAG and SMILE). PERIPH = infant's head directed off line from mother's face, but less than 90° off that line. DULL = head toward mother, but eyes closed or glazed. *Expected [chance] joint occurrence of mother *on* while infant *attentive*.)

team members and randomly ordered in such a way that 10 tapes (unknown to them) would be coded independently by two people at the beginning of the series, again in the middle, and again at the end. In this way we obtained both intercoder and intracoder reliability at times separated by 1–5 months, always with a minimum criterion of 85% agreement and less than 1 sec mean lag between agreed-on events.

Results

Three levels of relationship between the mothers' and infants' behavior will be discussed: mothers' expressive or stimulating behavior and infants' attention; infants' rates of facial expressions as a function of their attention to the mothers and of the mothers' facial activity; and the most common sequences of discrete events, manifested in terms of the conditional likelihood of certain behavior by one partner as a function of the other's behavior and the passage of time.

Infants' Attention and Mothers' Facial Activity

The mean proportion of time during which infants were oriented toward their mothers' faces declined with age, from 70.1% at 6 weeks to 32.8% at 26 weeks. As shown in Figure 1, the difference was made up by the Peripheral head direction (infant deviating less than 90° from the direction of mother's face), rather than by looking Away (further to the side, down to her lap, etc.). The state *attention*[2] (Alert as well as Toward) accounted for a similarly declining proportion of the sessions: 53.6% at 6 weeks, 36.9% at 13 weeks, and 30.2% at 26 weeks. The rate with which this state cycled on and off more than doubled over this period, from 1.6 cycles/min at 6 weeks to 3.0 at 13 weeks and 3.4 at 26 weeks. This means, on the average, that a cycle consisted of about 20 sec *attending* and 18 sec *not attending* at 6 weeks, compared with about 5 sec *attending* and 12 sec *not attending* at 26 weeks. However, there was no rhythmicity in these cycles. The distribution of onset-to-onset intervals was essentially Poisson (random); that is, the onset of *attention* was independent of the time since the last cycle.[3]

[2] Throughout, the terms *attention* and *attending* are used interchangeably to denote the same coding category; see Table 1.

[3] At all ages, the rate of attention cycles/min was 30%–40% faster in boy infants than in girls, $F(1, 31) = 4.67, p < .05$.

Table 2
Indices of Infants' Responsibility for Change in Joint State: Likelihood Each Joint State of Attention and Maternal Facial Activity Will End by Infant Shifting Attention

	Likelihood infant will attend before mother changes state: Infant *not attending* to mother		Likelihood infant will stop attending before mother changes state: Infant *attending* to mother	
Age group	Mother *on*	Mother *off*	Mother *on*	Mother *off*
6 weeks	.30	.53	.18	.33
13 weeks	.38	.58	.48	.52
26 weeks	.41	.56	.55	.56

Note. Indices of mothers' responsibility for ending joint states are 1 minus the numbers shown.

Mothers spent nearly 100% of every session watching their babies directly; glances away were brief and nearly always due to an interruption by another person, usually an older child.[4] So there were no on-and-off cycles of maternal attention to correspond to the babies'. What did correspond to those cycles were the periods of mothers' expressive facial activity. When a mother was smiling or making an exaggerated face or bobbing her head, she was considered *on*. Like the infants' *attention* cycles, the mothers' *on* cycles were nonrhythmic: As with any Poisson process, their distributions could be characterized solely by their mean rate. Unlike the infants' *attention*, however, the mothers' *on* cycles occurred at the same mean rate for each infant age: 3.1–3.3 cycles/min, or about 6 sec *on* and 13 sec *off*.

During the time mothers' faces were *off*, they were not immobile. They spoke to the infants throughout the sessions (Kaye, in press-a, in press-b), but their facial movements were either small (lips moving in speech) or involved the whole trunk (moving into the infant's field of vision) as opposed to the major facial activity and head bobbing we classified as *on*.

Multiplying the two proportions at each age gives the expected proportion of co-occurrence, the time one would find mothers *on* while infants were *attending*, by chance. As Figure 1 shows, the actual co-occurrence was significantly higher than expected at all three ages ($p < .01$, sign tests) and remained at about 20% (two thirds of the time mothers were *on*) despite the steep decline in the overall proportion of time infants *attended* to their mothers' faces. In other words, as the older infants spent more time looking at things besides mothers' faces, this came out of the time they had spent watching the mothers' resting faces; they continued to spend just as much time watching the more expressive behavior.

The mothers, in turn, engaged in more of this behavior when the infants were watching them, and the difference increased with age. During *attention* the rates were significantly higher than during *inattention* at all three ages, Wilcoxon t(42, 46, and 42, respectively), $p < .001$; binomial sign tests, $p < .05$, but they were less than twice as great at 6 weeks, whereas at 26 weeks they were nearly three times as great: one discrete Smile, Exaggeration, or Head bob every 6.5 sec during *attention* compared with one every 18.4 sec at other times. As the infants grew older and decreased their proportion of *attention* to the mothers, the mothers only increased their expressive activities during periods of infant *attention*.

A high overlap between states of behavior in two partners can come about in a variety of ways: by either of them being more likely to start after the other starts (i.e., less likely to start until the other does); by either of them being more likely

[4] Even these attempts at interruption usually failed to make the mother take her eyes off the baby; she merely reminded the other child to stay away for a few minutes or called to someone else to come take the child away. To some extent this commitment to the infant must have been due to the videotaping situation, but it was interesting that mothers often combined their message to the other person with all of the prosodic features they were addressing to the baby, for example, singing, "pát-a-cake, pát-a-cake, báker's mán, Jo̊hn go awáy please líke I sa̋id."

to stop after the other does (i.e., less likely to stop until the other does); or by some combination of these contingencies.

An index of the infant's likelihood of shifting *attention* toward or away from the mother as a function of her behavior is shown in Table 2. (Although a finite-state Markov model oversimplifies the transitional probabilities by ignoring the continuous passage of time, in this case these indices capture the essence of a more complex analysis.) The results confirm Fogel's (1977) impression that mothers' displays were not particularly effective at attracting infants (who were 50%–75% more likely to begin *attending* when the mothers' faces were *off*). Mothers' exaggerated facial activity was effective in holding the attention of the infants once they were already *attending*, but this was only true at 6 weeks. At that age, once an infant was watching the mother, the odds were 9 to 2 (82% vs. 18%) that the infant would continue watching so long as the mother continued her expressive behavior. The 13-week and 26-week infants were about as likely to stop *attending* as to continue (columns 3 and 4 in Table 2 are about 50% at those ages), and about as likely to stop *attending* when their mothers were *on* as when they were *off* (column 3 is about the same as column 4).

Another correct inference from Table 2 is that the oldest infants were about as likely to follow the mothers' *on*s and *off*s as the mothers were to follow theirs (.41 and .44 for switching *on* when the partner had switched *on*, .56 and .59 for switching *off* when the partner had switched *off*, respectively). Thus a symmetry had emerged, but it was the mothers' state of facial expressiveness, rather than mothers' attention, that was symmetrical with infant *attention*. The two partners' looking at one another was not at all symmetrical, since the mothers' constant attention provided a frame within which the infants cycled Toward versus Peripheral and/or Alert versus Dull.

Before comparable analyses could be done with the two other modes of maternal behavior, Touches and Posture Changing, some recoding was required. In each case the total number of events was large—each discrete occurrence had been coded—but we used the computer to distinguish bursts of *touching* or *bouncing*. All Touches less than 2 sec apart were grouped into continual states of *touching*, and all Bounces less than 2 sec apart were grouped into bursts of *bouncing*.[5] In the average session with infants aged 6 weeks, 33.4% of the time was occupied by *touching* and/or *bouncing*, 31.8% at 13 weeks, 33.4% at 26 weeks. In absolute levels and in their lack of change over time, these proportions resemble those for the mothers' *on* state (Figure 1). However, that state and *touching* or *bouncing* bursts did not particularly co-occur—the overlap was at a chance level.

Touching and *bouncing*, with infants aged 6 and 13 weeks, occurred more when the infants were *inattentive*, Wilcoxon t(42 and 46, respectively), $p < .05$; binomial sign tests, $p < .05$. This was true of Posture-Changing and isolated Bounces and Touches as well as of the bursts. These behaviors appear to have been used to attract the infants' *attention*, and then the mothers switched to Smiles, Exaggeration, and so forth. By 26 weeks neither the bursts nor the isolated Touches, Bounces, and so forth, were related to the infants' state of *attention*.

In summary, mothers of younger infants used vestibular stimulation to attract the infants' *attention*, but as the mothers' share of their infants' time declined with age, they made no attempt to compete for it by using facial expressiveness, and they also stopped using Touch, Bounce, and Posture-Changing behavior for that purpose.

Infants' Expressive Behavior

Although the mothers' facial expressions appeared as sustained states, the infants' expressions occurred as fairly discrete events or as onsets of a new expression that soon tapered off without a clear offset. These events (Mode 3 in Table 1) were therefore coded and analyzed as a stream of discrete events rather than as continual states. Still photographs of these expres-

[5] The 2-sec criterion was chosen after examination of the distribution of all intervals between Touches and between Bounces. The distributions were bimodal and dipped nearly to zero at 2 sec.

sions resemble the facial accompaniments of adult speech rather precisely, as Trevarthen (1977) has pointed out. In motion, however, the differences are more apparent than the similarities. Furthermore, the development they require before becoming communicative gestures is not a matter of form but of the context in which they are used. There is no reason to consider them intentionally directed at mothers unless two conditions are met: (a) the expressions occur more frequently when babies are looking at mothers than when they are looking around the room, and (b) the expressions occur with some frequency as initiated behavior, not simply as elicited by the mothers' displays.

The first of these conditions was not met by our 6-week-old subjects. At that age, though they spent most of their time looking at their mothers, their rates of positive facial expressions shown in Table 3 were not significantly higher during periods of *attention* to the mothers than at other times. (The same was also true of Cry.) The positive expressions were, however, significantly higher during the mothers' *on* phases. We shall see shortly that this accounts for the somewhat higher though nonsignificant difference during *attention*.

At 13 weeks, the mean interval between events in any of these categories was still about 26 sec when infants were *not attending*, but only 11 sec (i.e., the rate more than doubled) when they were *attending*. By 26 weeks the rates had increased further in both states so that the difference was of less magnitude, but it was still significant. Figure 1 shows that as the infants' *attention* to the mothers' faces declined, it was more restricted to the time when those faces were especially active, *greeting* the infants and responding to them in a variety of ways. Now we find a greater frequency of similar kinds of behavior in the infant.

We were able to test the separate and interacting effects of *attention* to the mother and of the mother's being *on* by computing a rate of facial expressions for each infant under each of the 2×2 joint states of *attention* and maternal activity. The $2 \times 2 \times 3$ (age) repeated-measures analysis of variance confirmed the main effects appearing in Table 3 of age, $F(2, 54) = 15.1$, $p < .001$, *attention* to the mother, $F(1, 27) = 23.8$, $p < .001$, and mother's *on* versus *off*, $F(1, 27) = 23.9$, $p < .001$.[6] Most important, however, was the interaction between *attending* and mother's activity, $F(1, 27) = 13.6$, $p < .01$. The difference between rates of infant facial expressions when *attending* versus when *not attending* to mothers was very small when mothers were *off* (in fact, there was no difference at 6 weeks, when infants averaged only 1.3 expressions/min if the mother's face was at rest). The infant's direction of gaze made a greater difference, however, when the mother was *on*; and her behavior made a greater difference when the infant was *attending*.

The net effect was to make the infant's expressions appear to cluster into "runs" (Fogel, 1977), which we now conceive of as a matter of stochastic rates. The expressions were in fact distributed randomly in time—the log-survivorship function of the inter-event intervals fit a straight line as predicted by the Poisson model—but with different rate parameters depending on whether the infant was looking at the mother and whether the mother was *on* or *off*. So the infant's behavior, at least in this mode, does not have its own endogenous "organization," as Brazelton et al. (1974) and Trevarthen (1977) have claimed. On the other hand, it is true that a mother does not "elicit" a response; what she actually elicits is an increase in the rate parameter for a few seconds, and this in turn tends to create a run of infant expressive behavior.

By 26 weeks, however, the infant expressions did cluster into runs even when the mother was *off*, and deviation from the Poisson model was apparent. This is most simply reflected in the fact that after a 26-week-old infant produced an expression, even with the mother *off*, the likelihood of another such act within 2–4 sec was nearly three times what it would be after a few more seconds had passed.

In summary, these data capture the transformation of behavior at first mainly re-

[6] $N = 28$, all of whom had periods of *attention* and *inattention* to mother when she was *on* and when she was *off* at all three ages.

Table 3
Infants' Mean Rates Per Minute of Positive Facial Expressions, Related to Infant Attention *and Mothers' Facial Expressiveness*

Expressions	Infant *attending*	Infant *not attending*	Difference[a] ($p<$)	Mother's face *on*	Mother's face *off*	Difference[a] ($p<$)
6 weeks (N = 43)						
Vocalizations	1.31	.91	*ns*	1.62	.98	.05
Smile/laugh	.29	.17	*ns*	.48	.16	.01
Wide mouths	.48	.39	*ns*	.74	.31	.05
Total rate	2.08	1.47	*ns*	2.83	1.45	.01
M interval (in sec)	28.8	40.8		21.2	41.4	
13 weeks (N = 47)						
Vocalizations	3.15	1.45	.001	2.77	1.79	.001
Smile/laugh	1.64	.43	.001	1.39	.47	.001
Wide mouths	.51	.42	*ns*	.65	.25	.01
Total rate	5.31	2.30	.001	4.81	2.51	.001
M interval (in sec)	11.3	26.1		12.5	23.5	
26 weeks (N = 43)						
Vocalizations	4.12	2.59	.01	3.66	2.75	.05
Smile/laugh	2.50	1.33	.01	2.43	1.20	.01
Wide mouths	.18	.20	*ns*	.27	.17	*ns*
Total rate	6.80	4.12	.01	6.37	4.12	.01
M interval (in sec)	8.8	14.6		9.4	14.6	

[a] Wilcoxon t tests for matched samples. Binomial sign tests were also significant beyond $p < .05$ except where marked *ns*.

sponsive to the mother into behavior that was more autonomous and increasingly clustered into the runs or turns that are an essential part of human discourse. The sequence with which these expressive acts occurred in relation to the mothers' remains to be examined.

Mutual Contingencies

The results so far suggest a typical sequence: The mother greets the infant's onset of *attention* with one or more Smiles, Exaggerated faces, or Head bobbing, and the infant then responds by greeting her with a Smile, Vocalization, Wide mouth, and so forth. Although these responses seem to be more a matter of altered stochastic rate than of direct stimulus–response contingency, they can best be characterized by contingency functions taking account of real time, as shown in Figure 2. The picture is different at each age.

These graphs plot the conditional likelihood of an infant *greeting* as a function of time following the onset of *attention* to the mother's face, under two different conditions: when the mother has *greeted* the onset of *attention*, and when she has not. The likelihood in each 2-sec interval is calculated as the number of instances in which an infant *greeting* did occur divided by the number of instances in which it could have occurred (the latter number is shown at the bottom of the figure). So long as the mother had not yet *greeted* the infant, the instance was counted as an opportunity in which an infant *greeting* could occur in the function plotted with the broken line. Once the mother had *greeted* the infant (as long as he or she had not previously *greeted* her, and as long as she continued her behavior), the instance would count among those plotted with the solid line. For the time intervals after the one in which an infant *greeting* occurred, the instance no longer entered into the calculations. This type of intensity or contingency function is commonly used to plot mortality rates as a function of age and conditional probabilities in general as a function of time (Kaye & Wells, 1980).

Since the two conditions were mutually exclusive for any particular time interval apparent stability turned out to be that this rate of ill-timed expressions, very low among most of the mothers, was higher among a few who turned out to be the same mothers at those two sessions.

Summary of Results

Although it is true that growing infants spend a declining proportion of time gazing at their mothers' faces, those declining periods contain a richer and more balanced exchange of expressive acts between the two partners.

With the younger infants, mothers used *touching*, Posture Changing, and *bouncing* to try to attract infants. At all three ages they used facial activity to hold the infants' *attention*. Their absolute rates of discrete changes in facial expression while they had the infants' *attention* increased by about 50% over the period from 6 weeks to 6 months, and the infants' corresponding rates also increased, by about 200%. Although mothers did not typically wait for their infants' expressions before responding (at all three ages the mothers often *greeted* the onset of infant *attention*), the infants were less and less likely to wait for the mothers' *greetings* before *greeting* them. So although the overlap between mother and infant activities increased (both as a proportion of the infants' time *attending* and in terms of each partner's rate of expressive behavior when the other was *on*), the contingency functions actually show an increasing independence, of sorts, in the babies' behavior: There was a shift from mere responsiveness to spontaneous, reciprocal communication.

Discussion

Facial expression is not the only modality of communication in the face-to-face situation; we have merely focused on the faces as a way of studying some of the processes characterizing the whole interaction. Excluded from this study were the bursts of arm, leg, and hand movements that seem both subjectively and on neurological grounds to signal arousal or excitement in the baby. We could not test Trevarthen's (1977) impression that some of these movements, especially fine finger movements, co-occur significantly with speechlike facial expressions. If that is true, however, then our positive facial categories can be taken as representing the larger set of behaviors that tend to accompany them.

The changes in the infant's behavior over this period are more striking than those in the mother's. Yet the mother does adjust to her infant's attentional preferences by the timing of her expressive displays. She also avoids certain other kinds of adjustment one might have expected. For example, though the infant's periods of *inattention* to her increase in number, she does not increase her *touching* or *bouncing* activities during these periods. This may be due to the fact that as the *inattentive* periods become more frequent, they also become shorter, so that the probability of the infant's returning his gaze to her spontaneously in any given second actually increases with age. In any case, a mother seems to yield to her infant's shifting agenda, spending her energy on enriching the periods of joint gaze whenever they happen to occur.

Perhaps one reason this is easy for a mother is that her own agenda is also shifting. Her adjustment is not just a matter of picking up whatever happens to interest the baby at the moment. She pushes for further development and therefore is alert to new possibilities. Whereas at 6 weeks she tries basically to capture and hold the infant's *attention*, perhaps to get some sign that he is really tuned in, later she wants more: Within the periods of *attention* she strives for contingent responses from the infant. By 26 weeks, many mothers indicated that our face-to-face situation was already obsolete; they wanted to incorporate objects into their play, to try to provoke a shared reaction to external events rather than maintain a purely phatic exchange.

The effect of these first 6 months' exchanges is more specific than merely a shift toward reciprocity. As infants become less dependent on mothers' initiations, their own behavior acquires more internal organization. The runs of facial expression are not the first burst–pause pattern to appear in the infant's behavior—his sucking is innately organized in such a pattern, to which mothers' feeding behavior is quite sensitive (Kaye & Wells, 1980)—but it is the first to *develop* from a more diffuse, disorganized stream. We have to explain not only how this process occurs but why it needs to occur at all, instead of the infant coming equipped with innate organization like the sucking pattern.

In light of the present study, it would not be correct to describe this developmental process as though infants were being entrained by mothers' rhythms. For the mother's behavior, in fact, is not rhythmic. What does seem to happen, at least in the case of the facial expressions explored here, is that the mother's background behavior (or "frame") affects the stochastic likelihood of occurrence of infant behaviors, themselves also entirely arhythmic. This creates "runs", which consist essentially of an aperiodic rise and fall in the infant's rates of expression, and which gradually transfer to other contexts without the frame.

"Runs" or "turns" could have been built into the human infant, either in the form of such aperiodic waxing and waning of stochastic rates or in the form of much more regular cycles. If one were designing a system in which two organisms were going to be communicating with one another in a great many different and changing ways, however, it would be more adaptive to leave the development of their mutual fit to their mutual experience. Rather than let either partner's behavior be clock dependent, one would provide an emergent cyclicity by means of stochastic processes sensitive to particular events whose occurrence is guaranteed in a general way by the other partner's behavior. This, we believe, is what provides the openness to interdependent yet flexible organization in the human species.

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