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Differential Effects of Happy, Neutral, and Sad Still-Faces on 2-, 4- and 6-Month-Old Infants

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The role of facial expression in the determination of infants' reaction to the sudden still-face of a social partner was investigated. In a within subject design, 2, 4 and 6-month-old infants were tested in periods of normal interaction interspersed with periods of prolonged still-face episodes in which the female adult social partner adopted either a happy, neutral, or sad static facial expression while maintaining eye contact with the infant. Proportion of infants' smiling and gazing at the social partner as indices of reaction from the various still-face episodes reveal that, in comparison with same age control groups, four and six-month-old infants did not demonstrate any differential responses depending on either happy, neutral, and sad still-faced expression. In contrast, two-month olds demonstrated some evidence of a reduced still-face effect in the happy still-face condition. These results point to early developmental changes in the mechanisms underlying the still-face phenomenon. We propose that by 4 months, and not prior, the reaction to still-face episodes are essentially based on the detection of social contingencies. Copyright © 2002 John Wiley & Sons, Ltd.

Key words: gazing; smiling; still-face; facial expression; emotion; social interaction

By 3 months, infants start to demonstrate marked negative responses to the sudden adoption of a still face by their mother in ongoing face-to-face play interactions. During the still-face episode, infants are typically reported to smile less and look away, in addition to displaying enhanced negative affects and associated self-comforting behaviour (Cohn and Tronick, 1989; Gianino and Tronick, 1988; Mayes and Carter, 1990; Muir and Hains, 1993; Toda and Fogel,

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1993; Tronick *et al*., 1978; Weinberg and Tronick, 1996). The still-face phenomenon is interpreted as an index of young infants' affective attunement to social partners in dyadic exchanges (Stern, 1985), as well as evidence of early social expectations (Tronick *et al*., 1978; Muir and Hains, 1993).

Of all existing experimental paradigms, the phenomenon associated with the still-face procedure is arguably the most robust and reliable measure of affective attunement and implicit social cognition in early development. It points to young infants' sensitivity of others as communicative agents who, when engaged in eye-to-eye contact, are expected to be socially responsive and to reciprocate (Rochat and Striano, 1999). In general, the still-face phenomenon suggests that early on infants are actively engaged in monitoring how people relate to them: how they feel and what they will do next in the context of dyadic exchanges.

Although the still-face phenomenon is well documented, questions remain as to what exact mechanisms underlies it. Studies conducted mainly with 5–6 month-old infants provide important, but for the most part non-developmental information regarding the determinants and modulation of the still-face phenomenon. Reactions to the still-face are attenuated when physical contact (touch) is maintained during the episode (Stack and Muir, 1992; Stack and LePage, 1996). The phenomenon is moderated but persists when the infant interacts with the partner appearing on a TV and while her interacting voice is still heard by the infant during the still-face episode displaying a suddenly frozen face on the screen (Muir and Hains, 1993). In general, reactions to the still-faced partner is not exclusively controlled by visual information specifying changes from dynamic and reciprocating, to abruptly static and non-reciprocating facial display (Muir and Hains, 1993).

The early sensitivity to the contingent responses by the social partners as well as infant's attunement to the sequence of dyadic states are probably important determinants of the still-face phenomenon (Cohn and Tronick, 1987). By 5–6 months, infants appear to develop specific patterns of contingent social responses in face-to-face interaction (e.g. smiling), that match the level of their mother's contingency (Bigelow, 1998). Based on a close-circuit video system paradigm Murray and Trevarthen (1985) reported in infants as young as 2 months changes in emotional and attentional responses when interacting with their mother live, compared to a replay of a previous session (but see Rochat *et al*., 1998). Using the same paradigm, young infants from approximately 2 months of age are reported looking and smiling more at a live compared to a replayed interaction with their mother (Nadel and Trembley-Leveau, 1999), or a female stranger (Hains and Muir, 1996).

Related to social contingency detection, and probably the still-face phenomenon, between 2 and 6 months young infants develop a sensitivity to the invariant spatio-temporal structure of routine plays introduced by social partners. Recent evidence demonstrates that by 4 months infants detect protonarrative envelopes in face-to-face play interactions (Rochat *et al*., 1999). In contrast to 2-month-old infants, 4- and 6-month olds look more and smile significantly less at an adult stranger engaging in a systematically disorganized (scrambled) peek-a-boo game, compared to an organized one (Rochat *et al*., 1999).

If contingency detection and the sensitivity to spatio-temporal invariants of face-to-face exchanges probably contribute to the still-face phenomenon and are the basis of the apparent reaction to a violation of infants' social expectations regarding the social partner (Tronick, 1979), another determinant might be the expressionless, flat affect adopted by the social partner while maintaining eye contact during the still-face episode. In existing studies dealing with the still-face phenomenon, experimenters or mothers are typically instructed to adopt a neutral expression, starring at the infant while remaining still. There is a possibility that infants might react mainly to the flat affect expressed by the still-faced partner, in addition to the sudden absence of social contingency (Cohn and Tronick, 1989). D'entremont and Muir (1997) recently addressed this issue with an experiment where 5-month-old faced their mothers posing either happy, sad, or neutral expressions in a succession of still-face episodes interspersed by normal interactions. They report some evidence that infants smile slightly more to their mother with a happy still-faced expression compared to neutral and sad combined. However, this difference was markedly less pronounced compared to the overall still-face phenomenon comparing normal and still-face episodes regardless of emotional expression. No difference was found in relation to infants' gazing or grimacing responses to either still-faced emotional expressions. These findings reinforce the idea that the sudden absence of contingent response on the part of the adult is the major determinant of the still-face phenomenon, although a positive still-faced expression moderates this phenomenon in relation to infants' smiling response only.

The present study was designed to pursue further the investigation of the potential role played by facial expression in the still-face phenomenon. Although the findings of D'entremont and Muir are intriguing, they leave important questions unanswered regarding the development, and the eventual meaning of the differential smiling they report for the happy still-faced expression. In particular, when does such differential smiling response emerge in early development and what might be the function of such response in the context of the experimental still-face paradigm? Why do infants appear to modulate only their smiling and not their gazing response to particular still-faced expressions? We addressed these questions by comparing 2-, 4- and 6-month-old infants' gazing and smiling reactions to neutral, happy, and sad still-face episodes. We consider these responses in relation to a sudden still-face episode in comparison to the preceding normal interaction. Furthermore, to control for fatigue effect as a potential factor in the still-face phenomenon, we compared responses to emotional still-face to the responses of same age infants who experienced a continuous positive face-to-face interaction for approximately the same duration. Muir and Hains (1993, 1999) point out that comparison to a no-change control group who experiences continuous normal social exchange is necessary to rule out the possibility of fatigue and boredom on the part of the infant as determining the still-face phenomenon.

The rationale guiding the research was developmental. Important changes occur between 2 and 7 months regarding infants' visual attention to faces, as well as their detection of facial features (Haith *et al.*, 1977; Johnson *et al.*, 1991; Bushnell, 1979), including gaze direction (Symons *et al.*, 1998), and facial expressions as categories standing for specific affects (Caron *et al.*, 1985; Ludemann and Nelson, 1988). We considered that these changes could potentially contribute to differential still-face effects, particularly in the context of systematically varied still-faced expressions. As infants become increasingly perceptive of internal facial features, whether dynamic or static, and as they develop an ability to categorize emotional expressions, infants should also respond differentially to sudden still-faces that convey more or less congruent affects in relation to the positive exchanges preceding the still-face episode.

In short, the research was aimed at capturing the modulation of smiling and gazing responses in the contexts of sudden interruptions of on-going positive face-to-face interactions, as a function of age and as a function of more or less congruent (i.e., positive or not) emotional expressions by the social partner. As a working hypothesis, we anticipated that between 2 and 6 months still-face effects should become increasingly dependent on the emotional expression of the still-faced partner.

METHOD

Participants

A final sample of 39 infants were included in the analysis of the experimental condition: 12 2-month olds (mean = 2 months, 14 days; range = 1 month, 24 days–2 months, 30 days), 15 4-month olds (mean = 4 months, 13 days; range = 4 months, 1 day–5 months, 2 days), and 12 6-month olds (mean = 6 months, 8 days; range = 5 months, 18 days–6 months, 30 days). Overall, a total of 76 infants were tested, 49 in the experimental condition and 27 in the control condition (see Procedure below). Ten additional infants were tested but not included in the final sample due to fussiness ($N = 4$) and technical errors ($N = 6$). As for the control condition, a final sample of 24 infants were included: 8 2-month olds (mean = 2 months, 9 days; range = 1 month, 27 days–2 months, 15 days), 8 4-month olds (mean = 4 months, 18 days; range = 3 months, 29 days–4 months, 25 days), and 8 6-month olds (mean = 6 months, 11 days; range = 5 months, 30 days–6 months, 19 days). Three additional infants were tested but not included in the final sample, all due to fussiness. Gender was approximately counterbalanced across age groups.

Infants were part of the Emory Laboratory participant pool recruited from a large North Atlanta maternity hospital serving a majority of white middle class families. All infants were full term (>38 weeks gestational age) with Apgar scores between 8 and 10 and a birth weight of 2500 g or more. No health problems were reported by the mother at the time of testing and on the medical chart consulted at the time of delivery. Parents brought their infant to the Emory Infant Lab on a voluntary basis, drawn predominantly (80%) from middle-class Caucasian families living in suburban Atlanta.

Design and procedure

Infants were videotaped while interacting with a female adult stranger sitting across from them 2.5 ft away with their faces aligned for eye contact. Infants were placed in an commercial upright infant seat resting on a table.

In the experimental condition, infants and experimenter faced each other in seven alternating episodes of 30-s periods totaling 210 s. The testing always began and ended with a 30-s period of normal interaction. Each 30-s period of normal interaction was followed by a 30-s period of still-Face. In general, there was an alternation of 30-s normal interaction and 30-s still-face periods (7×30-s episodes for a total of 210 s of testing).

Each still-Face period varied according to the emotional expression adopted by the experimenter while displaying a frozen face, staring toward the infant's eyes whenever the infant was looking toward her. In the *neutral* still-face, the experimenter held a neutral, resting expression with her mouth closed and relaxed. In the *happy* still-face, the experimenter assumed a large, toothy, static smile with an upturned mouth, lifted cheeks, and creased outside eye corners. Finally, in the *sad* still-face, the experimenter slightly tilted her head forward, furrowed her eyebrows inward, and stuck out her lower lip in a pout. This posture was the natural playout of sadness by the experimenter. During the *normal* interaction periods, the experimenter was instructed to actively engage the infants, trying to make them smile and maintain eye contact, talking to them and displaying dynamic facial expressions, but never touching them (Stack and Muir, 1992). The order of still-face emotions (happy, neutral, sad) was counterbalanced across infants of each age group. Overall, there were six different possible orders. Parent(s) watched their infant on a TV monitor, out of sight and silent. In the experimental still-face condition, the experimenter was cued by an assistant standing behind the infant, timing the experiment and signaling when to start and end a particular still-face expression. There was a total of four normal interaction periods and three still-face periods, adding to a total of 210 s of testing time.

The same experimenter posed as the interactive partner and was highly trained for the task. Post hoc viewing by two independent observers of the tapes revealed no accidental change in facial expression during any of the still-face episodes. Pilot observations showed that mothers have typically a hard time holding a still-face while facing their infant, particularly with a specific static emotional expression. For this reason, we reverted to a trained female stranger as the experimenter.

In the control condition, infants and experimenter faced each other in one continuous episode of 3 successive minutes of normal interaction (see above). Note that in comparison, the experimental condition was slightly greater in overall duration (210 s vs 180 s). Considering that this group was meant to control for a fatigue effect contributing to still-face reactions (see introduction), the fact that it is longer in duration increases the probability of a fatigue effect, thus makes the comparison more conservative. Again, the experimenter was instructed not to touch the infant during the interaction, simply voicing and facially gesturing toward the infant while maintaining eye-contact. Parent(s) watched their infant on a TV monitor, out of sight of the infant and silent. Their presence was not noticeable to the infant.

Apparatus

For later analysis, Experimenter and infant were videotaped via two synchronized cameras. Both images were mixed and recorded via a video splitter (Robot mode MV45). A mini-video camera was fastened on a metal rod attached to the back of the infant seat behind the headrest (Computar EM200-L38), providing a frontal view of the experimenter's face as she interacted with the infant. A zoom-lens video camera placed on a tripod behind the experimenter (Panasonic AG-186) recorded a frontal view of the infant's face, including torso. The infant face was also recorded as a single image on a separate video tape for later analysis. This image allowed for an enlarged view of the infant and for blind coding in relation of the particular still-face or normal interaction experienced by the infant.

Large 5″×5″, white Styrofoam boards were placed to the sides of the infant seat as occluders and in order to prevent visual distraction. For coding, a video timer with hundredth second precision (Burst Electronics TC-3 SMPTE) was superimposed onto the recorded image of the infant.

Coding and reliability

Smiling and gazing were coded and measured in percent of the total duration of a period during the testing session.

Smiling was operationally defined as an upturned motion of at least one corner of the mouth, raising of the cheeks, and a creasing of the outward corners of the eyes, regardless of gaze direction.

Gazing was defined as looking toward the experimenter's face.

Coding of smiling and gazing was performed in different real-time passes of the video recording using a computerized event recorder with on/off activation of a keyboard key corresponding to the occurrence of either gazing or smiling. A program calculated the percent of the total episode time the key was activated.

For reliability, two independent coders analysed 20% of the infants of all ages for both the experimental and control groups. For the Experimental group, both coders were blind as to the particular still-faced expression infants were exposed to. Cohen–Kappas for both gazing and smiling on a l-s time base were above 0.85. In addition, correlation coefficients were above 0.92 for all measures, in all conditions, and for all coded episodes.

RESULTS

Results obtained with the experimental infants in each still-face episode were first compared to same age infants exposed to continuous positive interaction (control group). For the analysis, we treated the first and second successive intervals of interaction as distinct episodes (two successive 1-min normal interaction episodes for the control infants; a 30-s normal interaction followed by a 30-s happy, neutral, or sad still-face episode for the experimental infants). We compared separately each of the three emotional still-face experimental events to same age controls in 3 (age: 2-, 4- and 6-month olds) $\times$ 2 (condition: control vs experimental) $\times$ 2 (episode: first and second interval) mixed design analyses of variance (ANOVA). The results of these analyses are presented below in relation to the proportion of time (%) infants gazed at the experimenter (gazing) or smiled (smiling). Note that in the experimental neutral still-face condition, the data set had two empty cells (both from 2-month-olds) which explains the differences in reported degrees of freedom (57 instead of 59).

Gazing

As illustrated in Figure 1, in the context of either the neutral or sad still-face, infants of all age groups demonstrate a decrease in the proportion of gazing toward the experimenter's sudden still-face. This phenomenon is supported by the ANOVA yielding significant condition $\times$ episode interactions, respectively $F(1,57) = 12.98$, $p < 0.0007$ for the neutral still-face, and $F(1,59) = 9.84$, $p < 0.0027$ for the sad still-face. The ANOVA also yielded a significant main effect of age (respectively $F(2,57) = 11.86$, $p < 0.0001$ for the neutral still-face, and $F(2,59) = 9.88$, $p < 0.0002$ for the sad still-face), as well as a significant main effect of episode (respectively $F(1,57) = 15.44$, $p < 0.0002$ for the neutral still-face, and $F(1,59) = 11.70$, $p < 0.001$ for the sad still-face). These main effects are due in both neutral and sad still-face conditions to 1) overall decrease of gazing as a function of testing time, and 2) overall decrease of gazing as a function of age, and in particular by 6 months of age (see Figure 1).

In contrast to the preceding results, in the context of the happy still-face, ANOVA yielded a significant three way interaction of age $\times$ condition $\times$ episode interaction ($F(2,59) = 3.41$, $p < 0.039$). As shown in Figure 1, this interaction rests

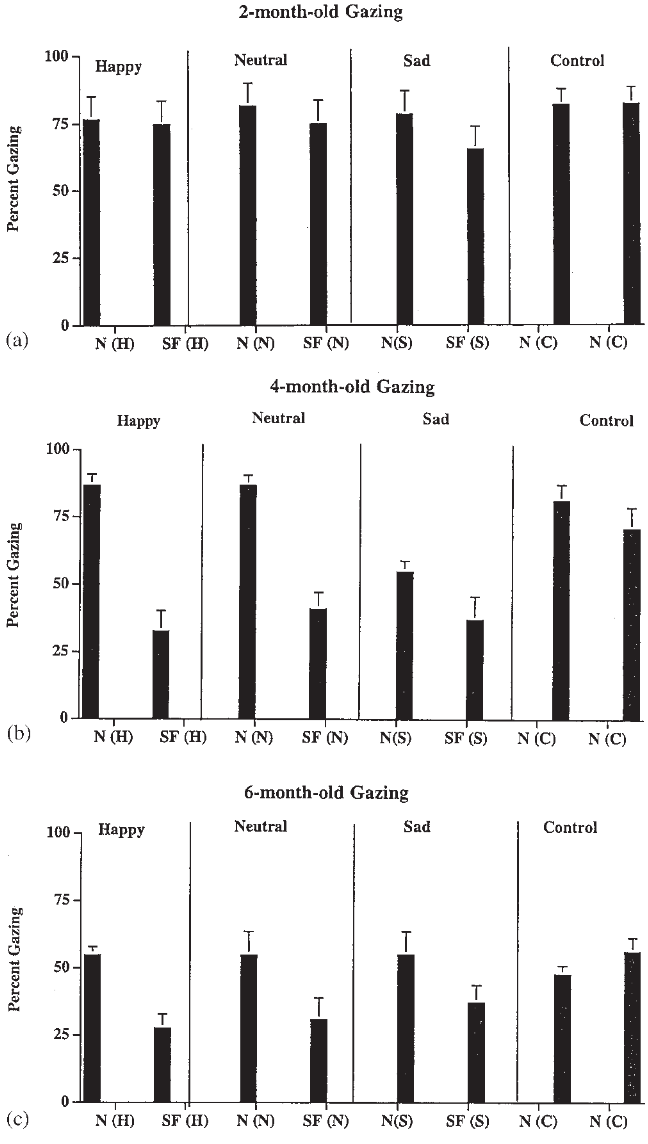

Figure 1. Percent of gazing in the normal interaction episodes (N), preceding and during the happy (SF(H)), neutral (SF(N), and sad (SF(S) still-face episodes, as well as the two successive normal interactions (N(C)) in the control condition for the groups of 2-month olds (lA), 4-month olds (lB), and 6-month olds (1C).

on the fact that compared the 4- and 6-month olds, the group of 2-month-old infants did not show any significant evidence of differential gazing as a function of episode and in comparison to the same age control infants. In other words, in the context of the display of a happy, although static expression, the younger infants demonstrate no evidence of a still-face phenomenon (mean percent gazing for first and second episode of 79.68, and 74.68, respectively, for the experimental group and 81.7 and 82.18 for the control group).

Note that for the group of 4-month olds, the amount of gazing during the normal interaction that preceded the sad still-face episode is markedly reduced compared to the first normal interaction in all the other conditions. There is no apparent explanation for this difference, especially considering that later within subject comparisons yielded no significant order of still-face condition effect (see below).

Smiling

In sharp contrast to gazing, results on the percent of smiling did not yield any significant or even marginally significant results relative to age or condition (see Figure 2(A)–(C). The only significant result across all happy, neutral, and sad still-face contexts is a main effect of episode whereby infants tend to smile markedly less in the second compared to the first episode, independent of age or condition (F's = 21.148; 17.35, and 23.63 for happy, neutral and sad contexts respectively, $p < 0.0001$ for all). This systematic result reflects probably an overall fatigue or familiarization effect, control and experimental infants demonstrating the same trend over time, across age, context, or condition. Overall, the results regarding smiling, and contrary to gazing, do not index any still-face phenomenon.

Note that 4-month olds, in the control condition, demonstrated less smiling in the first minute of normal interaction compared to all the other normal interactions preceding still-face episodes. Such observation might be due to a cohort effect, as different infants comprised control and experimental groups. However, it is interesting to note that such inconsistency in relation to smiling was also found with the experimental group of 4-month olds in relation to gazing (i.e., sad condition, see above). Four-month olds might fluctuate more in their social responses compared to either younger or older infants.

Comparison of emotional still-face types

Subsequent analyses included only experimental infants. We first compared change in proportion of gazing toward the experimenter and smiling from normal interaction factoring both emotional still-face condition and order of presentation (six possible orders, see method). This was meant primarily to assess potential order effects.

Gazing: We performed a 6 (order) $\times$ 3(facial expression: happy, neutral, sad) $\times$ 2(episode: normal vs still-face) mixed design analysis of variance (ANOVA) with order as a between factor. The ANOVA yielded no significant main effect of order, nor any interaction with any of the other variables. Therefore, we collapsed order in a subsequent 3(age) $\times$ 3(facial expression: happy, neutral, sad) $\times$ 2(episode: normal vs still-face) ANOVA. This analysis yielded a significant main effect of age ($F(2,36) = 7.23$, $p < 0.002$). As in the previous analyses, results indicate an overall decrease of gazing as a function of age. Confirming the previous analyses, the ANOVA yielded a significant episode effect ($F(1,36) = 46.14$, $p < 0.0001$), as well as a significant age $\times$ episode interaction ($F(2,36) = 6.79$, $p < 0.003$). The episode effect tends to increase as a function of age. No significant effect of facial expression, nor any significant interactions between age and facial expression, nor any age $\times$ condition $\times$ episode interactions were found.

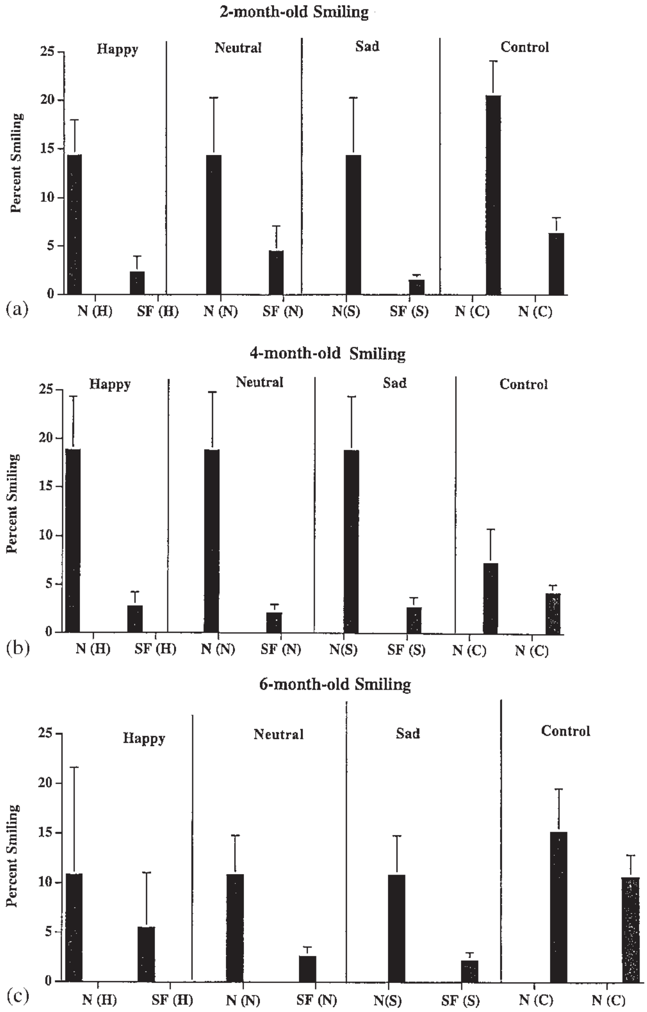

Figure 2. Percent of smiling preceding (N or normal interaction) and during the happy (SF(H)), neutral (SF(N), and sad (SF(S) still-face episodes, as well as the two successive normal interactions (N(C)) in the control condition for the groups of 2-month-olds (1A), 4-month olds (lB), and 6-month olds (1C).

For further control of a possible order effect, we also compared infants' responses to the first experimental still-face event (either neutral, happy, or sad) following the first normal interaction episode. We performed a 3 (age) × 3(facial expression) × (episode) mixed design ANOVA with age and facial expression as between subject variables, and episode as a within subject variable. Confirming general trends from the previous analyses, this ANOVA yielded significant main effects of age and episode (respectively $F(2,30) = 10.81$, $p < 0.0003$ and $F(1,30) = 29.74$, $p < 0.0001$). Interestingly, the ANOVA also revealed a significant condition main effect ($F(2,30) = 7.03$, $p < 0.003$), infants tending overall to gaze more in the happy still-face condition compared to the sad or neutral condition (average looking at the experimenter of 78% in the happy condition compared to 52% and 54% for the sad and neutral conditions). However, this condition effect interacts significantly with the episode variable (($F(2,30) = 4.99$, $p < 0.01$). Analyses of the simple effects indicate that there is a significant episode effect (i.e. significant still-face effect) in all but the neutral still-face condition ($p = 0.442$ compared to $p < 0.0001$ for the sad condition and $p < 0.02$ for the happy condition). Finally, and most interesting is the fact that the ANOVA yielded a significant age-by-episode interaction ($F(2,30) = 6.25$, $p < 0.006$). Analyses of the simple effects confirm the developmental trend toward greater episode effect between 2 and 6 months of age. Four and six-month-old infants did show a significant decrease of gazing toward the experimenter during the still-face episode (respectively $p < 0.001$ and $p < 0.013$), as 2-month olds did not ($p = 0.387$).

Smiling: Once again, to assess a potential order effect, we performed a 6(order) × (facial expression: happy, neutral, sad) × (episode: normal vs still-face) mixed design analysis of variance (ANOVA) with order as a between factor. The ANOVA yielded no significant main effect of order, nor any interaction of order with any of the other variables. Collapsing order in a subsequent 3(age) × 3(facial expression: happy, neutral, sad) × 2(episode: normal vs still-face) ANOVA, this analysis yielded only a significant episode main effect ($F(1,36)=16.60$, $p < 0.0002$). No significant interactions with either age or facial expression were found. Confirming the previous analyses, overall, infants smiled significantly less during the still-face episode, regardless of facial expression.

For further control of a possible order effect, we also compared infants' smiling to the first experimental still-face event (either neutral, happy or sad) following the first normal interaction episode. Again, we performed a 3(age) × 3(facial expression) × 2(episode) mixed design ANOVA with both age and facial expression as between subject variables, episode as a within subject variable. The analysis yielded once more a significant episode main effect ($F(1,30) = 19.12$, $p < 0.0001$), the overall proportion of smiling markedly decreasing during the second (still-face) episode. No other significant main effect, nor any significant interaction were found.

DISCUSSION

The present research was designed to investigate further the determinants of the still-face phenomenon, as a function of age and of the emotional context of the sudden still-face episode. Age and the facial expression during the still-face were both considered as contributors to the phenomenon.

In order to control for a potential fatigue effect possibly confounded with the still-face effect, a first set of analyses was performed in reference to same age control infants who interacted for a comparable overall duration with a female adult stranger without any still-face interruptions. Finally, we compared directly the still-face phenomenon as a function of age, in relation to the three types of facial expression of the Experimenter during the episode.

In general, we confirm the reliable effect of sudden still-face in infants as young as 2 months (see Figures 1 and 2). What is particularly remarkable is that this effect is found in the context of our repeated design dictating successive interaction episodes of only 30 s. Previous studies have typically reported a still-face phenomenon in the context of 1 min or longer episodes (Muir and Hains, 1993; Tronick *et al.*, 1978).

Although our data suggest that age and emotional content of the social partner's facial expression plays a role in modulating the still-face phenomenon, it did not in the way we anticipated. We hypothesized that as a function of age, and in particular between 2 and 6 months, infants would become increasingly sensitive to the emotional content of the still-face. What we found is actually some evidence for the reverse.

In the first set of analyses (comparison with same age control group), and in relation to gazing, it is the youngest infants (2-month olds) who demonstrated a sensitivity to such content in their reaction to the still-face. When the experimenter adopted a happy still-face, their visual attention was unaffected during the still-face episode. In contrast, 4- and 6-month olds showed significant decrease in visual contact with the experimenter during the still-face episode. In the context of a happy still-face, the younger infants did not react with gaze aversion as they did for the neutral and sad still-faces. So why do younger infants only demonstrate some evidence of a sensitivity to the emotional content in this analysis, and why the contrast between happy vs neutral or sad content of the still-face phenomenon?

These findings need to be considered in relation to the positive emotional context that preceded and followed immediately the still-face episode. When not engaging in the still-face, the experimenter was interacting with the infants, instructed to make them smile and actively engage positive affective responses from them. The context scaffolded by the experimenter was therefore highly positive. The still-face interrupted this positive exchange and the facial emotion adopted by the experimenter during this episode was more or less congruent in content with the preceding lively exchange. Two-month olds appear to have picked up on the congruence of the happy still-face, continuing to gaze equally toward the Experimenter. Four and six-month olds did not, so why?

In a recent study, we found that 4- and 6-month olds, in contrast to 2-month olds, are sensitive to the spatio-temporal invariants of play interactions with a social partner (Rochat *et al.*, 1999). This research suggests that by 4 months, infants become newly sensitive to the timing and spatio-temporal contingencies of face-to-face interactions. These contingencies would define narrative envelopes in protoconversation, as for example in the succession of predictable events offered by peek-a-boo games.

From 4 months on, infants appear to develop social expectations in dyadic exchanges that are primarily based on a sensitivity to social contingencies or sensitivity to what can be expected next in the behaviour of an interacting and reciprocating social partner (Rochat and Striano (1999); see also Tronick and Cohn (1989) for evidence of developing coordination in mother-infant exchanges between 3 and 9 months). Prior to 4 months, and from the second month when they start to open up to the social world via enhanced visual attention to faces and socially elicited smiling (Wolff, 1987), infants seem particularly attuned to positive mirroring of their own facial expressions (i.e. smiling and gazing) by the social partner. Progressively, by 4 months they might pick up the spatio-temporal contingencies that define the pragmatic of dyadic exchanges and from which they can develop new, more precise social expectations, independently of static facial expressions.

Supported by the findings of the first set of analyses, we propose that compared to 4- and 6-month-olds, 2-month-old infants are differentially attuned to the social partner in face-to-face interactions. Two month olds are primarily focused on the positive facial expression that mirror theirs as a consequence of prior scaffolding by the social partner. In contrast, 4- and 6-month olds might be primarily focused on the degree to which the social partner is contingent and responsive, independently of facial expression. Following this interpretation, between 2- and 4-month infants appear to develop a new approach of others in dyadic exchanges based on information specifying the dynamic of these exchanges and their contingency. From this information infants would develop novel social expectations that reflect a new understanding of others as communicative agents (Rochat and Striano, 1999). Note that this developmental interpretation does not preclude a sensitivity to social contingency by 2-month olds, as suggested by Nadel and Tremblay-Leveau (1999) on the basis of recent empirical findings (Nadel *et al*., 1999; but see also Murray and Trevarthen, 1985; Muir and Hains, 1993; Rochat *et al*., 1998). What is proposed here is that if already by 2-months infants might begin to display sensitivity to social contingency, it is probably on different ground (e.g. social mirroring) and toward a different kind of contingency as compared to 4- and 6-month olds (e.g. spatio-temporal components of interaction, see Watson, 1984, 1995; Gergely and Watson, 1999). Such observations and their interpretation might also depend on the infant's interaction with a stranger, and not the mother. It is feasible that the familiarity of the mother as a social partner plays a role and could yield different results (see for example the differential detection of social contingency observed in 5-month olds interacting with either their mother or a female stranger by Muir and Hains, 1993, 1999).

The fact that 2-month olds did react to the neutral and sad still-face by gazing significantly less to the experimenter during this episode, indicates that they are particularly attuned to the relative congruence of facial expression prior and during the still-face episode. They demonstrate that they are not exclusively attuned to the sudden absence of social contingency, as they are not affected by a happy still-face. For 4- and 6-month olds, sensitivity to changes in social contingency seems to overrides the variety of emotional content displayed during the still-face, whether happy, neutral, or sad.

If gazing responses provided interesting developmental facts in the first set of analyses, smiling did not. When compared to control, infants did not demonstrate a still-face effect *per se*. The overall significant decrease of smiling as a function of episode across experimental and control infants can be attributed to overall fatigue or habituation. These results point to the fact that gazing and smiling should not be considered as equivalent indices of the still-face phenomenon, and of early social understanding in general. Our results show that infants monitor others visually and smile probably for different reasons, suggesting that gazing and smiling might have different functions from the outset.

As suggested by the Sroufe and Water (1976), smiling emerges in ontogeny as part of tension-release mechanisms. Considering that the still-face episodes is stress inducing (Weinberg and Tronick, 1996), the general enhancement of smiling following such episodes would indicate that it is the expression of an overall tension release as it is manifested reliably at the resumption of the normal interaction. Following Sroufe and Waters (1976) model, smiling is the expression of a mechanism allowing infants to regulate the flow of stimulation in face-to-face exchanges and terminate current engagement in order to attend to new situations in the environment. From the second month, it is also the primary expressive component of well-being which is highly reinforcing to caregivers who tend to repeat engaging actions based on this particular behaviour expressing positive affective attunement (Stern, 1985). If smiling has primarily a regulatory function, gazing could be construed as having primarily a perceptual and attentional (exploratory) function. If gazing might have from an early age some social regulatory function in face-to-face exchanges, it is feasible that this function, in contrast to smiling, is secondary. More research specifically designed to test this interpretation is needed.

Additional support for the differential functions of gazing and smiling in early development is provided by the results of our first set of analyses which show that if smiling behaviour is, overall, quantitatively stable between 2 and 6 months, this is not the case for gazing. As a function of age, infants spend proportionally less time attending to faces in dyadic exchanges. These changes are yet for the most part unexplained and in need of further investigation. From 2-month postnatal, infants engage in long bouts of gazing toward others' faces. However, by 4 and 6 months, infants' visual attention to interacting faces becomes more fleeting and gazing bouts toward other faces in social exchanges tend to decrease markedly in duration, although they might increase in frequency (Rochat *et al.*, 1999). A functional explanation for such robust decline still needs to be provided, either in the context of general developmental changes in infant visual attention (e.g. Ruff and Rothbart, 1996), or more specifically, in relation to developing social monitoring skills (Caron *et al.*, 1997).

The second set of analyses in which we compared directly the still-face phenomenon in relation to the three facial expressions of the experimenter while controlling for an eventual order effect, yielded some converging evidence supporting our interpretation. Overall, these analyses yielded the same developmental trend for the overall proportion of gazing as a function of episodes. With age infants tend, overall, to gaze less at the experimenter. Furthermore, infants at all ages demonstrate a significant still-face effect regarding their gazing response. In relation to smiling, regardless of age, infants did show a significant overall episode effect, smiling less during the second (still-face) episode. However, in general, this second set of analyses revealed no effect of facial expression, regardless of age.

In conclusion, the present findings point to important changes in what determine the well-documented still-face phenomenon between 2 and 6 months of age: from a sensitivity to the more or less congruent emotional display and contingency of the social partner, to a sensitivity geared exclusively toward the contingency of the social partner. However, these findings are relative to gazing, not smiling responses. Aside from the age factor, the research points to the importance of considering the still-face phenomenon in relation to the different functions that might be attached from the outset to early social gazing and smiling, as well as the developing sensitivity to social contingency in the dynamic of early face-to-face exchanges.

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