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Developmental Changes in the Relationship Between the Infant's Attention and Emotion During Early Face-to-Face Communication: The 2-Month Transition

Manuela Lavelli
University of Verona

Alan Fogel
University of Utah

Weekly observations documented developmental changes in mother–infant face-to-face communication between birth and 3 months. Developmental trajectories for each dyad of the duration of infant facial expressions showed a change from the dominance of Simple Attention (without other emotion expressions) to active and emotionally positive forms of attention to the mother toward the end of the 2nd month. The results support an overlapping waves model, rather than a stage model, of developmental change. Sequential analysis found developmental changes from cycling between Gaze Elsewhere and Simple Attention to the Mother's Face in the early weeks to a complex sequence of transitions between Concentrated Attention, Smile, and Cooing Expression nested into sequences of positive communication during the 2nd and 3rd months.

The psychological literature has shown the important role that the infant's gaze plays in early social interactions. Specifically, the infant's gaze behavior regulates his or her perceptual input and internal physiological state—particularly arousal and affect (Field, 1981; Stern, 1974)—signaling readiness to engage in communication (Adamson, 1995). Gaze aversion suggests the need to withdraw from a too-demanding situation (Keller & Gauda, 1987; Stern, 1985) or simply to recover from the excitement of the interaction (Brazelton, Koslowski, & Main, 1974). These functions of gazing provide a "regulatory background" for affective behavior (Stern, 1974, p. 195) and early experiences of mutual regulation between infant and mother (Fogel, 1993a, 1993b; Reddy, Hay, Murray, & Trevarthen, 1997; Robson, 1967; Trevarthen, 1993; Tronick & Weinberg, 1997).

Infant gaze behavior during early interactions has typically been studied in quantitative terms, that is, measured in terms of gazing duration (at and away from the partner) or of the number of visual fixations or attention shifts. These approaches give little consideration to the emotional dimension of the infant's attention to the partner's face, a dimension that is an integral part of the infant's daily experience. Some scholars of mother–infant interaction have recognized the clustering of infant affective and attentive behavior by conceptualizing units of analysis such as "monadic phases" (Tronick, Als, & Brazelton, 1980) or infant "affective configurations" (Weinberg & Tronick, 1994). Only a few studies have specifically focused on the relationship between the infant's gaze behavior and his or her facial and vocal emotional expressions during early communication with the mother (Fogel et al., 1997; Hsu, Fogel, & Messinger, 2001; Messinger, Fogel, & Dickson, 1999, 2001; Yale, 2000). These studies showed that the co-occurrence of gazing at the mother's face and specific facial and vocal indices of positive emotion shown by the infant (e.g., open-mouth smiling) increased in frequency and stability from the 2nd to the 6th month. Thus, there are configurations of facial expression, vocalization, and gazing at the mother that form regularly co-occurring patterns in relation to maternal behavior during face-to-face communication.

These studies, however, started observations when the infants were about 6 weeks old, or later, leaving the 1st month and a half of life relatively unexplored. During the 2-month transition (Emde & Buchsbaum, 1989; Rochat & Striano, 1999)—against the background of mother–infant regulation of patterns of waking, sleeping, and feeding—a first unequivocal relationship between attention and emotion emerges in face-to-face communication. This is the onset of social smiling (Spitz, 1965; Wolff, 1987), which is associated with a significant increase in the duration of visual fixation to the mother's face. Before 2 months of age, infants show *endogenous* smiling, which occurs primarily during REM sleep states and during transitions from waking to sleep, and an early form of *exogenous* smiling, which occurs irregularly in relation to particular forms of auditory, tactile, and visual (especially when combined with auditory) stimulation (Emde, 1991; Wolff, 1987). This early exogenous smiling increases in frequency and is closely connected to active alertness and arousal states. Early exogenous

Manuela Lavelli, Department of Psychology and Cultural Anthropology, University of Verona, Verona, Italy; Alan Fogel, Department of Psychology, University of Utah.

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Correspondence concerning this article should be addressed to Manuela Lavelli, Dipartimento di Psicologia e Antropologia Culturale, Università degli Studi di Verona, via S. Francesco 22, 37129, Verona, Italy. E-mail: manuela.lavelli@univr.it

smiling appears developmentally before the onset of social smiling, that is, smiling elicited by the human face (Emde, 1991).

With the transition to exogenous control of emotion and attention, enriched possibilities of face-to-face communication develop. Improvements in the ability to maintain eye contact—which, from the time the infant was about 1 month old, served also as a base for forays to the areas surrounding the eyes and the face outline (Blass, 1999; Blass & Camp, 2001)—as well as improvements in the ability to maintain visual attention for a long time (Aslin, 1987) and to explore systematically the internal features of the face (Acerra, de Schonen, & Burnod, 1999; Haith, Bergman, & Moore, 1977) allow the infant to gather perceptual cues about the partner's emotions (Rochat & Striano, 1999). In other words, these behavioral changes lead the infant to the development of capabilities that are crucial for the emergence of a new experience of sharing emotion within face-to-face communication. This promotes the coupling of the infant's own expressive behavior with the partner's expressions, amplifying the sequences of enjoyed coordinated actions between partners (Fogel, 1981; Papousek & Papousek, 1989; Stern, 1985, 1990).

With regard to the interdependence between attention and emotion during mother–infant face-to-face communication, the literature has shown that exogenous smiles occur cyclically, in recursive patterns involving alternations of infant attention to the mother's face and maternal facial and vocal expression (Fogel, 1982; Oster, 1978; Trevarthen, 1979, 1993). In this study, we examined the frequency and duration of the co-occurrences of gazing at the mother and the infant's *expressive configurations*—defined as the combination of facial actions and motor activity. We also studied the sequential relationships between these co-occurrences as well as between infant and maternal expressions.

The literature on the relationship between the infant's attention and emotion during the first months of life is scant. Most of the sparse information comes from microdescriptive accounts such as those documented by Wolff (1963, 1987) or Trevarthen (1977, 1979). Some other information comes from observations focused on the facial actions shown by 2 infants during face-to-face play in the 2nd and 3rd months of life; in particular, it was found that the onset of early social smiling is preceded by a 3–20-s period of brow knitting and visual fixation to the mother's face, so that the onset of smiling is accompanied by a relaxation of the brows (Oster, 1978). According to the model of the "tension–relaxation cycle" produced by the infant's engagement of the stimulus (Sroufe, 1995), the relaxation of the brows and the emergence of smiling may reflect a release of tension built up during a period of effortful visual fixation on the part of the infant. The data collected by Oster are empirically supported by Trevarthen's (1979, 1993) microanalytic observations; these observations show that as early as 6 weeks of age, during periods of infant attention to the mother's face, brow knitting followed by smiles of different intensity, vocalizations, and hand gestures occurs in an intelligible pattern of communicative intent.

Longitudinal observations of the relation between infants' attention and emotion during face-to-face communication in the first 2 months of life, and particularly across the 2-month transition, have not been carried out systematically. We know little about how individual infants change in their emotion and attention across this transition. In addition, because prior observations have focused primarily on smiling expressions, little is known about the whole range of attention-related expressions and how they develop in early infancy.

In this study, we aimed to document the process of developmental change in the infant's attention to the mother's face and attention-related expressions during mother–infant face-to-face communication across the key developmental transition from endogenous to exogenous smiling. We used a microgenetic design in which observations were conducted before, during, and after the key developmental transition of interest (Fogel & Thelen, 1987; Lavelli, Pantoja, Hsu, Messinger, & Fogel, 2004; Siegler, 1995; Thelen, 1990). Our aim was to document the diversity of attention-related expressive configurations and to study the shape of the developmental trajectories formed by weekly observations of the durations of each expression. The shape of such developmental trajectories can give us information about the presence or absence of developmental change, the rate of change (the slope of the trajectories), and possible increases or decreases in the rate of change (changes in slope) indicating the presence or absence of a marked developmental transition or a more gradual one.

On the basis of the previous considerations, we were guided in this study by the following specific aims:

1. To identify whether young infants show specific expressive configurations when they are gazing at the mother's face during early face-to-face communication.

2. To document the developmental trajectories of the durations of the identified patterns of attention and emotion—that is, joint states of gazing at the mother's face and displaying specific expressive configurations—during the first 14 weeks of life (i.e., before, during, and after the key developmental transition at around 2 months). On the basis of the literature that documents changes in infant gaze and facial (and vocal) behavior coincident with the 2-month developmental transition, we expected curvilinear developmental trajectories with a significant increase or decrease near the end of the 2nd month.

3. To investigate whether there are particular temporal relationships (e.g., significant transitional probabilities or cycles) among the identified patterns of attention and emotion during mother–infant face-to-face communication, and, if recurrent sequences or cycles of patterns of attention and emotion were found, to examine whether and how these patterns changed across the 14 weeks. On the basis of Oster's (1978) findings, we expected to observe a cycle between attention (indexed by brow knitting) and smiling. However, considering that Oster's study was focused on episodes of smiling, from our sequential analysis performed on all of the infant's joint states of gaze direction and expressive configurations, we expected to find other possible kinds of cycles or recurrent sequences between patterns of attention and emotion. Moreover, considering that a significant increase in the infant's active engagement in face-to-face communication takes place during the 2nd month (Lavelli & Fogel, 2002), we hypothesized an increase of complexity in the cycling between patterns of attention and emotion over developmental time.

4. To investigate whether the infant's patterns of attention and emotion are associated with maternal vocal and facial expressions, either in terms of a real-time relationship (e.g., significant co-occurrences or significant transitional probabilities) or in terms of a developmental time relationship (e.g., same shape of developmental trajectories), and, if some associations were found, to

examine whether and how these associations changed over the 14 weeks. We expected to find temporal relationships between similar expressions shown by infants and mothers because of the "echoing" (Papousek & Papousek, 1995) that seems to characterize mother–infant "protoconversations," at least during the 3rd month. Thus, we can assess whether any association is observable in the first 2 months or, on the contrary, only after the 2-month transition.

Method

Participants

Sixteen firstborn neonates (6 girls and 10 boys) and their mothers participated in the study. Mothers were contacted 1 month before childbirth, during one of the meetings of their prenatal education classes at the hospital in Lecco, a town in the north of Italy. Of all the mothers approached in several meetings, about 25% agreed to participate. From the pool of primiparous mothers interested in our study, mother-neonate dyads were selected on the basis of (a) absence of obstetrical and neurologic complications (no particular medication during pregnancy and delivery, spontaneous full-term delivery, normal birth weight [i.e., above 2,500 g], 1- and 5-min Apgar scores of 8 or above), (b) absence of indications of physical or psychological problems on the part of the mothers, and (c) both the mother and the father living in the home. All of the dyads were Italians. Mothers ranged in age from 21 to 38 years ($M = 28.8$ years); none of them returned to work during the 14 weeks of observation. Fourteen out of 16 infants were initially breast-fed; 3 of them turned to bottle-feeding within the 2nd month.

The sample was balanced in relation to parents' education and socioeconomic status. In particular, 25% of mothers had compulsory schooling, 37% had a high school education, 19% had post-high-school training, and 19% had a university degree. All of the fathers, except for 2, had educational levels and occupations similar to those of their wives. Using the Nakao and Treas (1992; reprinted in Entwisle & Astone, 1994) Socio-Economic Index of Occupations, we found that the occupational prestige scores of the infants' parents ranged widely ($M = 51.5$, $SD = 24.4$).

Research Design

Because of the focus on the process of developmental change in infant's patterns of gaze direction and attention-related expressions during early face-to-face communication, this study was based on a microgenetic design (Lavelli et al., 2004; Siegler & Crowley, 1991). Microgenetic designs are focused on the moment-by-moment change observed in an elevated number of sessions within a relatively short (weeks, months), but rapidly changing, developmental period. Observations are conducted before, during, and after—that is, not simply before and after—a period during which a developmental change takes place in a particular domain. There is an elevated number of observations, because observations are conducted at time intervals that are considerably shorter than the time intervals required for the developmental change to occur. In this study, we used intensive observations of mother–infant face-to-face communication in a longitudinal design over a relatively short (3½ months) period that crosses a key developmental transition.

Procedure

Videotaping. Mother–infant dyads were videotaped during spontaneous face-to-face communication in a naturally occurring context at their homes, weekly, between the ages of 1 week and 14 weeks. The decision to conclude observations at the 14th week was based on the fact that during the 4th month, infants start to shift their attention from the mother's face to objects (Fogel, Hsu, Pantoja, & West-Stroming, 2003; Legerstee, Pomerlau, Malcuit, & Feider, 1987). Because of the importance of behavioral states for young infants' attention and engagement in communication, the requisite for videotaping was the alert state. To be present when the infants were alert, the researcher kept in close phone contact with the mothers; nevertheless, the neonates' unpredictability often required several hours of waiting in participants' homes for the babies to calm down or naturally awake. Because of the high individual variability in sleep-wake cycles, the best moment to observe mother–infant face-to-face communication was immediately or 10–20 min after feeding for some neonates but after a calm awakening 2–3 hr after the last feeding for others.

Each week, mother–infant face-to-face communication was videotaped for at least 3 min. The infant was semi-reclined on a sofa facing the mother. The infant's head and upper body were supported by a soft pillow, which helped to maintain a frontal orientation, and the mother knelt in front of the baby (at a distance of about 30 cm) to make possible visual contact easier.

Mothers were asked to talk naturally to their infants and to possibly adapt their head position to the infant's head position to facilitate possible visual contact, because the focus of our study was on the emotional aspects of the infant's attention to the mother's face. In other words, considering the immaturity of the postural control in the young infants, we needed to guarantee the requisites for the infant's attention to the mother's face. Videotaping was done with a color camcorder focused on the infant's face and body. A mirror (measuring 50 × 70 cm) was mounted behind the infant so that the mirror image of the mother's face and upper body was clearly seen. The time (in minutes, seconds, and tenths of a second) was registered on all videotapes. If the infant and the mother were still actively engaged in face-to-face communication at the end of the 3 min of observation, videotaping was prolonged until the end of the sequence. In these cases, a continuous segment of 3 min of video was then selected for coding on the basis of the maximum proportion of face-to-face communication. Out of the 224 planned sessions (16 subjects × 14 age levels), only 2 sessions were missing (owing to a lack of infants in the quiet or active alert state).

Coding. The infant's gaze direction during face-to-face communication was coded as Gaze at the Mother's Face or Gaze Elsewhere. The infant's attention-related expressions were coded in terms of infant expressive configurations, which were identified by combinations of facial actions and motor activity. Initial viewing of the videotapes suggested that there was a relatively small number of regularly recurring composites of facial actions and body movements that were easily interpretable with respect to the infant's states of attention and emotion. Then, through the procedure described in detail in the Appendix, we identified seven different expressive configurations shown by the infants during face-to-face communication—regardless of their gaze direction—over the first 14 weeks of life. These configurations were labeled as Neutral (an absence of any particular facial action), Concentrated Attention (brow knitting), Excited Attention (brow raising with strong motor activity), Astonished Attention (brow raising with motor activity quiet), Attentive Smile (lip corner raising with mouth only partially open), Open Smile (lip corner raising with mouth totally open), and Cooing Expression (lip shaping for cooing or "pre-speech" movements, regardless of the emission of sounds). To these categories we added another, labeled Fussy/Cry State-Related Expression, which included any expressive configurations shown by the infants during the few moments of transition or a sudden change from quiet or active alertness to a fussy or cry state. The eight infant expressive configurations (see Table 1 for detailed descriptions) were then used as mutually exclusive categories for coding all of the tapes.

Because our focus was the relationship between attention and emotion on the part of the infant, maternal expressions were coded into only four macro and mutually exclusive categories: Maternal Neutral Expression (absence of any vocal and particular facial action), Maternal Smile (any kind of smile directed to the infant without vocal actions), Maternal Talk (any kind of vocalization and verbalization directed to the infant without smiles), and Maternal Talk/Smile (any kind of vocalization and verbalization co-occurring with smiles directed to the infant). Maternal gaze direc-

Table 1
Infant Expressive Configurations During Mother–Infant Face-to-Face Communication

Expressive configuration	Description
1. Neutral (or Simple Attention)	*Indices:* No particular facial action except for reflexes and vegetative neonate movements including rooting, occipito-frontalis reflex, startle, chin tremble, "munchies," yawning, hiccup, and jaw dropping. *Global description:* Relaxed neutral expression, with possible visual attention, in a quiet alert state.
2. Concentrated Attention	*Indices:* Brow knitting (AU 3) without other brow actions; motor activity quiet. *Additional actions frequently observed:* Relative stillness of the lower face with lip pursing or mouth only partially open. *Global description:* High arousal and sustained visual attention with effortful concentration.
3. Excited Attention	*Indices:* Brow raising (AU 1+2) and fast brow-raising movements; strong motor activity including fast limb movements such as open arm up-and-down movements with fits and/or waving and leg kicking. *Additional actions frequently observed:* Mouth closed with lip pressing or mouth only partially open. *Global description:* High arousal and sustained visual attention accompanied by motor excitement and body tension.
4. Astonished Attention	*Indices:* Strong brow raising (AU 1+2); motor activity quiet including relative stillness of the face. *Additional actions frequently observed:* Eye widening (AU 5); jaw dropping and mouth open in O shape. *Global description:* Fascinated and motionless visual fixation.
5. Attentive Smile	*Indices:* Lip corner raising (AU 12) with mouth only partially open. *Additional actions frequently observed:* Motor activity quiet. *Global description:* Relaxed expression of pleasure during visual attention.
6. Open Smile	*Indices:* Lip corner raising (AU 12) with mouth totally open. *Additional actions frequently observed:* Cheek raising (AU 6) and lower lid pouching; eye narrowing; head slightly reclining. *Global description:* Relaxed, full expression of positive affect.
7. Cooing Expression	*Indices:* Lip shaping for cooing, with upper lip raising and protruding, or lip and tongue prespeech movements (i.e., mouth positions for forming speechlike sounds), either with or without actual vocalizing. *Additional actions frequently observed:* Lower face protruding upward within an approaching postural orientation; arm raising with arm and/or hands waving. *Global description:* Approaching expression.
8. Fussy/Cry-State-Related Expression	*Indices:* Any facial and body action related to aversive responses and transitional states such as the precry state, as well as fussy or cry states. Typically, facial actions include brow knitting, lower lid raising, pouting or horseshoe-mouth (Oster & Ekman, 1978), or lip corner horizontal stretching with lip pressing or squared open mouth. Body actions include head rotation related to gaze aversion and limb tension or stiffening. *Global description:* Any expression of negative affect regardless of intensity.

Note. AU = facial action unit.

tion was not coded because all mothers gazed at their infants for the duration of the videotaped sessions.

Tapes were played in slow motion for coding. The coding strategy was continuous event coding in which onset times for each category were recorded from a clock superimposed on the video screen.

Reliability. Interobserver reliabilities for infant gaze direction, infant expressive configurations, and maternal expressions coding were calculated on a random sample of 40 out of 222 sessions (18%). At least one reliability analysis for each infant and mother was calculated before and after 7 weeks of age. Each time the three pairs of two independent observers entered the same code with less than 1.5 s of difference, it was considered agreement; otherwise, it was considered disagreement. The average Cohen's kappa was .87 for infant gaze direction, .72 for the infant expressive configurations, and .74 for the maternal expressions.

Statistical Analysis

First, GSEQ (Bakeman & Quera, 1995; Quera & Bakeman, 2001)—a program for performing sequential and synchronic analyses of sequential behavioral data—was used to analyze co-occurrences between infant gaze direction and infant expressive configurations. The analysis was performed on each subject separately. The significance of co-occurrences was assessed by the adjusted residuals statistic (Bakeman & Quera, 1995); adjusted residuals are standardized versions of the raw residuals, similar to the Allison and Liker z score in the sequential analysis literature (Bakeman & Gottman, 1986). For each co-occurrence, the significance of the proportion of subjects with significant adjusted residuals was then calculated by a binomial test.

A class of joint states (infant gaze direction + infant expressive configurations) representing different forms of relationship between the infant's

attention and emotion was then created. Afterward, a multilevel modeling technique (Bryk & Raudenbush, 1992; Hoeksma & Koomen, 1992; Woodhouse, 1996) was used to determine the developmental trajectories of Simple Attention (i.e., the Neutral Expression co-occurring with Gaze at the Mother's Face), as well as of each of the other expressive configurations significantly co-occurring with Gaze at the Mother's Face, across the 14 weeks. To this end, Attentive Smile and Open Smile were grouped as Smile. The multilevel modeling technique was also used to determine developmental trajectories of maternal expressions across the same age range. In this statistical technique, repeated measures multilevel models are used to depict the developmental trajectories of variables by fitting polynomial growth curves to the data. In the repeated measures models that we used, data are structured as a two-level hierarchy. Level 1 units are measures from repeated observation sessions (the infant's age in weeks), which are nested within Level 2 units (subjects); in other words, Level 1 refers to intraindividual change, whereas Level 2 refers to interindividual differences in intraindividual change. In these models, statistics are estimated at both group and individual levels. The average developmental curve of all subjects as a group is modeled by an *n*th degree polynomial function of age. The parameter weights for the age variable in determining the shape of the average developmental curve estimated from the data, that is, the fixed parameters, are comparable to regression coefficients in a regression model. Parameter weights must be at least twice as large as their standard error to be included in the model. The only inclusion of an intercept (initial status β_0) and a first-order age parameter ($\beta_1 \cdot \text{Age}_t$) in the model (i.e., $Y_t = \beta_0 + \beta_1 \cdot \text{Age}_t$) indicates that the development of the variable of interest (Y at time t) is best described by a linear trend. Inclusion of higher order age parameters (e.g., $\beta_2 \cdot \text{Age}_t^2$) in the model (e.g., $Y_t = \beta_0 + \beta_1 \cdot \text{Age}_t + \beta_2 \cdot \text{Age}_t^2$) indicates a curvilinear developmental trend.

In addition to the multilevel analysis of developmental trajectories, we collapsed the data into three temporal intervals or age periods (1st, 2nd, and 3rd months). We assessed the effect of age period by applying a repeated measures analysis of variance (ANOVA) to the average session duration for each of the expressive configurations co-occurring with Gaze at the Mother's Face, as well as for each of the four categories of maternal expression. A *t* test was applied matching the different age periods; it served the function of a post hoc test.

Finally, a sequential analysis (GSEQ; Bakeman & Quera, 1995) was performed on all of the infant's joint states (infant gaze direction + infant expressive configurations), as well as on the infant's joint states as a *target* and maternal expressions as a *given*, and vice versa, grouped into three age periods (1st, 2nd, and 3rd months), to assess any temporal association either between the different patterns of the infant's attention and emotion, or between the infant's and the mother's expressions during face-to-face communication. The analysis was performed on each subject separately. The significance of transitional probabilities was assessed with the adjusted residuals statistic (Bakeman & Quera, 1995). For each transitional probability, the significance of the proportion of subjects showing that transition significantly was calculated by a binomial test. The transitional probabilities found to be significant in most of the subjects were compared across the three age periods by applying a repeated measures ANOVA to the adjusted residuals. This allowed us to document developmental changes in the patterns of the infant's attention and emotion. A *t* test—applied matching the different age periods—served the function of a post hoc test.

With regard to our fourth aim, in addition to developmental and sequential analyses, co-occurrences between the infant's joint states and maternal expressions were also calculated for each dyad separately. Also in this case, the significance of co-occurrences was assessed by the adjusted residuals statistic, and the significance of the proportion of dyads with significant adjusted residuals was calculated by a binomial test.

Results

The results are grouped according to the four specific aims addressed in this study.

Co-Occurrences Between Infant Gaze Direction and Infant Expressive Configurations During Early Face-to-Face Communication

The synchronic analysis between infant gaze direction and infant expressive configurations observed during mother–infant face-to-face communication over the first 14 weeks of life revealed that five of the identified expressive configurations—Concentrated Attention, Excited Attention, Attentive Smile, Open Smile, and Cooing Expression—co-occurred at a greater than chance level with Gaze at the Mother's Face. However, the Neutral Expression and the Fussy/Cry State-Related Expression co-occurred at a greater than chance level with Gaze Elsewhere. These findings indicate that young infants show specific expressive configurations when they gaze at the mother's face during early face-to-face communication.

Developmental Changes in Patterns of Attention and Emotion

All of the mean durations for the joint states of infant expressive configurations and Gaze at the Mother's Face during face-to-face communication over the 14 weeks—except for Astonished Attention and the Fussy/Cry State-Related Expression, which occurred with low frequency—are presented in Figure 1. The numbers of infants presenting each of these patterns of attention and emotion (i.e., expressive configurations co-occurring with Gaze at the Mother's Face) at different age levels over the 14 weeks are depicted in Figure 2. As shown in Figure 1, only Simple Attention (i.e., the Neutral Expression co-occurring with Gaze at the Mother's Face) and Concentrated Attention (i.e., the form of attention characterized by brow knitting) were observed from the 1st week of life, although the presence of Concentrated Attention was noticed rarely. In particular, Figure 2 shows that Concentrated Attention was observed only in 2 out of 16 infants from the 1st week of life, but it was present in 6 infants at 3 weeks and in most of the infants at 5 weeks. Regarding the duration of Simple Attention and Concentrated Attention, it is interesting to observe a relatively consistent presence of Simple Attention until 8 weeks, when the time spent in effortful Concentrated Attention equaled the time spent gazing at the mother's face without any sign of active engagement (see Figure 1). After that age, the durations of Simple Attention and Concentrated Attention reversed, with a consequent gradual decreasing of Simple Attention and a stabilization of Concentrated Attention.

The other patterns of infant's attention and emotion were instead observed beginning between the 3rd and 7th weeks, depending on the subject (see Figure 2), with Excited Attention emerging for most of the infants only around the 9th–10th weeks. Moreover, from Figure 2 it can be seen that some patterns, such as those for Astonished Attention, Excited Attention, and Open Smile, were weaker than others and that Astonished Attention and Excited Attention were shown by 11 and 13 infants, respectively, out of 16 infants, at each of the age levels where they were more frequently observed.

Figure 3 compares the average modeled developmental trajectory for Simple Attention with the average modeled trajectories for Concentrated Attention and the other more active and emotionally positive forms of attention to the mother's face: Smile (Attentive

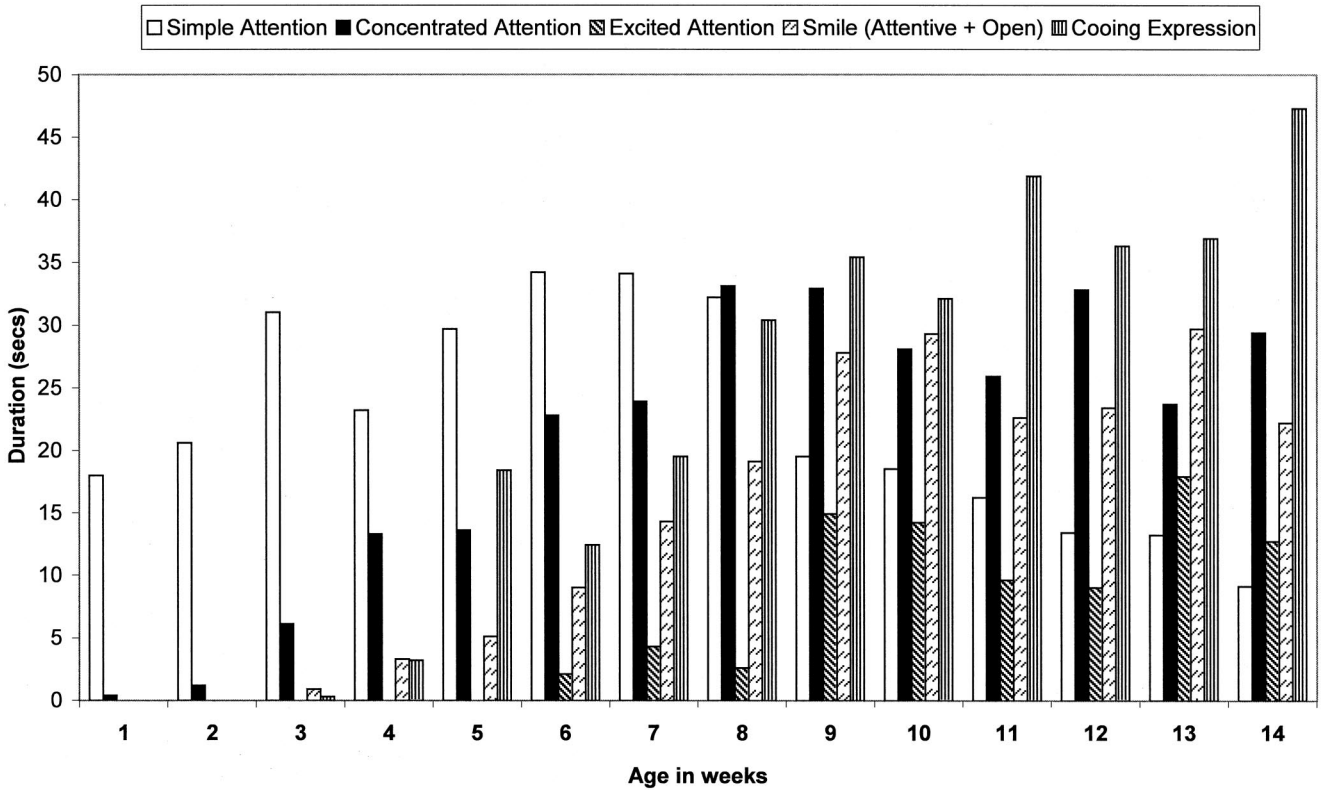

Figure 1. Mean duration of the infant's expressive configurations co-occurring with Gaze at the Mother's Face during mother–infant face-to-face communication over the first 14 weeks of life.

Smile + Open Smile), Cooing Expression, and Excited Attention (as well as all these modeled trajectories with modeled trajectories for maternal expressions). As shown by the estimated parameters of the modeled trajectories in Table 2, the durations of Simple Attention, Concentrated Attention, Smile, and Cooing Expression were all modeled by a second-degree polynomial function. This indicates a curvilinear developmental trend, negative for Simple Attention and positive for the other different patterns of attention and emotion, over the age range investigated. The duration of Excited Attention—which for most of the infants emerged only toward the end of the 2nd month—was instead modeled by a linear function indicative of a linear increase over the 3rd month.

From Figure 3 it is interesting to observe that the developmental trajectories of Simple Attention on the one hand and of Concentrated Attention and Cooing Expression on the other hand cross each other exactly at 8 weeks. A separation between the first 2 months and the 3rd month was confirmed for the duration of Simple Attention by a repeated measures (age period) ANOVA and *t* tests used as post hoc tests. In fact, the ANOVA showed a significant main effect for age period, $F(2, 30) = 4.93$, $p < .05$, and *t* tests indicated that the duration of Simple Attention decreased significantly from the 2nd month ($M = 30.53$ s) to the 3rd month ($M = 14.09$ s), $t(15) = 3.36$, $p < .01$.

However, the duration of Concentrated Attention to the Mother's Face began to strongly increase only during the 2nd month. A repeated measures (age period) ANOVA demonstrated a significant main effect for age period, $F(2, 30) = 8.27$, $p < .01$. *T* tests revealed that the amount of time the infants showed effortful concentration in attention to the mother's face was significantly longer during the 2nd month ($M = 25.65$ s) and during the 3rd month ($M = 27.39$ s) than during the 1st month ($M = 5.27$ s): $t(15) = -4.11$, $p < .01$ and $t(15) = -3.29$, $p < .01$, respectively. No significant differences were found between the 2nd and 3rd months.

Figure 3 also shows that Smile (Attentive Smile + Open Smile) and Cooing Expression began to strongly increase during the 2nd month but, unlike Concentrated Attention, continued to increase over the 3rd month. In particular, a repeated measures (age period) ANOVA applied to data collapsed by month showed a significant main effect for age period on the durations of Smile, $F(2, 30) = 33.55$, $p < .01$, and Cooing Expression, $F(2, 30) = 16.47$, $p < .01$. *T* tests used as post hoc tests revealed that the duration of Smile increased significantly not only from the 1st ($M = 1.16$ s) to the 2nd month ($M = 15.32$ s), $t(15) = -4.88$, $p < .01$, but also from the 2nd to the 3rd month ($M = 25.9$ s), $t(15) = -3.18$, $p < .01$. In a similar way, the duration of Cooing Expression increased significantly from the 1st ($M = 0.88$ s) to the 2nd month ($M = 24.58$ s), $t(15) = -5.9$, $p < .01$, and almost significantly from the 2nd to the 3rd month ($M = 37.5$ s), $t(15) = -1.91$, $p = .06$.

On the whole, in terms of developmental changes in the infant's patterns of attention and emotion during early face-to-face communication, the results indicate (a) the emergence of a first pattern characterized by "effortful" concentration on the mother's face by the end of the 1st month, (b) the emergence of expressive config-

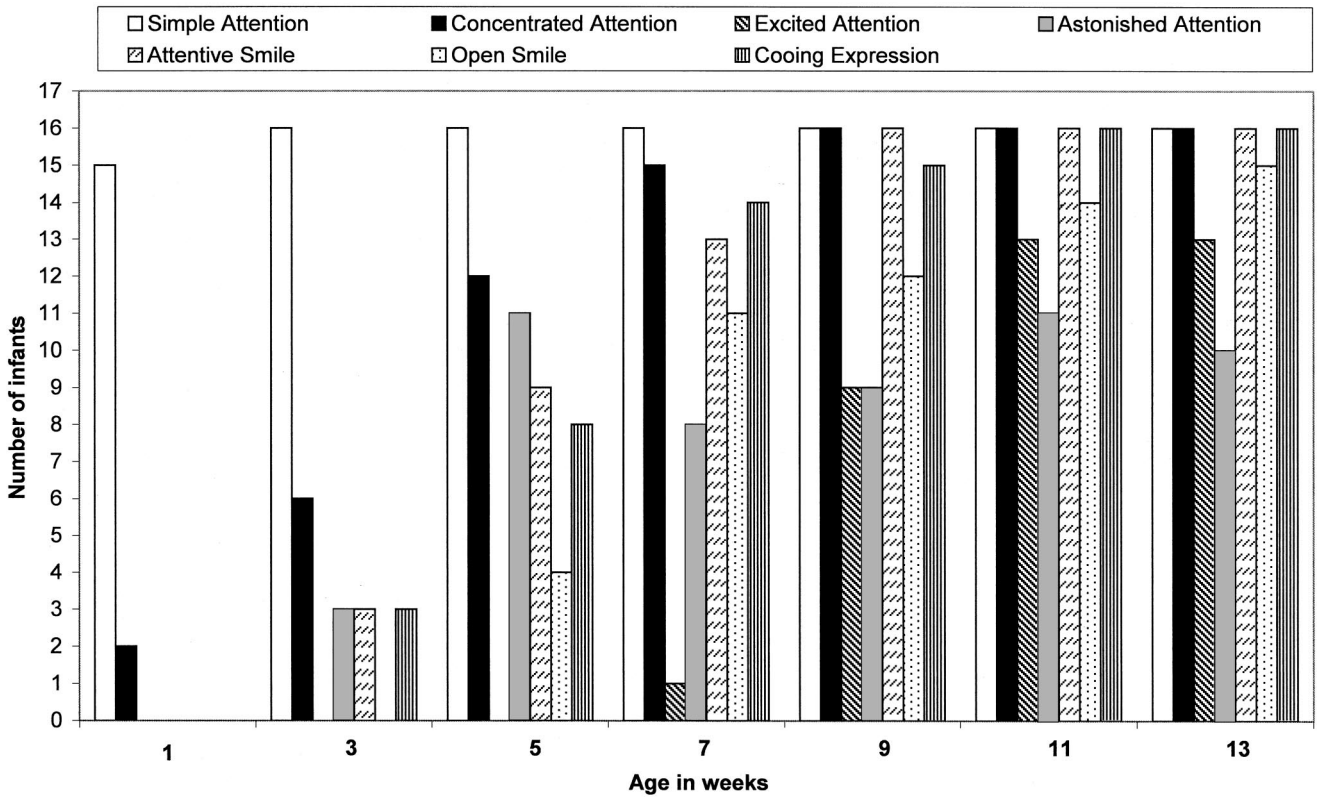

Figure 2. Number of infants who presented a particular expressive configuration co-occurring with Gaze at the Mother's Face, at different age levels, over the 14 weeks.

urations that show more active and emotionally positive forms of attention to the mother's face between the end of the 1st month and the middle of the 2nd month (depending on the different patterns and, especially, on the infants), and (c) a main qualitative change from the dominance of Simple Attention to the dominance of more active patterns of attention and emotion around the end of the 2nd month.

Sequential Patterns of Attention and Emotion

Sequential analysis performed on the infant's joint states (infant gaze direction + infant expressive configurations) revealed significant transitional probabilities and cycles between patterns of attention and emotion over the age range investigated. In particular, Neutral Expression Gazing Elsewhere was significantly associated with Neutral Expression Gazing at the Mother's Face (i.e., with Simple Attention to the Mother's Face) across the 14 weeks but never with any of the other patterns of attention and emotion. On the contrary, some forms of active and emotionally positive attention to the mother's face were significantly associated with each other from the 2nd month.

Figure 4 compares the state transition diagrams representing the transitional probabilities calculated on data grouped into three age periods (1st, 2nd, and 3rd months) and found to be significant for most of the subjects. As shown in this figure, during the 1st month, there were elevated significant probabilities of transition only from Neutral Expression Gazing Elsewhere to Simple Attention to the Mother's Face, and vice versa. However, during the 2nd month, the probabilities of transitions from Simple Attention to Concentrated Attention to the Mother's Face and, especially, from Concentrated Attention to Smile (either Attentive Smile or Open Smile) at the Mother's Face, and from Smile to Cooing Expression at the Mother's Face, emerged as significant in most of the subjects. A main developmental change from the 1st to the 2nd month was confirmed by a repeated measures (age period) ANOVA applied to the adjusted residuals of the transitional probabilities, and *t* tests were used as post hoc tests. In particular, the ANOVA showed a significant main effect for age period on the probability of a transition from Simple Attention to the Mother's Face to Neutral Expression Gazing Elsewhere, $F(2, 30) = 9.40$, $p < .01$, indicative of a significant decrease from the 1st month (mean adjusted residual = 3.29) to the 2nd month (mean adjusted residual = 1.97), $t(15) = 2.88$, $p < .05$. In the opposite direction, ANOVAs also showed significant main effects for age period on the probabilities of transition from Concentrated Attention to Smile and from Smile to Cooing Expression, $F(2, 30) = 15.57$, $p < .01$ and $F(2, 30) = 15.10$, $p < .01$, respectively. *T* tests used as post hoc tests indicated that the probability that the infant would show Smile after he or she had shown Concentrated Attention to the Mother's Face increased significantly from the 1st month (mean adjusted residual = .41) to the 2nd month (mean adjusted residual = 2.07), $t(15) = -3.67$, $p < .01$; in the same way, the probability that the infant would show Cooing Expression after he

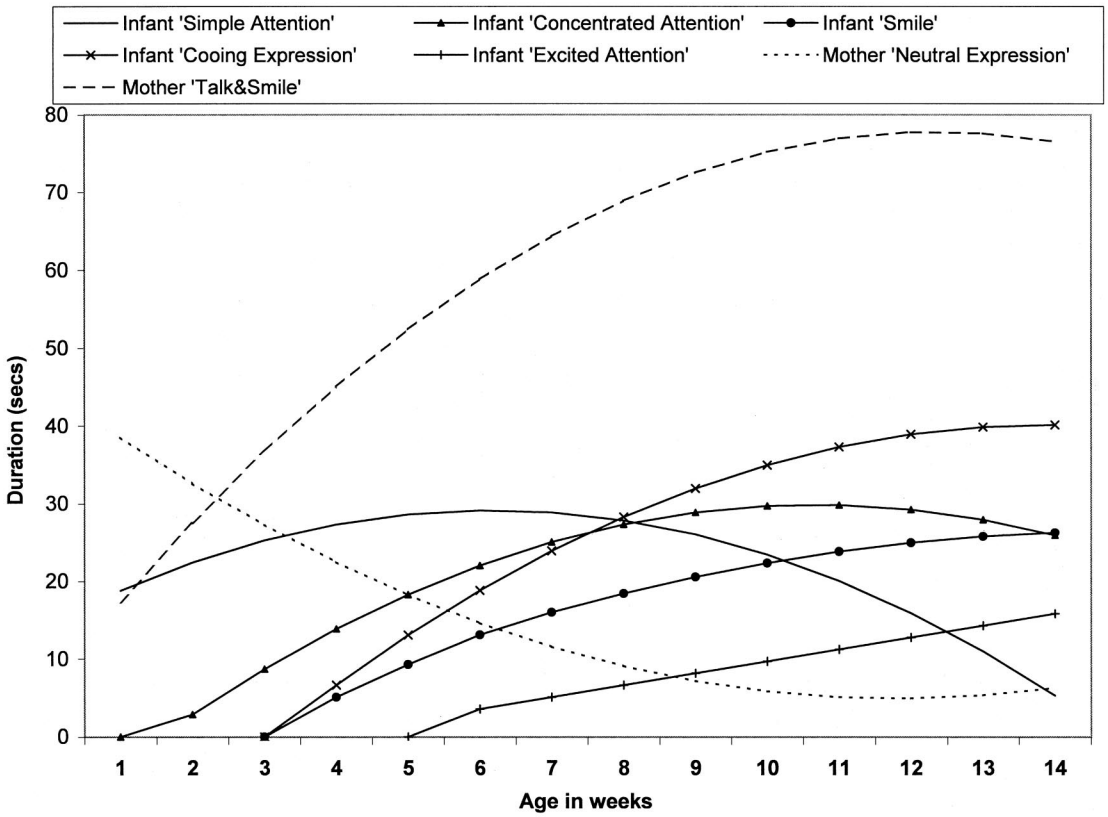

Figure 3. Predicted average developmental trajectories for Infant Simple Attention, Infant Concentrated Attention, Infant Smile (Attentive + Open), Infant Cooing Expression, and Infant Excited Attention and for Maternal Neutral Expression and Maternal Talk/Smile.

or she had shown Smile at the Mother's Face increased significantly from the 1st month (mean adjusted residual = .11) to the 2nd month (mean adjusted residual = 1.81), $t(15) = -5.46$, $p < .01$. Through the 3rd month, the sequential pattern of Cooing Expression given Smile remained quite stable, whereas the pattern of Smile given Concentrated Attention continued to increase and became significant for a significant number of subjects. Moreover, the probability of a transition between Cooing Expression and Concentrated Attention became significant for most of the subjects. These findings indicate an increasing complexity in the recurrent sequences and cycles of the infant's patterns of attention and emotion with developmental time.

Relationship Between Infant Patterns of Attention and Emotion and Maternal Expressions

Figure 3 compares the average modeled developmental trajectories for Maternal Neutral Expression and Maternal Talk/Smile (i.e., talk co-occurring with smiling to the infant) with the average modeled trajectories for the infant's patterns of attention and emotion. No trajectories were modeled for the duration of Maternal Smile (i.e., smile without any vocal action) and Maternal Talk (i.e., vocalization or verbalization without any smile) because both were independent of the infant's age, that is, relatively stable over the 14 weeks. As shown by the estimated parameters of the modeled trajectories in Table 2, the durations of Maternal Neutral Expression, as well as of Maternal Talk/Smile, were modeled by a second-degree polynomial function, indicating a curvilinear developmental trend, negative for Maternal Neutral Expression and positive for Maternal Talk/Smile, over the age range investigated. Figure 3 shows that these modeled developmental trajectories were almost mirror images, with a strong decrease and a strong increase, respectively, during the 1st and the 2nd months, and a sort of stabilization during the last weeks of the 3rd month. When comparing infant and maternal trajectories, it is interesting to observe that changes in maternal expressions paralleled changes in the infant's patterns of attention and emotion (a decrease in Simple Attention, i.e., gazing at the mother's face with a neutral expression, and an increase in more active and expressive patterns).

This observation was confirmed by a repeated measures (age period) ANOVA and *t* tests used as post hoc tests, which indicated a significant decrease in the duration of Maternal Neutral Expression from the 1st month ($M = 31.15$ s) to the 2nd month ($M = 10.56$ s), $F(2, 30) = 9.89$, $p < .01$, $t(15) = 3.41$, $p < .01$, as well as a significant increase in the duration of Maternal Talk/Smile from the 1st month ($M = 30.65$ s) to the 2nd month ($M = 64.75$ s), $F(2, 30) = 17.73$, $p < .01$, $t(15) = -4.49$, $p < .01$.

With regard to the real-time relationship between infant and maternal expressions, significant associations and developmental

Table 2
Means (and Standard Errors) for Estimated Parameters of the Multilevel Models for Infant's Simple Attention, Concentrated Attention, Smile (Attentive + Open), Cooing Expression, and Excited Attention and Maternal Neutral Expression and Talk/Smile

	Infant					Maternal	
Parameter	Simple Attention	Concentrated Attention	Smile	Cooing Expression	Excited Attention	Neutral Expression	Talk/Smile
			Average curve				
Intercept	14.43 (4.62)	−11.02 (5.04)	−9.98 (3.75)	30.21 (4.87)	9.71 (2.69)	45.09 (9.77)	6.22 (7.02)
Age	4.77 (1.86)	7.76 (1.91)	4.84 (1.28)	3.69 (1.10)	1.53 (0.76)	−6.80 (1.48)	11.58 (2.95)
Age^2	−0.38 (0.12)	−0.35 (0.14)	−0.16 (0.08)	−0.34 (0.17)		0.28 (0.06)	−0.46 (0.18)
			Random				
σ_0^2				251.20 (109.00)	32.04 (17.37)	1351.00 (433.20)	
σ_{01}				46.32 (24.05)	7.82 (3.11)	−167.70 (52.74)	
σ_1^2	23.55 (10.51)	20.54 (9.91)	5.13 (3.30)	14.76 (6.38)		18.80 (5.93)	66.22 (29.04)
σ_{02}						5.27 (1.69)	
σ_{12}	−1.70 (0.80)	−1.64 (0.83)	−0.39 (0.27)	1.06 (0.45)		−0.43 (0.13)	−3.86 (1.84)
σ_2^2	0.12 (0.06)	0.15 (0.07)					0.26 (0.13)
			Error				
σ^2	388.1 (39.83)	462.6 (47.47)	255.6 (26.28)	676.6 (75.88)	317.5 (42.42)	201.4 (20.68)	896.9 (92.01)

Note. Standard errors are in parentheses.

changes in associations over the 14 weeks were revealed by both synchronic and sequential analyses. The co-occurrences between infant joint states (expressive configurations + gaze direction) and maternal expressions found to be significant in most of the dyads during face-to-face communication are compared across the three age periods (1st, 2nd, and 3rd months) in Table 3. As shown in the table, Infant Neutral Expression Gazing Elsewhere co-occurred at a greater than chance level with Maternal Neutral Expression during the 1st month but with Maternal Talk during the 2nd and 3rd months; Infant Simple Attention to the Mother's Face co-occurred at a greater than chance level with Maternal Talk/Smile during the 1st and 2nd months but not any more during the 3rd month; on the contrary, during the 3rd month, but beginning from the 2nd month, Maternal Talk/Smile co-

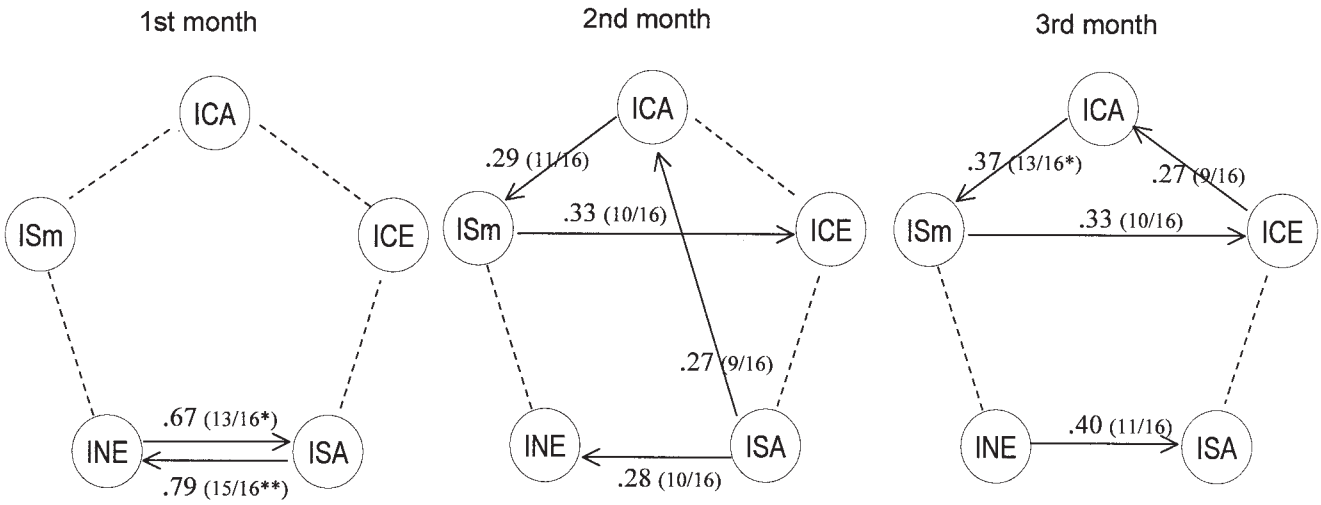

Figure 4. Mean transitional probabilities between the infant's joint states (expressive configurations + gaze direction) during mother–infant face-to-face communication. Only transitional probabilities found to be significant for most of the subjects are included. The proportions of subjects with significant transitional probability appear in parentheses. ICA = Infant Concentrated Attention to the Mother's Face; ICE = Infant Cooing Expression at the Mother's Face; ISA = Infant Simple Attention to the Mother's Face; INE = Infant Neutral Expression Gazing Elsewhere; ISm = Infant Attentive Smile or Open Smile at the Mother's Face. *$p < .05$. **$p < .01$.

Table 3
Co-Occurrences (in Seconds) Between Infant Joint States (Gaze Direction + Expressive Configuration) and Maternal Expressions Found to Be Significant in Most of the Dyads

	Maternal expression		
Infant joint state	Neutral Expression	Talk	Talk/Smile
	1st month		
Neutral Expression Gazing Elsewhere	1,583 (13.4; 10/16)		
Simple Attention to the Mother's Face			671 (12.7; 10/16)
	2nd month		
Neutral Expression Gazing Elsewhere		2,733 (17.1; 10/16)	
Simple Attention to the Mother's Face			1,182 (2.1; 9/16)
Smile at the Mother's Face			804 (24.8; 11/16)
Cooing Expression at the Mother's Face			856 (8.2; 10/16)
	3rd month		
Neutral Expression Gazing Elsewhere		2,207 (21.4; 12/16)	
Smile at the Mother's Face			1,355 (25.1; 13/16)*
Cooing Expression at the Mother's Face			1,316 (3.6; 10/16)

Note. Adjusted residuals, followed by the proportion of subjects with significant adjusted residuals, appear in parentheses.
* $p < .05$.

occurred at a greater than chance level with Infant Smile and Infant Cooing Expression.

These associations between infant and maternal expressions, as well as their developmental changes, were highlighted by sequential analysis. The transitional probabilities between infant joint states (expressive configurations + gaze direction) and maternal expressions calculated on data grouped into the three age periods and found to be significant in most of the dyads are compared in Figure 5. As shown in this figure, only the significant probability of Maternal Talk (to get the infant's attention) given Infant Neutral Expression Gazing Elsewhere remained stable across the 3 months. In fact, a main developmental change from a significant

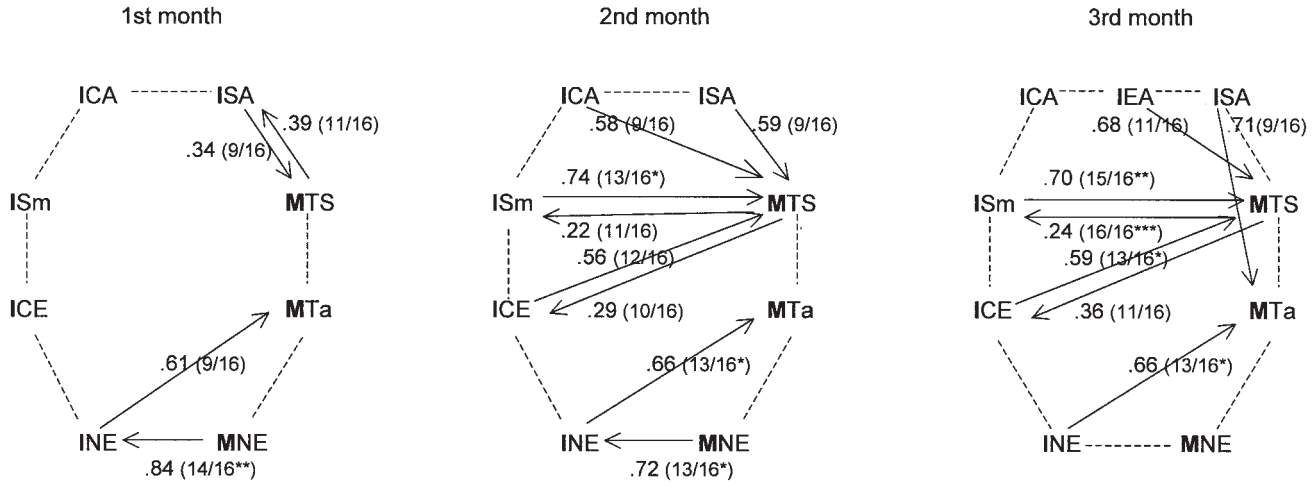

Figure 5. Mean transitional probabilities between infant's joint states (expressive configurations + gaze direction) and maternal expressions during mother–infant face-to-face communication. Only transitional probabilities found to be significant for most of the subjects are included. The proportions of subjects with significant transitional probability appear in parentheses. **M**TS = Maternal Talk/Smile; **M**Ta = Maternal Talk; **M**NE = Maternal Neutral Expression; **I**NE = Infant Neutral Expression Gazing Elsewhere; **I**CE = Infant Cooing Expression at the Mother's Face; **I**Sm = Infant Attentive Smile or Open Smile at the Mother's Face; **I**CA = Infant Concentrated Attention to the Mother's Face; **I**EA = Infant Excited Attention to the Mother's Face; **I**SA = Infant Simple Attention to the Mother's Face. *$p < .05$. **$p < .01$. ***$p < .001$.

association between Maternal Talk/Smile and Infant Simple Attention to a significant transition from Infant Concentrated Attention to Maternal Talk/Smile, and significant associations between Maternal Talk/Smile and Infant Smile, as well as between Maternal Talk/Smile and Infant Cooing Expression, were observed from the 1st to the 2nd month. In particular, starting from the 2nd month, the probability of Maternal Talk/Smile given Infant Smile was significant for a significant number of dyads. Through the 3rd month, the mutual influence between the infant's and the mother's expressions of positive affect and active engagement in face-to-face communication continued to increase, so that the probability of Infant Smile given Maternal Talk/Smile, as well as of Maternal Talk/Smile given Infant Cooing Expression, became significant for all of the dyads or (in the latter case) for a significant number of them. Moreover, the emergence of Infant Excited Expression also significantly affected the occurrences of Maternal Talk/Smile.

Discussion

In this study, we preliminarily documented the diversity of the infant's expressive configurations related to early attention to the mother's face. Then, in particular, we documented the process of developmental change in the relationship between the infant's attention and emotion, as well as in the relationship between infant and maternal expressions during mother–infant face-to-face communication over the first 14 weeks of life (i.e., across the key developmental transition related to the emergence of exogenous smiling).

Emotional Aspects of the Infant's Attention to the Mother's Face

The identification of a conspicuous number of different infant expressive configurations that co-occurred at a greater than chance level with gazing at the mother's face suggests that qualitatively different forms of infant attention to the mother's face are associated with qualitatively different emotions, such as interest, effortful concentration, astonishment, and pleasure from the 4th to the 6th weeks of life, depending on the dyad, and cheerfulness and excitement only a short time later. These findings suggest that a range of different patterns of infant attention and emotion is a hallmark of mother–infant face-to-face communication from the 2nd month of life. In addition, the fact that the same patterns of attention and emotion were shown by some infants 3–4 weeks later than they were shown by other infants (see Figure 2) highlights the wide interindividual variability in the relationship between attention and emotion during early face-to-face communication.

These findings also suggest that the infant's attention to the mother's face is emotional. From a functionalist perspective, "emotions are the process by which an individual attempts to establish, change, or maintain his or her relation to the environment on matters of significance to the person" (Witherington, Campos, & Hertenstein, 2001, p. 429). If we assume that young infants regulate their relationship with the environment primarily via gaze direction changes, our findings show that gaze/attention is not merely neutral or cognitive. Developmental analysis revealed how, across the 2-month transition, the relationship between the infant's attention and emotion developed and became more complex and diverse.

Complexity of Change Across the 2-Month Transition

The results support the hypothesis of curvilinear developmental trajectories for the durations of the joint states of gazing at the mother and infant expressive configurations—except for Excited Attention, which showed a linear trend—over the age range investigated. A main qualitative change from the dominance of Simple Attention (i.e., gazing at the mother's face without any sign of emotional engagement) to the dominance of expressive configurations that showed more active and emotionally positive forms of attention to the mother was found around the end of the 2nd month, supporting the hypothesis of a qualitative change in the relationship between attention and emotion in coincidence with the 2-month developmental transition.

In particular, although a significant decrease in the duration of Simple Attention emerged in the 3rd month, a significant increase in the duration of all the main different patterns of attention and emotion—except for Excited Attention, which emerged later—occurred during the 2nd month. The durations of Smile and Cooing Expression continued to increase significantly and almost significantly, respectively, also during the 3rd month. These findings provide clear evidence that the 2nd month marks the beginning of a relationship between attention to the mother's face and positive emotions on the part of the infant.

Three Developmental Phases

These findings also highlight three different phases in the development of the relationship between the infant's attention and emotion across the first 3 months of life (see Figure 3): the dominance of Simple Attention, that is, of the absence of a relationship between attention and emotion, during the 1st month; the co-presence of Simple Attention and a variety of different patterns of attention and emotion, including attention associated with effortful concentration (as a main pattern), as well as with smiling, an approaching expression, and, later, motor excitement, during the 2nd month; and, finally, the dominance of a more active and approaching pattern of attention and emotion such as Cooing Expression, together with an increase in other active and playful patterns, such as Attentive Smile, Open Smile, and Excited Attention, during the 3rd month.

Two Types of Patterns of Infant Attention and Emotion

The different phases point out a main difference in the trajectories of the diverse patterns of attention and emotion: in particular, a difference between the trajectory of Concentrated Attention, which peaks toward the end of the 2nd month and then tends to stabilize, and the trajectories of Cooing Expression, Smile, and Excited Attention, which, to the contrary, continue to increase over the 3rd month. This difference suggests that there are two different types of developmental patterns of attention and emotion. The first type, occurring from the 2nd month and expressed by what we have called Concentrated Attention, is more receptive. The second type, occurring after 8 weeks, is characterized by more approaching and playful associations of attention and emotion, such as

Cooing Expression, Smile, and Excited Attention. This finding is consistent with Kokkinaki and Trevarthen's (1998) observations that the infant's engagement in face-to-face communication seems to be characterized by a more "serious" (because it is effortful) participation during the 2nd month, whereas during the 3rd month it seems to be characterized by more playful and cheerful ways of interacting. This may be understood by considering that in young infants, the receptive effort needed to follow the complex pattern of stimulation produced by the mother and to engage in face-to-face communication is greater—that is, takes more time—than that in older infants. Moreover, the literature documents that during the 2nd month, infants typically show long periods of visual fixation "locked on" (Karmel, Gardner, & Magnano, 1991) a main stimulus because they still have scant flexibility in moving their gaze.

Overlapping Developmental Trajectories

On the whole, the phases depicted by the emergence and development of the different patterns of attention and emotion, when contrasted with the development of Simple Attention over the first 3 months of life, show an overlapping of developmental trajectories that emerge at different times and that increase and cross each other, exceeding Simple Attention toward the end of the 2nd month (as in the case of Cooing Expression and Concentrated Attention) and also later, when Simple Attention decreases significantly (as in the case of Smile and Excited Attention). Thus, although a main qualitative change emerges in coincidence with the 2-month developmental transition, the co-presence and overlapping of a variety of different patterns of attention and emotion over the 2nd and 3rd months suggests that developmental changes in the relationship between infant's attention and emotion might be better explained by an overlapping waves model (Chen & Siegler, 2000; Siegler, 2002) than by a sudden shifts stage model. Although the overlapping waves model has arisen from Siegler's and other investigators' microgenetic studies as a theory of cognitive change, it also seems to us a useful way of thinking about developmental changes in the patterns of the infant's attention and emotion during early face-to-face communication. Indeed, results from our microgenetic research design allowed us to document that change in the relationship between the infant's attention and emotion across a key transitional period does not coincide with a sudden upward shift from the absence of an association to an association between attention and emotion, or from a simpler pattern to a more complex pattern of attention and emotion, but, rather, with a co-presence of simple attention and both older and newer increasing patterns of attention and emotion.

The temporary co-presence of earlier patterns during a period of time when newly emerging patterns are being formed has been observed in a number of recent microgenetic studies (Camaioni, Aureli, Bellagamba, & Fogel, 2003; Granott, 2002; Granott, Fischer, & Parziale, 2002; Fogel & Lyra, 1997) and has been called *bridging*. Similar to Vygotskij's (1978) notion of the zone of proximal development, bridging is a way in which the child or the adult makes explicit links between what is newly emerging and what is already known (Rogoff, 1990; Valsiner, 1997). In distinct contrast to dynamic systems and stage theory models of nonlinear transitions in development, overlapping waves, or bridges, reveal a dynamic developing system that spontaneously creates emergent buffers for change such that individuals can move toward the future from the safety of what has already been established. Developmental dynamics are apparently more complex than simple stage models would predict. This is further supported by findings from sequential analyses across the 3 months of age investigated, which show both stability and developmental changes in transitional probabilities between patterns of infant's attention and emotion, as well as between infant patterns and maternal expressions, during face-to-face communication.

Developmental Changes in Sequential Patterns of Infant Attention and Emotion

The results show that the different patterns of the infant's attention and emotion are organized in recurrent sequences and cycles within the context of face-to-face communication across the age range investigated. In particular, findings from sequential analyses across the 1st, 2nd, and 3rd months indicate an increasing complexity in sequential patterns of attention and emotion with developmental time, from a simple cycle between Neutral Expression Gazing Elsewhere and Simple Attention to the Mother's Face, observed from the very first weeks of life, to recurrent sequences in which more active forms of attention are related to positive emotions and approaches to the mother.

The fact that Concentrated Attention to the Mother's Face—identified by brow knitting—preceded Smile significantly in most of the subjects supports data collected by Oster (1978) and suggests that brow knitting may reflect a buildup of tension produced by intense gazing that is then released through smiling. Moreover, our findings indicate that from the 2nd month, in most of the subjects, both Concentrated Attention to the Mother's Face and Cooing Expression were significantly related to Smile at the Mother's Face, often in a sequence of transitional patterns. In addition, during the 3rd month, this sequence was enriched by a third transitional probability—from Cooing Expression to, again, Concentrated Attention—in a recurrent sequence of different patterns of attention and emotion. This might suggest that approaching actions on the part of the infant are nourished by the release of tension produced by intense looking and, at the same time, by the pleasure of getting emotional information from the mother's face. This sequence reveals a process of mutual amplification between receptive (effortful attention) and approaching (Smile and Cooing Expression) patterns of attention and emotion, each supporting and enhancing the other through cyclical iteration.

These findings are consistent with a model of development that evolves through reiterated microdevelopmental sequences (Granott, 2002) and suggest that the relationship between infant attention and emotion is stabilized dynamically by positive feedback (amplification). In contrast to negative feedback (regulation, control, homeostasis), positive feedback is related to the growth of an attractor over time (Lewis, 1995; Thelen & Smith, 1994). Positive feedback is the hallmark of a dynamic system in which new developmental forms emerge and stabilize over time by means of the mutual associations among existing components. In this case, the association strength of the attractor is directly related to the felt significance (the growth of positive feelings) of gazing at the mother. Conversely, attention grows because particular objects of attention become increasingly attractive, that is, because the attention means something increasingly positive to the infant in establishing an increasingly stable relationship to the mother.

Mutual Influence Between Infant Patterns of Attention and Emotion and Maternal Expressions

The mother's expressions also play an important role in the process by which the infant's receptive and approaching patterns of attention and emotion are amplified and organized in relatively stable sequences of communication, as suggested by findings from the sequential analysis of infant expressions and maternal expressions. These findings clearly indicate that the relationship between infant's attention and emotion in the context of mother–infant face-to-face communication cannot be considered independently of maternal behavior. Positive feedback within the infant, that is, between receptive and approaching patterns of infant attention and emotion, is nested into sequences of positive feedback between the infant's and the mother's behavior.

As shown in Figure 5, in the 2nd and 3rd months, but not in the 1st month, Infant Smile and Infant Cooing Expression are sequentially linked with Maternal Talk/Smile. These sequential linkages go in both directions so that Maternal Talk/Smile, Infant Smile, and Infant Cooing Expression can cycle between each other in different ways, suggesting the existence of a positive emotional attractor. At 2 months, Infant Simple Attention, as well as Infant Concentrated Attention, followed by Maternal Talk/Smile, give access to this attractor. By 3 months, infant receptive patterns such as Simple Attention and Concentrated Attention are not sufficient to engage the attractor, but Excited Attention, a more positive and approaching form of expression, serves that function. In the 3rd month, Infant Simple Attention leads the dyad into its alternative sequential attractor, the sequence between Infant Neutral Expression and Maternal Talk, which has been a stable attractor in the system at each of the 3 months.

Our co-occurrence analyses (see Table 3) provide another confirmation of a stable positive emotional attractor at 2 and 3 months. Infant Smile and Infant Cooing Expression significantly co-occurred with Maternal Talk/Smile at both ages. Infant Simple Attention also co-occurred significantly with this maternal expression at 2 months but not at 3 months. These data are consistent with findings from other co-occurrence studies showing that, during early face-to-face interaction, when the infant gazes at the mother's face, the infant tends to smile significantly more when the mother smiles than when the mother does not smile (Kaye & Fogel, 1980; Messinger et al., 2001) and tends to produce vocalizations of positive affect significantly more when gazing at the mother than when gazing away from the mother (van Beek, Hopkins, Hoeksma, & Samsom, 1994; Weinberg & Tronick, 1994).

A third and independent confirmation of the emergence of a stable emotional attractor around the 2nd month comes from the convergence of the developmental trajectories of mother and infant expressions. These findings show that developmental changes in maternal expressions, indexed by a significant decrease in Maternal Neutral Expression during the 2nd month in coincidence with a significant increase in more approaching and emotionally positive expressions (Maternal Talk/Smile), parallel developmental changes in the infant's patterns of attention and emotion during face-to-face communication.

Taken together, these findings suggest that infant positive emotional configurations emerge developmentally as a result of positive feedback relationships with infant attention and maternal expressions. Although simple attention and simple endogenous smiling exist from birth, these expressions await a dynamic social engagement that activates iterative sequential linkages. These sequences become consolidated by positive feedback and mutual amplification, both between the infant and the mother and within the infant. In other words, complex positive emotions are the result of a developmental process that begins in the 2nd month of life and continues thereafter.

Conclusion

This study provides new data on how the relationship between the infant's attention and emotion when the infant is in an alert state during face-to-face communication changes from the relatively unexplored period of the 1st month of life, through the key transition related to the acquisition of exogenous smiling, and then through the 3rd month. The use of a microgenetic research design, in which intensive observations were conducted over a relatively short but rapidly changing developmental period, allowed us a fine-grained examination of the early change processes in the relationship between the infant's attention and emotion during mother–infant face-to-face communication. In particular, the possibility of modeling the average developmental trajectories of the different patterns of attention to the mother's face and emotion with a multilevel modeling technique allowed us to visualize the form of developmental change around the 2-month transition.

This change is not a sudden shift but, rather, a cross between a significantly decreasing trajectory of simple attention and older and newer increasing trajectories of active and emotionally positive forms of attention to the mother. Moreover, the shapes of the different developmental trajectories highlight two types of patterns of attention and emotion on the part of the infant engaged in face-to-face communication: a more receptive and effortful pattern, dominant during the 2nd month, and a more approaching and playful pattern, which characterizes the 3rd month.

Finally, the microanalysis of change processes in the relationship between the infant's attention and emotion in real time, achieved through sequential analysis, allowed us to document the presence of attentional processing efforts related in significant sequences with pleasurable approaching expressions from the 2nd month of life. As described above, the cyclic sequence of significant transitions between receptive and approaching patterns in the infant's attention and emotion becomes organized and stabilized within sequences of mother–infant face-to-face communication via positive feedback between the infant's attention and emotion. Further research will be focused on deepening the analysis of the individual differences that emerged in this study.

The relatively small sample size, which was due to both the choice of a microgenetic design based on weekly observations and the practical difficulties of data collection with newborn infants, was counterbalanced by an elevated number of videotaped sessions ($N = 222$). Nevertheless, the sample size clearly needs to be enlarged to assess the consistency of our findings. On the whole, these findings document that the 2nd month is a special period of developmental change and reorganization in the patterns of the infant's attention and emotion during face-to-face communication and highlight the importance of studying the relationship between infant attentional and emotional processes starting from the beginning of the 2nd month of life.

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(*Appendix follows*)

Appendix

Procedure for Identifying the Infant Expressive Configurations

The infant expressive configurations were discovered using both quantitative and qualitative analyses. For the quantitative part, two independent researchers certified in the Facial Action Coding System (FACS) and trained in its application to infants (Baby FACS, Oster & Rosenstein, in press) used the Baby FACS coding system to select those facial actions shown repeatedly by all of the infants during face-to-face communication regardless of the infants' gaze direction. The following facial action units (AUs) identified by both the researchers were selected as candidates for including in the definitions of the expressive configurations.

Upper face actions. We selected the following expressions: (a) brow raising (AU 1 + 2), produced by the action of the *frontalis* muscle, which raises the eyebrows and the skin of the forehead, and (b) brow knitting (AU 3), produced by the action of the *corrugator supercilii*, which in infants creates a typical appearance of "butterfly wing muscle bulges curling up from the inner corners of the brows," as described by Oster and Ekman (1978, p. 250). Although cheek raising (AU 6), produced by the contraction of the muscle encircling the eye (*orbicular oculis, pars lateralis*), was frequently and quite easily observed in most of the infants, it was not considered as a main index for identifying expressive configurations because of the difficulty of distinguishing this action in 3 of the infants.

Lower face actions. We selected the following expressions: (a) lip corner raising (AU 12), produced by the action of the zygomatic muscle, which is responsible for basic mouth smiling, and (b) lip parting (AU 25), produced by a slight action of the *depressor labii*, and mouth opening to varying degrees (AU 26b/c/d), produced by a relaxation of the muscles which keep the jaw closed. In this sample, we could not distinguish between the different intensities of lip parting, so we chose to limit our description to the simple contrast between "mouth only partially open" and "mouth totally open." Also with regard to the observed different kinds of lip and tongue movements—such as lip protruding, tightening, shaping for cooing, and lip and tongue appositions to forming speechlike sounds—we distinguished only the presence versus the absence of "lip shaping for cooing or prespeech movements" (Trevarthen, 1979) regardless of the emission of sounds, in order to focus on mouth shapes that seemed to have communicative intent.

Because in young infants engaged in face-to-face communication, lip shaping for cooing and prespeech movements are frequently produced silently, and because the emission of sounds does not change the infant's global expression, we considered the presence or absence of vocalizations as part of the same infant expressive configurations. Because pure motor quiet was shown only for brief periods, whereas slow hand and arm movements seemed to accompany most of the infant facial actions during face-to-face communication, we chose to distinguish between "scant motor activity" (including either motor quiet or hand and/or arm or limb movements) and "strong motor activity" (including fast limb movements such as open arm up–down movements and leg kicking) to discriminate between different expressive configurations shown by the infants.

In a second level of quantitative analysis used for the development of the expressive configuration coding system, the presence versus absence of each of the selected facial actions (brow raising, brow knitting, lip corner raising), as well as the presence of "mouth only partially open" versus "mouth totally open" versus "lip shaping for cooing or prespeech movements" considered as mutually exclusive categories, and the presence of "scant motor activity" versus "strong motor activity" considered as mutually exclusive categories as well, were coded continuously—and independently—for a small sample of 3 mother–infant dyads. The aim of this particular coding was to assess any particular co-occurrence of these facial actions and co-occurrences with the two categories of motor activity.

Findings from this preliminary co-occurrences computation (GSEQ, Bakeman & Quera, 1995) showed that both brow knitting and brow raising never co-occurred with smiling (lip corner raising) and, between them, rarely co-occurred. Brow knitting alone never co-occurred with "mouth totally open" and "strong motor activity." On the contrary, brow raising co-occurred with "strong motor activity" as well as with "scant motor activity" and with the different categories of mouth opening. Lip corner raising co-occurred with both "mouth only partially open" and "mouth totally open" and with "scant motor activity." "Lip shaping for cooing or prespeech movements" co-occurred rarely with brow raising, brow knitting, and lip corner raising but co-occurred with "scant motor activity."

Finally, on the basis of these quantitative results, and of a further qualitative analysis consisting of repeated observations of videos, we considered the absence or the presence of at least one of the selected facial actions and their co-occurrences with the categories of motor activity as criteria for developing the infant expressive configuration coding system.

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