THE INTERACTIVE DEVELOPMENT OF SOCIAL SMILING

Daniel Messinger[a] *and Alan Fogel*[b]

[a]DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF MIAMI, CORAL GABLES, FL 33124, USA
[b]DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF UTAH, SALT LAKE CITY, UT 84112, USA

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Infant smiles elicit feelings of sympathetic engagement from researchers as well as parents. Early social smiles appear to be direct behavioral expressions of positive emotional engagement. This apparent link between behavior and meaning lies behind a century of research on the causes, emotional significance, behavioral correlates, and developmental consequences of infant smiles. In this chapter, we review that literature with a critical eye, focusing on the emergence and early development of social smiling, the possibility that different types of smiles index different types of positive emotion and new evidence that smiles index a single dimension of positive emotion, the interactive development of different types of smiling and the origins of emotion regulation, the integration of smiling into referential communication, and the use of smiles to distinguish between infants and predict outcomes. The review covers the results of studies of infant perception, infant smile production, observers' ratings of those smiles, and the smiling of nonhuman primates. We begin with a theoretical overview, review the neurophysiology of smiling, and examine the heritability of smiling and lessons from the smiling of blind infants. Throughout, our intent is to present new findings and highlight areas of potential investigation.

I. Overview

A. THEORETICAL ORIENTATION

More than a century of research into emotional expression has produced a rich diversity of theoretical perspectives. Here we provide a brief overview of those perspectives as they pertain to the development of smiling. No attempt has been made to explicate each perspective or its variants fully. Instead our goal is to identify the strengths of these perspectives and situate our own approach with respect to them. This will involve noting areas of overlap—as well as divergence—between theoretical perspectives on the development of smiling.

Cognitive/constructivist (differentiation) approaches suggest that discrete affects develop from earlier more diffuse states. Joy, for example, develops out of states of pleasurable positive valence (Sroufe, 1979, 1995; Sroufe & Waters, 1976). This perspective is part of a long theoretical tradition suggesting that emotions occur only in the presence of a cognitive interpretation of affective valence (Barrett, 2006; Bridges, 1932; Sroufe, 1995). Smiles in the first 2–3 months are thought to index pleasure and to occur when the infant experiences a relaxation in cognitive tension related to recognizing a visual stimulus. The development of an increasing capacity for cognitive engagement is thought to lead to more dramatic drops in arousal and more specifically joyful emotion (Sroufe, 1995; Tomkins, 1962). These developments are thought to occur around 9 months and to be paralleled by more intense infant smiling and laughing (Sroufe, 1995).

Differential and discrete emotion theories champion the straightforward hypothesis that infant facial expressions such as smiles are the product of discrete affect programs (Ackerman, Abe, & Izard, 1998; Izard & Ackerman, 2000; Lewis, 2000). These neurophysiologically based affect programs simultaneously trigger expressive actions such as smiles and feeling states such as joy. By positing that infant smiles are direct indices of joy, this perspective has facilitated extensive research in which smiles are measured among different infant populations at different ages. This theory focuses on structures within the organism that are responsible for emotion and its expression. Recent articulations of differential emotion theory, however, have stressed a functional role for emotions. Joy, for example, is thought to motivate social approach behaviors and the continuation of interactions. At a societal level, smiles are seen as communicating positive feelings and facilitating social cohesion. An early propensity toward joy, as expressed in smiling, is hypothesized to facilitate extraverted personality traits.

Functional perspectives focus on the role of emotions such as joy in the creation and maintenance of relationships with the environment, particularly with significant others (Barrett, 1993; Campos *et al.*, 1994; Witherington, Campos, & Hertenstein, 2001). This perspective has served to direct attention to vocal, gestural, and whole-body expressions of emotion in context, warning against exclusive reliance on smiles or other facial expressions of emotion. Potentially relevant to functionalist perspectives are ethological attempts to understand smiles solely as communicative signals to conspecifics (Fridlund, 1994). Ethological approaches have generated impressively clear research results on the communicative functions of smiles and similar expressions in monkeys, chimpanzees, and human beings (Bard *et al.*, 1992; Burrows *et al.*, 2006; Mizuno, Takeshita, & Matsuzawa, 2006; Redican, 1975; van Hooff, 1972). Functionalist approaches stress the importance of identifying the infant's goal orientation in a given situation and suggest, along with other approaches, that joy is a product of goal attainment.

Our approach uses dynamic systems as a higher order theoretical orientation with which to integrate insights from other perspectives (Camras, 2000; Fogel *et al.*, 1992; Messinger, Fogel, & Dickson, 1997; Thelen & Smith, 1994a, 1994b; Thelen, 1991; Witherington *et al.*, 2001). A dynamic systems approach focuses on social smiling as a reflection and constituent of an interactive relationship. The focus is the bottom–up interrelationship of constituents of positive emotional expression as they emerge in social contexts. This approach has also focused on the temporal dynamics of social smiling, their rise and fall in time, and the relation of such emergent processes to emotional development more generally. This has involved examining the creation of smiles and other facial expressions in real time and the possible ramifications of such real-time processes for emotional development.

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From a dynamic systems perspective, expressive configurations such as smiles are conceptualized as constituents of infant emotional processes. The expression

is part of what the infant feels and is central to the infant's ongoing interchange with the environment. Smiles are an emotional signal to the self as well as the interactive partner. They are simultaneously experiential and social. As such, the dynamics of facial expression can shed light on the dynamics of emotion.

By using a dynamic systems approach as a higher order theoretical framework, we seek in part to emphasize areas of overlap and agreement between different perspectives. Differing theoretical perspectives define emotion in different ways and emphasize different research agenda, creating overlaps between perspectives. Both functional and dynamic systems approaches, for example, locate emotion in the relationship of the infant to his or her environment. A cognitive/constructivist perspective highlights developing cognitive capacities in the emergence of smiling in a fashion that exemplifies the dynamic systems emphasis on nonobvious components in the bottom–up emergence of emotional expressions. Though only differential emotion theory may emphasize the logical primacy of the neural components of positive emotional functioning, no perspective challenges their importance. Finally, both differential emotion theories and dynamic systems approaches are concerned with the temporal dynamics of smiles—albeit for different reasons.

B. THE NEUROPHYSIOLOGY OF SMILING

The neural origins of smiling are clear (Elliot, 1969; Williams *et al.*, 1989). Smiles occur when the zygomatic major muscle contracts, pulling the corners of the lips upward and laterally (see Figure 1). The zygomatic is innervated by the facial nerve, the seventh cranial nerve, which emanates from the facial nucleus. The facial nucleus is an aggregation of motor neurons in the ventrolateral region of the lower pontine tegmentum, at the level of the pons in the brain stem. By contrast, afferent sensation from the face during smiling is carried by the fifth cranial nerve, the trigeminal. This afferent feedback may be a physiological basis for the facial-feedback hypothesis. Empirical support for this hypothesis indicates that the process of smiling can itself contribute to the experience of joy (Izard, 1981; Soussignan, 2002).

The neurophysiological evidence of an affect program for joy is less than clear. The facial nucleus receives two sets of inputs. Voluntary or deliberate smiling (being asked to produce a smile) is thought to originate in the cortical motor strip and travels to the nucleus via pyramidal tracts (Rinn, 1984). However, most social smiling in infancy is spontaneous and expressive and, according to differential emotion theory, is a motor expression of an affective neural program for joy. Spontaneous facial expressions involve an "extrapyramidal" pathway that involves subcortical (e.g., basal ganglia) as well as deep cortical structures such as the amygdala.

Fig. 1. Six-month-old infant displaying a high-amplitude interactive smile involving eye constriction and mouth opening.

Reviews of neuroimaging studies in adults (Barrett & Wager, 2006) suggest that joyful responses may not be associated with a specific pattern of activation (Murphy, Nimmo-Smith, & Lawrence, 2003; Phan, Wager, Taylor, & Liberzon, 2004). One meta-analysis reviewed suggests an association between joy and activation of the rostral supracallosal anterior cingulate cortex (Murphy, Nimmo-Smith, & Lawrence, in press). Another suggests an association between joy and activation of the basal ganglia, a set of structures associated with voluntary movement (Phan *et al.*, 2004). One possibility is that anterior cingulate cortex, a section of limbic cortex, is associated with joyful responses, whereas basal ganglia are involved in related action tendencies. Nevertheless, the lack of consistency does not readily suggest support for an affect program as there is no consistent neural pathway for joy.

Stronger meta-analytic evidence (Barrett & Wager, 2006) supports the supposition that positive affect and approach-oriented emotional orientations are associated with greater left than right cerebral activation both overall (Murphy *et al.*, 2003) and specifically in frontal areas (Wager *et al.*, 2003). This pattern of activation also accompanies emotionally positive Duchenne smiles, which involve constriction of the eyes, in infants (Fox & Davidson, 1988). These left frontal areas, however, are not dedicated structures. Instead, specific elements of perceiving and acting joyfully in an interactive situation (e.g., smiling while gazing at and moving toward a parent) may yield more consistent patterns of neurophysiological activation than investigations of abstracted emotion categories such as joy (Barrett & Wager, 2006). As suggested by a dynamic systems approach, the neural "structure" of joyful smiling is likely to be both embodied and interactive (Fogel & Thelen, 1987).

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C. TEMPERAMENT-BASED STUDIES OF SIGHTED INFANTS AND SMILING IN BLIND INFANTS

In this section, we examine temperamental approaches to the smiling of sighted infants, which provide an overview of factors impacting the expression of positive emotion. These temperamental approaches are complemented by reports on smiling in blind infants, which illustrate how smiling develops in the absence of visual input.

There tends to be a gap between broad-scope temperamental approaches to infant positive emotion expression and more detailed interactive approaches. Investigations of temperament often employ genetically informative designs and employ linear modeling of heritable and environmental variance of indices of positive emotion. Interactive approaches investigate the development and in-time formation of positive emotional communication. The approaches are ultimately, however, complementary views of similar phenomena at different levels of analysis.

Patterns of parental response reveal the influence of both genetic and environmental effects on infant positive emotion expression (Goldsmith, Buss, & Lemery, 1997; Goldsmith *et al.*, 1999). This is in contrast to reports on negative emotion in which heritability estimates tend to be higher and environmental influences less pronounced. Shared environmental effects on infant expression of positive emotions include caregiving effects such as the impact of parent–child interaction.

Genetically informative temperament studies are typically based on parental reports of positive emotion (Goldsmith *et al.*, 1997, 1999). Parents' reports of infant smiling and laughter sometimes are and sometimes are not significantly correlated with investigator observations of positive emotion expressions (Bridges *et al.*, 1993; Rothbart, 1986). One possibility is that parental ratings are relatively uninformative when the parents engage in high levels of emotionally positive play with their infants (Hane *et al.*, 2006). It is only the ratings of parents who engage in low levels of mutually positive play with their infants that are predictive of observed infant smiling. Clearly, genetically informative studies of investigator-observed expressions are necessary to shed light on the relative impact of heritable and environmental factors on infant social smiling.

The development of smiling in blind infants provides intriguing clues into the role of environmental influences in the emergence of positive facial expressions (Fraiberg, 1975; Freedman, 1964; Ganchrow, Steiner, & Daher, 1983; Rogers & Puchalski, 1986; Thompson, 1941). Social smiling in blind infants occurs in response to events such as hearing a familiar voice. It typically elicits a parental response. Perhaps as a consequence, these social smiles become more frequent between 4 and 12 months. However, the smiles of blind infants are less frequent and briefer (more fleeting) than those of sighted infants. Deficits in smiling are

observed in blind infants after 2 or 3 years of age. On the one hand, normative experiences of caregiving are sufficient for the emergence of smiling; on the other hand, visually mediated interactive smiling appears to play an important role in maintaining smiles in real time (i.e., the duration of smiles) and in developmental time (i.e., the reduced smiling of older blind infants). Research with blind infants suggests that the emergence of social smiling is experience expectant, occurring even in the absence of visual feedback. The interactive intensification of smiling depends, however, on visual engagement. From a dynamic systems perspective, the absence of mutually reinforcing visually mediated feedback in the form of reciprocal smiling probably plays a role in these deficits. In the next section, we broaden our scope to examine the early development of smiling in typically developing infants.

II. Early Smiling

A. NEONATAL SMILING

In early development, neonatal smiling gradually becomes linked to environmental stimulation, setting the stage for the emergence of social smiling. In this section, we describe the association of neonatal smiles with particular behavioral states, their cortical origins, and observer studies of neonatal smiles. We go on to describe the anatomical topography of neonatal smiles and the subsequent development of smiling in response to sensory stimuli that set the stage for social smiling.

Neonatal smiles appear to be experience expectant. They occur in sleeping and drowsy states of rapid eye movement (REM) at an average rate of one smile per 5 min. Smiles during sleep are referred to as spontaneous or endogenous smiles because they have no obvious external cause (Emde *et al.*, 1978; Emde & Koenig, 1969a, 1969b; Emde, McCartney, & Harmon, 1971; Harmon & Emde, 1972a, 1972b; Messinger *et al.*, 2002; Wolff, 1987). Newborns also smile, though less frequently, during other behavioral states, including states of alertness (Dondi *et al.*, 2006).

A case report of neonatal smiling in an infant with microcephaly suggests a subcortical origin for neonatal smiling (Emde & Koenig, 1969a, 1969b; Emde *et al*., 1971; Harmon & Emde, 1972a). Developing cortical inhibition of smiling is suggested by the findings that infants born prematurely show more neonatal smiling than full-term infants and that this spontaneous smiling declines with age.

Neonatal smiles illustrate the dynamic principle of developmental heterochronicity (Fogel & Thelen, 1987). Smiles are present physically before they are integrated into patterns of social engagement and interaction that provide

evidence for joyful emotion. Neonatal smiles can, in fact, have a relatively mature form in which the zygomatic shows moderately strong contraction and the eyes are constricted to form a Duchenne smile (Messinger *et al*., 2002). This association between the strength of smiling and the strength of eye constriction reflects an early, apparently neuromuscular, synergy.

In humans, zygomatic contractions during sleep appear to decline in frequency as stronger zygomatic contractions during alert states become more frequent toward 1 month of age (Harmon & Emde, 1972a; Wolff, 1987). This pattern in human infants has similarities with accounts of smiling in young chimpanzees (Mizuno *et al.*, 2006). Chimpanzees also smile during REM sleep; this smiling declines in the first 2 months of life as social smiling increases. Although smiles can have an apparently mature form at birth, these patterns of increasingly strong and bilateral zygomatic contraction suggest a developmental process of neuromuscular coordination and synchronization that is consistent with a dynamic systems perspective.

Influenced by a dynamic systems perspective, Wolff (1987) documented the developmental emergence of infant smiling in response to first auditory and then visual stimuli in the first 2 months of life (Field *et al.*, 1986; Spitz, 1946; Sroufe & Waters, 1976). In the first week of life, infants do not smile reliably in response to sounds, visual stimuli, tactile stimulation, bouncing, or the like. Toward the end of the second week, half of the infants in Wolff's sample smiled regularly in response to the human voice when they were awake. By the fourth week, most infants smiled to both human and nonhuman sounds, although the human voice was more attractive. At 5 weeks, the combination of voice and face was a better elicitor of smiling than either of the two alone. By 8 weeks, infants smiled only after making visual contact with the mother's face (Harmon & Emde, 1972a; Spitz, 1946; Wolff, 1987).

An explanation of the apparent shift in the capacity of first auditory and then visual stimuli to elicit smiling might invoke features of the developing nervous system first in a uterine and then in an extrauterine environment (Huttenlocher, 1999; Lickliter & Bahrick, 2001). New descriptive and experimental studies such as those pioneered by Wolff are warranted. They would indicate whether individual differences in central nervous system maturity and/or early experience with smile-eliciting stimuli are related to the development of smiling responses to mechanical stimuli and indicate whether such smiling responses are linked to the emergence of social smiling (Kawakami *et al.*, 2006).

B. THE EMERGENCE OF SOCIAL SMILING

Smiles develop their familiar social form during interaction. Although mothers report the emergence of social smiles at about 1 month, experimenters are able to elicit social smiles between 1 and 2 months (Anisfeld, 1982). The emergence

of social smiling, however, appears to be contingent on postconceptional age in both preterm and full-term infants. This suggests social smiling is a function of neurological maturity rather than number of weeks in the postnatal environment, a possibility that appears ripe for further empirical study.

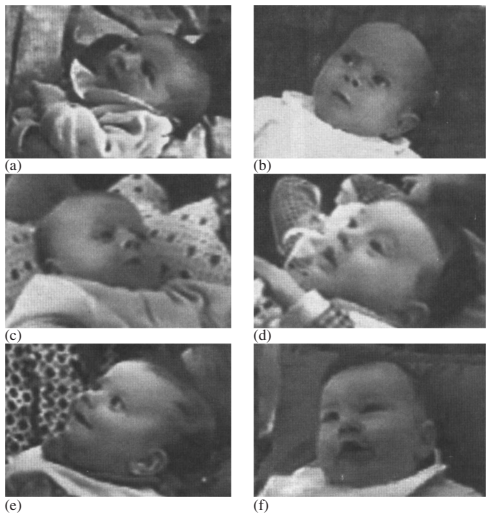
Social smiling develops as infants spend more time in states of alert inactivity (i.e., not fussing/crying) that facilitate gazing at the caregiver's face (Lavelli & Fogel, 2005). Social smiles, in fact, emerge in a period marked by the development of new patterns of visual attention. Although 1-month-olds gaze alternately at the edge of the head and the eyes, 2-month-olds gaze between the edge of the head, the eyes, and the mouth. This more integrative pattern of gazing is likely to encourage attention to the facial expression of others. Thus, linked components of neural maturity, state regulation, and perceptual competence appear to be necessary for the emergence of social smiling.

Social smiles are not present at birth. From an evolutionary perspective, the function of smiles is to keep parents and other potential caregivers close at hand (Bowlby, 1982). It is not clear, however, that observational studies have systematically examined whether infant smiles, in fact, predict increased parental proximity. Nevertheless, it appears plausible that earlier social smiling would increase an infant's inclusive fitness. It may be, of course, that heritable changes associated with the earlier emergence of social smiling are not available during the first month of postnatal physiological consolidation and energy conservation (Rovee-Collier, 1996; Sroufe & Waters, 1976). There is, however, some evidence suggestive of potentially heritable differences in the development of social smiling.

Group differences have been documented in the emergence of social smiling in an Israeli sample (Anisfeld, 1982). Both tester and maternal observation indicate that Sephardi Jewish infants engaged in social smiling about 1 month before Ashkenazi Jewish infants. Such a difference suggests a background of potentially heritable individual variability in the timing of the onset of social smiling. If such differences are, indeed, heritable, age of social smiling may be subject to evolutionary pressure. A crucial issue here is the psychological meaning of the emergence of social smiling to parents. A testable hypothesis with clear evolutionary implications holds that the emergence of social smiles would be associated with parental reports of increases in a feeling of connection or even a willingness to sacrifice for the newly smiling infant.

C. THE EARLY DEVELOPMENT OF SOCIAL SMILING

In this section we outline the developmental emergence of social smiling in a dyadic context. Inspired by Trevarthen's microanalytic observations (Murray & Trevarthen, 1986; Trevarthen, 2001), we examine how early smiling emerges



a. Neutral/Simple Attention. Reflexes and vegetative movements. Relaxed neutral expression, possible visual attention, quiet alert.

b. Concentrated Attention. Brow knitting (AU 3); motor quiet. Lower face still with lip pursing, or mouth partially open. High-arousal & sustained visual attention with "effortful" concentration.

c. Excited Attention. Brow raising (AU 1+2) & strong fast limb movements. Mouth closed or only partially open. High-arousal & sustained visual attention with motor excitement.

d. Astonished Attention. Strong brow raising (AU 1+2); motor quiet, relative facial stillness. Eye widening (AU 5); jaw dropping and mouth open in "o"-shape. "Fascinated," motionless visual fixation.

e. Attentive Smile. Lip corner raising (AU 12) with mouth only partially open. Frequent motor quiet. Relaxed expression of pleasure during visual attention.

f. Cooing Expression. Lip shaping for cooing, with upper lip raising / protrusion, or lip & tongue "pre-speech" movements. Approaching postural orientation; arm raising with arm / hand waving.

Fig. 2. Infant expressive configurations during mother–infant face-to-face communication (0–3 months). Source: Lavelli and Fogel (2005).

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from attentional expressive configurations (Lavelli & Fogel, 2002) (see Figure 2). We employ a dynamic systems perspective to find parallels between the real-time and the developmental emergence of positive facial expressions during social exchanges in the first 3 months of life.

In the first month, infants transition between neutral gazes away from mother's face and simple attention to her face (i.e., gazing at the mother's face without any sign of emotional engagement). The second month sees a sequential pattern of infant simple attention to mother's face, concentrated attention to her face, smiling at mother, and then cooing expressions also directed toward mother. This pattern is an interactive replication of findings that dynamically link cognitive processes to the emergence of social smiling as predicted by both cognitive/constructivist and dynamic systems approaches. Early social smiling is frequently preceded by a 3- to 20-s period of brow knitting and visual fixation on the mother's face (Anisfeld, 1982; Lavelli & Fogel, 2005; Oster, 1978). The brows then relax, indexing apparent cognitive recognition, and a smile appears. Real-time occurrences of this attention-related smiling pattern may, then, be the occasion for the developmental emergence of smiling. Research further specifying the type of cognitive processing preceding the occurrence and developmental emergence of social and nonsocial smiles would strengthen this conclusion.

During the second month maternal expressions change in a manner that parallel developmental changes in the infant's patterns of attention and emotion during

face-to-face communication (Lavelli & Fogel, 2002). Maternal neutral expressions decrease in conjunction with an increase in approach-oriented emotionally positive expressions in which mothers talk and smile simultaneously (talk/smile). At a dyadic level, infant smiling and cooing expressions become sequentially linked with maternal talk/smile in the second and third month. These sequential linkages are bidirectional. Maternal talk/smile, infant smile, and infant cooing expressions can cycle between each other in multiple patterns, suggesting the existence of a positive emotional attractor in the social communication system.

Taken together, these findings suggest that the smile does not occur alone but rather develops in a complex relation with other facial expressions, infant attention, and maternal facial expressions and attention. There is, in other words, a dynamic social–communicative system in which smiling develops and stabilizes. This suggests that smiling gradually develops as infants and their caregivers cocreate specific forms of social communication. In support of this proposition, 2-month-olds smile less at a stranger who is either more or less contingently responsive than the infant's mother (Bigelow & Rochat, 2006). That is, dyad-specific levels of interactive contingency that affect smiling levels develop by 2 months of age.

III. Quantity and Quality

Some smiles appear to be coy, others gleeful, and yet others riotous. In this section, we explore evidence suggesting that different types of smiling express qualitatively different types of positive emotion. This issue is theoretically meaningful. A multiplicity of emotionally different smiles would challenge the discrete emotion theory proposition of a single affect program for joy. In the next section, we present evidence for an alternate possibility—that social smiles express different degrees of a single dimension of positive emotion or joy—and attempt to integrate those perspectives. We begin this section by exploring the possibility that the presence of the Duchenne marker (eye constriction) and of mouth opening may index qualitatively different dimensions of emotional meaning in smiles.

A. DIFFERENT TYPES OF SMILING: DIFFERENT TYPES OF POSITIVE EMOTION?

1. Smiles Involving Eye Constriction—Duchenne Smiles

Researchers have long argued that Duchenne smiles (Duchenne, 1990 [1862]) involving eye constriction (produced by the orbicularis oculi and pars lateralis) are qualitatively different from smiles without eye constriction (see Figure 3).

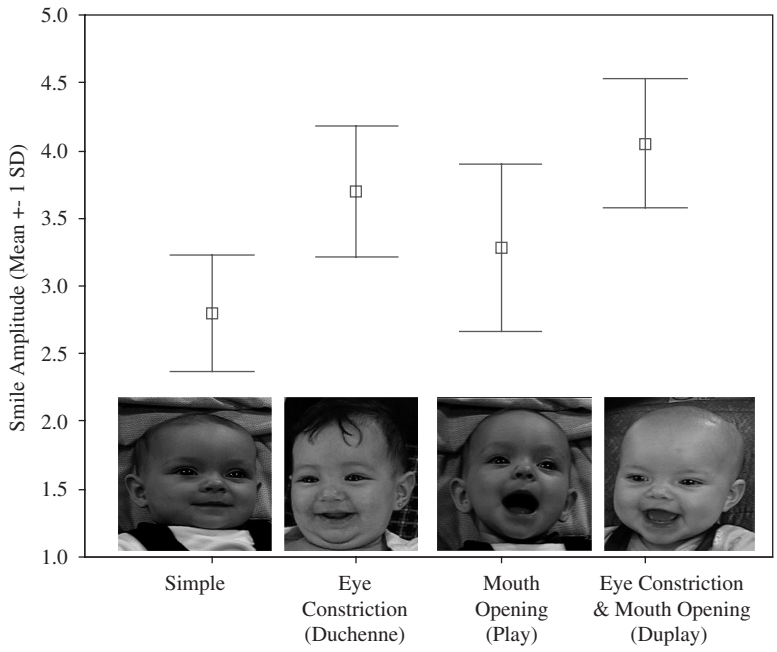

Fig. 3. Smile types.

One hypothesis is that (adult) smiles involving eye constriction are an expression of joy, but smiles without eye constriction are a nonemotional social signal (Ekman, Davidson, & Friesen, 1990). A similar distinction has been made for infants (Dawson *et al.*, 1997; Fox & Davidson, 1988). Ten-month-olds are more likely to produce smiles involving eye constriction when approached by their smiling mothers but are more likely to produce smiles without eye constriction when approached by an impassive stranger. Concurrent EEG recordings indicate that 10-month-olds' smiling with eye constriction is associated with greater relative activation of the left than the right frontal cerebral hemisphere (Fox & Davidson, 1988). Similar differences in relative activation are found in adults and appear to reflect greater approach orientation (Ekman *et al.*, 1990; Murphy *et al.*, 2003). This suggests that by 10 months there are at least two qualitatively different smiles: smiles with eye constriction used to express joyful engagement and smiles without eye constriction indexing a more cautious or less involved engagement.

A similar argument can be made for the qualitative distinctiveness of smiles with eye constriction produced by infants during face-to-face interactions with their mothers: Between 1 and 6 months, infants engage in relatively more smiling with

eye constriction than smiling without eye constriction when their mothers are smiling (Messinger, Fogel, & Dickson, 2001). During these smiles with eye constriction, they produce more speech-like syllabic sounds than during smiling without eye constriction, suggesting greater engagement with their partners (Hsu, Fogel, & Messinger, 2001). The results suggest smiling with eye constriction is a way to engage with the joyful expressions of another, a way to share positive affect during an ongoing interaction. One hypothesis is that infant smiles involving eye constriction are used to reciprocate the smiles of a social partner and, perhaps especially, to reciprocate the eye constriction smiling of another (Bachorowski, 1999).

The presence of eye constriction in an expression may, then, index qualitatively different emotional processes than are present in expressions without eye constriction. Eye constriction, for example, appears to index qualitative change in its occurrence with cry-faces, the prototypic infant negative expressions. Standard descriptions indicate that intense eye constriction transforms the cry-face from a discrete expression of anger into one of distress (Bolzani-Dinehart *et al*., 2005; Izard, Dougherty, & Hembree, 1983; Messinger, 2002; Oster, Hegley, & Nagel, 1992).

One hypothesis is that as eye constriction reduces the visual field it may contribute to a focus on the object of the emotion and to feelings of being caught up by the emotion (Messinger, 1994). Infant smiles with eye constriction may involve increased salience of positive feeling and also communicate this to the receiver. As such, smiles with eye constriction may be perceived to be more authentic infant expressions of joy than smiles without.

2. Smiles Involving Mouth Opening—Play Smiles

Another facial action that may produce qualitative changes in the meaning of infant smiles is mouth opening produced by jaw dropping. Mouth opening is associated with more rapid breathing, with vocalizations, and with laughter. Just as eye constriction may index positive emotional engagement with another, mouth opening may index aroused excitement and playfulness.

Other evidence concerning the function of open-mouth smiling comes from studies of primates (Bard *et al.*, 1992; Burrows *et al.*, 2006; Plooij, 1979; Redican, 1975). Chimpanzee zygomatic contraction produces a display of silent bared teeth, which seems to be a signal of submission ("I mean you no harm") that is frequently issued to a dominant individual. In chimpanzees, it has also come to be a signal of affiliation that is followed by behaviors such as holding out a hand. Among human beings and their predecessors, the silent bared teeth display may have evolved into smiling that does not involve pronounced mouth opening.

By contrast, the relaxed open-mouth display—also called a play face—is thought to be evolutionarily linked to human laughter and has morphological similarities with open-mouth smiling (Plooij, 1979; van Hooff, 1972; Waller & Dunbar, 2005). Both communicate a playful orientation that has an aroused quality. The chimpanzee relaxed open-mouth display, although common in affiliative contexts, is uniquely

linked to play. When two chimpanzees both engage in relaxed open-mouth displays, play bouts tend to last longer (Waller & Dunbar, 2005). In chimpanzee infants, it originates in mock biting play with the mothers (Plooij, 1979). One possibility is that, in human infants as well, open-mouth smiles reflect and communicate states of excited arousal and are a prototypic expression of social joy.

Like chimpanzees, human infants also engage in mouth opening that is not associated with smiling or with negative expressions, such as the "cooing expression" shown in Figure 2 (Kaye & Fogel, 1980; Messinger *et al*., 2001). These mouth-open displays tend to occur during positive periods of face-to-face interaction such as when the mother is smiling and making exaggerated displays and when the infant is gazing at the mother. Intriguingly, this suggests that mouth opening, like smiling, may be a characteristic of a relatively positive infant emotional engagement with the environment.

Relaxed open-mouth displays may also be phylogenetic precursors of human laughter. In infants, laughter is a smile-linked vocalization that appears to index intense positive emotion. Social routines (including tickling) and visual surprises (covering and uncovering objects) become more potent elicitors of laughter in the first year of life (Nwokah *et al.*, 1999, 1994; Sroufe & Waters, 1976; Sroufe & Wunsch, 1972). After 4 months of age infants laugh more frequently and the mean duration of these laughs increases. At the same time, the duration of the laughs of individual infants and mothers becomes more correlated. In the second year of life, the onsets and offsets of infant and mother laughs that overlap move increasingly closer in time. Both of these developments suggest the development of dyad-specific patterns of positive communication (Nwokah *et al.*, 1994). Such correspondences between partners are suggested by a dynamic systems perspective is also likely to characterize dyadic patterns of smiling.

Nonhuman relaxed open-mouth displays also have special ties to human open-mouth smiling. During face-to-face interaction, infants between 1 and 6 months of age engage in more open-mouth smiling when gazing at their mothers' faces. Among adults, open-mouth smiles involving eye constriction tend to occur in response to humorous stimuli (Ruch, 1997). Although neonates in sleeping and drowsy states emit smiles with eye constriction, smiles with mouth opening are much less frequent, offering indirect support for the arousal hypothesis (Messinger *et al.*, 2002). This pattern of results suggests an association between positive social engagement, arousal, and smiles involving mouth opening. In support of this association, still images of smiles with greater mouth opening are rated as involving more arousal than digitally edited versions of the same smiles involving less mouth opening (Bolzani-Dinehart *et al.*, 2003, 2005). The association between mouth opening and arousal is also seen in ratings of the negative, cry-face expression (Bolzani-Dinehart *et al.*, 2005).

We have suggested that expressions involving eye constriction index the increased salience of the emotional experience and that expressions involving mouth

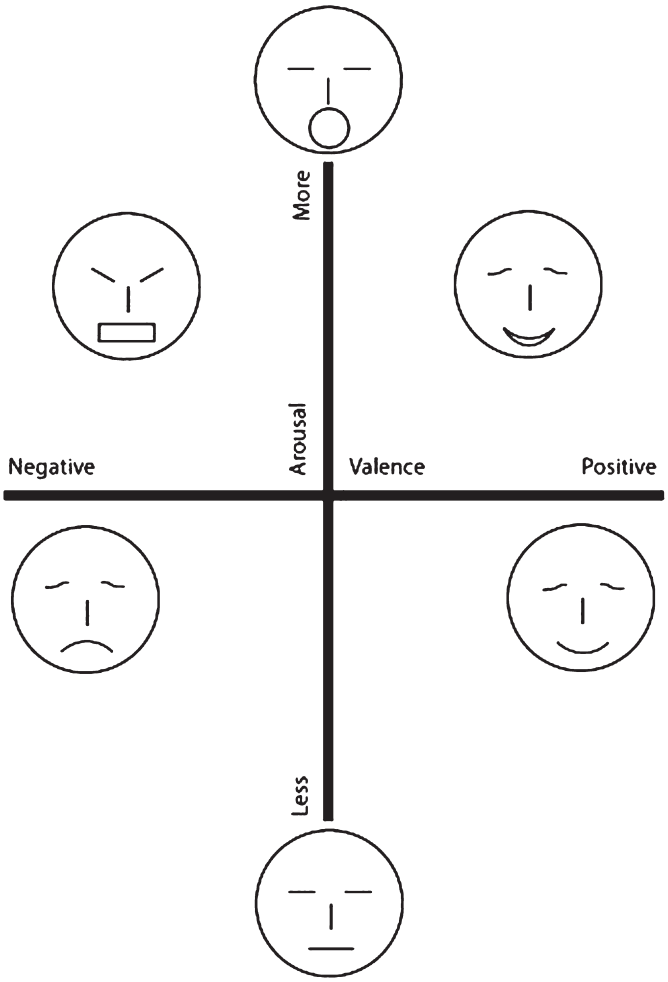

Fig. 4. An illustrative circumplex showing emotional valence on the horizontal axis and arousal on the vertical axis. Sad and angry faces indicate negative emotional valence, while smile-faces indicate positive emotional valence. Greater mouth opening indicates greater arousal regardless of emotional valence. At the highest level of arousal, the distinction between positive and negative emotional valence is lost. At the lowest level of arousal, no emotional valence is conveyed. Figure and caption courtesy of Mark Sheskin.

opening index increased arousal. These qualitative distinctions between facial expressions can be mapped onto circumplex models of emotion (Barrett & Russell, 1999; Russell, 1980; Yik, Russell, & Barrett, 1999) (see Figure 4). In this model, positive (pleasant) and negative (unpleasant) affect define two horizontal poles.

We hypothesize that such positive (smile) and negative (cry-face) expressions involve eye constriction. These expressions may communicate that the infant is in the throes of a "deeper" emotional experience. This valence dimension is at right angles to an arousal dimension. Emotion expressions high in arousal are hypothesized to involve mouth opening. Among infants, this would involve smiles with mouth opening in the upper right quadrant and cry-faces with mouth opening in the upper left quadrant. At the top of this pole, arousal becomes so extreme as to dominate the valence. In the same way, expressions of extreme arousal are hypothesized to involve extreme mouth opening that stretches out facial features, erasing the distinctive positive and negative characteristics of the expression.

3. Smiles Involving Both Eye Constriction and Mouth Opening—Duplay Smiles AQ5

Based on the meaning of their facial constituents, infant smiles that combine eye constriction and mouth opening are hypothesized to index sharing experiences of aroused positive engagement. During face-to-face interactions, these smiles are relatively more likely when infants are gazing at their smiling mothers (Messinger *et al.,* 2001). Levels of this type of smiling also vary systematically over the episodes of the face-to-face/still-face procedure (Adamson & Frick, 2003; Delgado, Messinger, & Yale, 2002; Moore, Cohn, & Campbell, 2001; Tronick *et al.,* 1978). Levels of combined open-mouth smiling with eye constriction are relatively elevated during the initial face-to-face interaction. They are relatively depressed during the stress of parental nonresponsivity in the still-face and the emotional regrouping that characterizes the reunion episode (Acosta *et al.,* 2004; Weinberg & Tronick, 1994). AQ6

The meaning of different types of infant smiles is revealed in peekaboo and tickle games between mothers and infants (Fogel *et al*., 2006). Both games involve a setup phase and a more intensely emotional climax phase. In peekaboo, the setup is the covering of the mother's face ("Where's mommy?"), and the climax is the uncovering ("Peekaboo"). Infants were more likely to smile during the climax than during the setup of peekaboo games but this pattern did not vary by type of smile.

Different phases of tickle games were associated with different types of smiling. In tickle games, the setup is the approach of the mother's hands toward the infant's body ("I'm gonna get you"), and the climax is the act of tickling (which may be accompanied by maternal vocalizations). Among infants at 6 and 12 months of age, combined open-mouth smiles with eye constriction tended to occur during the climax rather than during the setup phase of tickle games. This parallels the finding that, at home, 12-month-olds' combined open-mouth smiling with eye constriction predominates during physical play with parents (Dickson, Walker, & Fogel, 1997). These findings offer additional support

for the view that smiling involving eye constriction and mouth opening indexes sharing experiences of aroused positive engagement.

Approach and withdrawal indexed by patterns of gazing and movement during games also contribute to the meaning of smiles (Fogel *et al.*, 2000). During peekaboo games, for example, infants tend to gaze at the parent during all types of smiles, suggesting approach-oriented visual attention. During the climax of tickle games, by contrast, infants engaging in open-mouth smiles with eye constriction show mixed patterns of both gazing at and away from parents. Such patterns may correspond to feelings of enjoyment of active participation in a highly arousing situation and enjoyment of escape. These findings suggest that the same smiling actions can reflect different positive emotions depending upon co-occurring infant actions and the dynamics of the social process.

B. SMILES AS INDICES OF CONTINUOUS POSITIVE EMOTIONAL PROCESSES

In addition to evidence suggesting the existence of qualitatively different positive emotions indexed by different types of smiles, there is also strong evidence that smiles vary in the degree to which they express a single joyful positive emotion. This argument rests on examination of the strength of the smile action itself (smile amplitude, a continuous measure of the strength of zygomatic contraction), consideration of the role of amplitude in smiles involving eye constriction and mouth opening, the distribution of these types of smiles in different periods of interaction, rating studies, and the results of automated measurements being used to describe smile processes in time.

1. Smiling as a Continuous Action

Physiologically, smiles are continuous neuromuscular processes. The strength of zygomatic contraction determines, other things being equal, the amplitude of a smile, the extent of upward and lateral lip corner movement. If zygomatic contraction indexes positive emotion, it follows that stronger contraction indicates more intensely positive emotion. In fact, adults' self-reported feelings of pleasure are correlated with the amplitude of zygomatic major contraction in studies using both observational (Ekman, Friesen, & Ancoli, 1980) and electromyographic methods(Hess *et al.*, 1989). Similarly, smile amplitude appears to index directly the infant's positive emotional engagement with ongoing activities. Tickle games elicit higher amplitude smiling than peekaboo games. The climax of both games involves smiles of higher amplitude than the setup phases. Perturbations that involve dampening the climaxes of the games—such as substituting pretend for real tickling—result in lower-amplitude smiles (Fogel *et al.*, 2006).

2. *Smile Amplitude in Different Types of Smiles*

Coding of the mean amplitude of different types of smiles suggests anatomical constraints (Fogel *et al*., 2006) and the possibility that different types of smiles index different degrees of positive emotion. Despite evident variability within each type of smile, simple smiles show the lowest mean amplitude followed by open-mouth smiles, smiles with eye constriction, and then smiles that involve both mouth opening and eye constriction (see Figure 3). Both in the presence and in the absence of mouth opening, smiles with eye constriction tend to involve stronger zygomatic contraction. This is likely due to the synergistic functioning of these muscles. The muscles are agonists that raise the cheek and may share common pathways of innervation (Williams *et al*., 1989). This synergy is also presumably responsible for the tendency of some interactive smiles to "recruit" eye constriction as their amplitude increases (Messinger, Fogel, & Dickson, 1999; Messinger *et al*., 1997). By contrast, the tendency of smiles involving mouth opening to involve stronger zygomatic contraction than smiles without seems to resist those anatomical constraints. Stronger mouth opening is likely to be somewhat antagonistic to upward lip corner movement. This patterning is consistent with the view that eye constriction and mouth opening index the increased positive emotional intensity of smiling.

3. The Distribution of Smiles Types During Interaction

Even absent the dimension of smile amplitude, the occurrence of different types of smiles in different social situations supports the argument that infant smiles index a continuous positive emotion dimension. Simple smiles—those involving neither eye constriction nor mouth opening—are more likely to occur during periods of interaction likely to elicit positive emotion than are nonsmiles. These are periods of time when infants gaze at their mothers and when their mothers smile. By the same token, infant smiles involving eye constriction and mouth opening are relatively more likely than simple smiling in the same social situations. A conclusion is that simple smiles are more emotionally positive than neutral expressions, but smiles involving eye constriction or mouth opening are more emotionally positive than simple smiles. Different types of smiles, then, may reflect a continuous likelihood distribution of occurrence in affectively congruent situations, suggesting support for an underlying continuous dimension of positive emotion.

4. Rating Studies

The view that all infant smiles are emotionally positive but some infant smiles are more positive than others (Messinger *et al.*, 2001) is supported by observers' ratings of still images of smiles. Undergraduates rate simple smiles as more emotionally positive than nonsmiling neutral expressions (Messinger *et al.*, 2001). They rate smiles involving eye constriction and smiles of greater amplitude more

positively than, respectively, smiles without eye constriction and smiles of lower amplitude (Bolzani-Dinehart *et al.*, 2005). Smiles involving mouth opening also tend to be rated more positively than smiles without mouth opening, but this effect can be more subtle. The association between mouth-open smiles and greater positive emotion sometimes requires a rater who is a parent of an infant or is visible to a nonparent student rater only when video clips (rather than still images) are displayed (Cassel *et al.*, 2004).

Indirect support for the emotional intensity hypothesis stems from parallel findings with cry-faces. Student raters perceive cry-faces involving greater eye constriction (all cry-faces involve at least some eye constriction) as more negative than the same cry-faces with minimal eye constriction (Bolzani-Dinehart *et al*., 2005; Messinger, 2002). They perceive cry-faces involving greater mouth opening as more negative than cry-faces with less mouth opening. This suggests that the features that index stronger positive affect in smiles also index greater negative affect when they occur with some negative expressions.

5. *Automated Measurements of Smiles*

The research we have reviewed suggests that infant smile amplitude, eye constriction, and, perhaps to a lesser extent, mouth opening, are cumulative indices of positive emotional intensity. A premise of this research is the existence of distinct types of smiling. Emerging research techniques, however, are offering portraits of smiling and infant–mother interaction as continuous processes in time (Cohn & Kanade, in press; Cohn & Schmidt, 2004; Cohn *et al*., 1999; Messinger *et al*., 2005; Schmidt *et al*., in press; Schmidt, Cohn, & Tian, 2003).

We have complemented software measurements of facial features indexing the intensity of infant and mother smiles (see Figure 5) with nonexpert real-time ratings

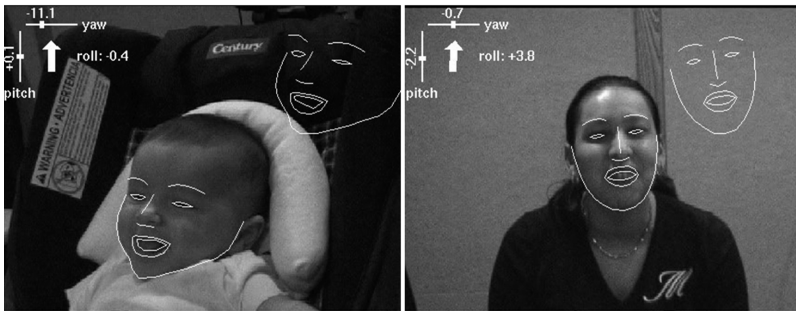

Fig. 5. Four-month-old infant and mother smiling interaction captured by Automated Face Analysis at Carnegie Mellon University, Robotics Institute. Analysis compliments of Jeffrey Cohn, Ph.D. Each partner's face is outlined to illustrate lip movement, mouth opening, and eye constriction, and these outlines are reproduced in iconic form to the right of each partner.

of the affective valence of the smiles (Messinger *et al*., 2005). Moment-by-moment analyses using software measurements reveal that, during face-to-face interaction, a single infant or mother smile can ebb and flow in amplitude over periods of 20–30 s (see Figure 3). Such lengthy smiling does not correspond to discrete emotion accounts of smiles as relatively brief, highly constrained (Ekman & Davidson, 1994; Frank, Ekman, & Friesen, 1993).

Infant and mother interactive smiles have a continuous structure. In the course of their smiles, both infants and mothers show a high correlation between smile amplitude and eye constriction. That is, when infants and mothers smile more strongly they also show greater eye constriction. It is frequently argued that Duchenne smiles express joy but non-Duchenne smiles are a social signal unrelated to positive emotional expression (Ekman *et al.*, 1990; Frank *et al.*, 1993; Soussignan, 2002). Eye constriction that waxes and wanes within a smile, however, may divide a smile into periods in which it is and is not a smile with eye constriction. It seems unlikely that some of those periods are emotional while others are not.

The finding that eye constriction changes continuously in concert with smile amplitude suggests difficulties with the division between Duchenne and non-Duchenne smiles in infancy. Such dichotomies appear to rest on underlying continuous changes in smile intensity. This suggests the need for new units of analysis that transcend smile types. The rise and flow of a single smile in time is one candidate; another potential unit of analysis is a bout of infant smiles that may have brief periods of nonsmiling between them. Ultimately, however, infant smiling is a constituent of a real-time *interactive* process and the most appropriate unit of analysis is likely to be dyadic. To understand this process, we begin with an examination of the characteristics of mothers' interactive smiles.

The differences between infant and mother interactive smiling are as revealing as the similarities. When infants engage in higher amplitude smiles and engage in greater eye constriction, they also engage in greater mouth opening. It is not clear, however, whether associations between smile amplitude and mouth opening are as strong as between smile amplitude and eye constriction. To some degree, then, infant smiles appear to involve a single joyful process that is simultaneously indexed by two to three facial indices of emotional intensity.

Unlike infants, mothers do not consistently open their mouths to a greater extent when smiling more strongly. Instead, mouth opening in mothers may be used both in coordination with speaking and to make exaggerated visual displays and vocalizations. For example, mothers often repeatedly open their mouths as they draw their head back from infants and then move their head toward the infant and close their mouth in a pattern that often involves vocalizing. In some ways, the caregiver's role is more complex than that of the infant. Caregivers are expected both to elicit pleasant, ideally positive, engagement from the infant *and* to respond to the infant joyfully in a fluid fashion.

C. SMILES AS CONTINUOUS INDICES AND SMILES AS DISTINCT TYPES—A RAPPROCHEMENT?

We have suggested that smiles are, on the one hand, discrete communications of qualitatively different engagement states and that, on the other hand, they are continuous signals of the intensity of emotional engagement. How can these views be integrated? A theoretically satisfying synthesis is that qualitatively discrete positive emotional "attractors"—such as a particular type of smiling in a particular interactive moment—may self-organize in response to underlying continuous processes (Chow *et al*., 2005; Weerth & Geert, 2000). AQ7

Currently, however, there may be no definitive resolution to this tension. Just as light behaves both as a particle and as a wave (Compton & Shankland, 1973), smiles may function both as discrete indices of specific states of engagement and as flowing indices of positive engagement. It may be productive, at this juncture, to adopt the view of social smiling most conducive to a specific phenomenon or research question while remaining open to the complementary perspective. Vocalizations, for example, tend to be embedded in the course of a smile such that the smile is punctuated by the vocalization (Yale, Messinger, & Cobo-Lewis, 2003; Yale *et al*., 1999). This may create a qualitatively distinct attention-getting positive emotional expression, or it may serve as an intensifier of facially communicated affect (Hsu *et al*., 2001).

IV. The Interactive Development of Smiling

Whether smiles index a related family of positive emotions or a single emotion of joy, smiling develops within real-time interactions between infants and social partners. In this section, we examine interactive smiling and its development from a dynamic systems perspective. We ask how infants' smiles are coordinated with mothers' smiling and with infants' gazes at mothers' faces and describe how these patterns develop to usher in the onset of intentional communication.

A. OVERVIEW OF INTERACTIVE SMILING

Mothers smile more readily than infants. Between 2 and 5 months, mothers' smiles and other displays such as head nodding and vocalizing are typically necessary to elicit infants' smiles. But infants frequently do not smile in response to mother. Mothers' smiles and other displays are not sufficient to elicit infant smiling (Symons & Moran, 1994). An infant smile, by contrast, is typically sufficient to elicit a mother smile. But infant smiles are by no means necessary to elicit mother smiles as mothers often smile in the absence of an infant smile (Cohn & Tronick, 1987; Kaye & Fogel, 1980). When mothers smile in response to

infants' smile onsets, they do so within 2 s (Malatesta & Haviland, 1982; Van Egeren, Barratt, & Roach, 2001).

Interactive smiles are not series of onsets, but continuous processes. Infant and mother influence not only the onsets of each other's smiles but the offsets as well. Mothers rarely break off bouts of mutual smiling. Instead, they terminate their smiles only after their infants have stopped smiling. When infants gaze away from mother, they typically terminate their smiles soon after. Thus the infant's prototypical experience of smiling is smiling with another.

During face-to-face interactions, infant smiles are often pursued by mothers and fathers. Fathers tend to employ a more physical style of play with their infants (e.g., bouncing games), whereas mothers rely more on visual and auditory expressive displays to elicit smiles (Dickson *et al.*, 1997). Perhaps as a consequence, infant positive emotional displays with mother build more gradually but positive emotional displays such as smiling appear more suddenly with father (Feldman, 2003).

Generally speaking, caregivers use a wide range of stimulating actions in multiple modalities (e.g., variations in vocal intensity and pitch, smile intensity, and moving their faces close to the infant), which facilitates the occurrence of complex, repeated, interactive patterns. Caregivers' tickling and high-pitched vocalizing, for example, might be followed by an infant smile, the infant gazing away from the caregiver, and a decrease in smiling followed by the infant gazing again at the caregiver. One possibility is that, in some respects, the caregiver's role in this interactive system is analogous to providing energy in the form of heat to chemical solutions (Hill & Moylan, 1976). The continuous provision of heat can yield a Benard cell that displays repeating, complex, but not entirely predictable, visual patterns (Prigogine & Stengers, 1984). Infant–caregiver play is also an open system in which the caregiver's positive expressive energy facilitates the emergence of complex, repeating, not entirely predictable interactive patterns.

B. THE DEVELOPMENT OF SOCIAL SMILING IN INTERACTIVE CONTEXT

Social smiling is typically studied in industrialized societies and typically studied during face-to-face interactions with a parent (see Figure 5). Infants smile for approximately 20% of face-to-face interactions. When observations are conducted on a weekly basis between 2 and 6 months, individual infants typically show stable quantities of smiling in face-to-face interactions (Malatesta *et al.*, 1989). Although approximately one-quarter of the variance in the development of smiling during this period is related to individual differences between infants, the origins and correlates of these differences are not well understood.

Between 2 and 6 months, infants spend increasing amounts of time smiling (Malatesta *et al.*, 1989, 1986). They become more likely to gaze at mother when she is smiling or creating other facial displays and become more likely to smile in response to maternal smiles (Cohn & Tronick, 1987; Kaye & Fogel, 1980; van Beek, Hopkins, & Joeksma, 1994). Infants' tendency to initiate smiles—even in the absence of a previous maternal smile—becomes pronounced between 6 and 9 months (Cohn & Tronick, 1987), signaling the infant's increasingly active, positive participation in the interaction.

Most of the types of smiling identified in the previous section arise during multiple periods of face-to-face interaction in the first 6 months of life (Messinger *et al.*, 2001). Simple smiles that involve neither eye constriction nor mouth opening, for example, arise in periods characterized by both the presence and absence of the infant's gaze at mother's face and the presence and absence of mother smiling (see Figure 6). This suggests that infants' use of less affectively intense simple smiling does not become more specific with age. This is surprising as simple smiling, by 12 months of age, predominates during pleasurable but not extremely arousing activities such as book reading (Dickson *et al.*, 1997).

In contrast with simple smiling, open-mouth smiling involving eye constriction shows a distinct developmental trajectory. Between 1 and 6 months of age, infants become increasingly likely to use open-mouth smiling with eye constriction—which is almost certainly high-amplitude smiling—to interact with their mothers when their mothers are smiling. They become increasingly less likely to engage in this smiling when they are not gazing at mother and mother is not smiling. In sum,

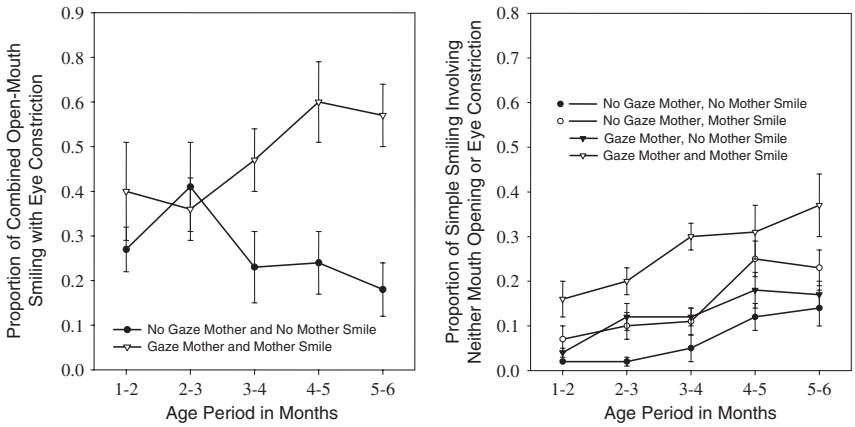

Fig. 6. Open-mouth smiling with eye constriction increases when infants are gazing at their mothers' faces while their mothers are smiling. It decreases when infants are not gazing at their mothers while their mothers are not smiling. By contrast, smiling with neither characteristic, that is, smiling alone, tends to increase irrespective of where the infant is gazing and whether or not the mother is smiling.

infants' increasing tendency to engage their smiling mothers with open-mouth smiling with eye constriction between 3 and 6 months appears to reflect their growing capacity to engage dynamically in intensely joyful interactions.

C. SMILING INTERACTION DYNAMICS

In interaction, caregiver and infant continuously provide and receive social information, via changes in facial expression, vocal tone, touch, movement, and the direction of infant gaze (Cohn & Tronick, 1987; Feldman, 2003; Feldman & Greenbaum, 1997; Feldman, Greenbaum, & Yirmiya, 1999; Feldman *et al.*, 1996; Fogel, 1988, 1993). To examine interactive emotional influence, we employed the automated measurements of smile intensity in infants and in mothers discussed earlier. As noted earlier, eye constriction and mouth opening were associated in infants, and smile amplitude and eye constriction were associated in mothers. This suggests at the outset that infant's use of mouth opening in smiles is not directly related to mother's use of mouth opening. In other words, infants and mothers are not precisely imitating the form of each other's smiles.

In examining how each partner influenced changes in the other's positive expressions, we identified two initial patterns. One dyadic pattern was characterized by rapidly repeating, tightly linked rises and falls in infant and mother smiling that were punctuated by the mother tickling the infant. Another pattern involved slower, less synchronous rises and falls in infant and mother smiling and a less prominent role for mother tickling. The ultimate goal of this research is to document how each partner influences the rate of change, the actual emotional dynamics, of the other partner's expressions (Boker & Nesselroade, 2000; Chow, 2005; Rotondo & Boker, 2002).

D. INFANTS' PERCEPTIONS OF INTERACTIVE SMILING

Infants' perceptions of the smiling of others also shed light on the development of positive emotion. Researchers often examine infant smiling within interactive contexts marked by responses to maternal smiles and vocalizations. Rarely, however, is this work integrated with investigations of the conditions under which infants recognize smiles. In fact, however, it is important to explore infants' comprehension of emotion expressions in an ecological context similar to that in which they communicate using these expressions. By 3½ months, infants gaze longer at a dynamic facial expression (happy or sad) that matches that of a concordantly presented vocalization, even after a brief delay. The effect is present, however, only when the infant's mother—not an unfamiliar female tester—produces the displays (Kahana-Kalman & Walker-Andrews, 2001; Montague & Walker-Andrews, 2002).

Contextual information—provided by peekaboo—also appears to facilitate early recognition of smiling expressions (Montague & Walker-Andrews, 2001). When 4-month-olds participate in peekaboo games in which a tester's happy/surprised expressions are systematically replaced with anger, fear, or sadness expressions, infants show greater interest and surprise and different patterns of visual attention to the discrepant expressions.

V. Smiling and Attention to the Caregiver

A. SMILES AND AROUSAL MODULATION

Although smiles are approach-oriented signals of enjoyment, infants may also use smiles to manage arousal. Arousal in infants is indexed by increased heart rate and by arousal-modulation activities such as mouthing objects and gazing away from engaging stimuli (Weinberg & Tronick, 1996). As in adults (Cacioppo *et al.*, 2000), an infant's heart rate is more rapid during smiling than during neutral expressions (Emde *et al.*, 1978). Infants tend to mouth their hands while smiling, suggesting that smiles may be involved in tension reduction.

Smiles typically occur while gazing at the caregiver's face (Weinberg & Tronick, 1994) and this may also may be relevant to infant arousal modulation. Face-to-face visual regard is a relative rarity among nonhuman primates. Among all primates, including humans, face-to-face visual regard can be used a threat display. It is possible, then, that infant smiles can be used to maintain arousing face-to-face eye contact (cf. Morris, 1967). We have, for example, observed smiles to occur in close temporal proximity and even overlap negative emotional expressions. This occurs, for example, as caregivers attempt to "cheer up" infants who have become overexcited in play or are recovering from the still-face perturbation (Weinberg & Tronick, 1996). Documentation of such patterns might suggest that smiles themselves can be used to regulate arousal and that the arousal regulation capacity of infant smiles is sometimes overwhelmed, leading to a negative expression.

B. THE EARLY COORDINATION OF SMILING AND GAZING AT THE CAREGIVER'S FACE

From a developmental perspective, infants between 2 and 3 months of age occasionally smile at a social partner (sometimes they smile at themselves in a mirror) and then gaze away. Smiles in which infants gaze away before the peak of the smile is reached have been described as communicating a "coy" quality and naïve observers perceive some smiles with these characteristics as indicative of shyness (Draghi-Lorenz, Reddy, & Morris, 2005; Reddy, 2000).

The coordination of smiles with gazing changes and becomes more precisely patterned with age (Yale *et al.*, 2003, 1999). Simulation studies suggest that, at

3 months, the pattern of gazing away during a smile actually occurs less than expected by chance (Yale *et al.*, 2003, 1999). The simulation studies indicate that 3-month-olds tend to begin and end their smiles within the course of a gaze at the parent's face (Yale *et al.*, 2003). That is, early expressions of positive emotion are dependent on continuous visual contact with the parent. By 6 months, infants redirect their attention after sharing positive emotional expressions with their parents. They tend to gaze at mother's face, smile, gaze away, and then end the smile. Such gaze aversions—at least among 5-month-olds playing peekaboo—tend to occur during higher intensity smiles and smiles of longer durations (Stifter & Moyer, 1991).

It is suggestive that toward 6 months of age infants become especially likely to control their own positive emotion by gazing away from mother during the course of a smile. This is also the period in which infants become adept at using intense open-mouth smiles with eye constriction to participate in highly arousing social situations. Infants are simultaneously becoming more actively positive during interactions and becoming more active at regulating the conditions under which they will become positive engaged (Messinger *et al.*, 2001; Yale *et al.*, 2003).

C. THEORETICAL PERSPECTIVES RELEVANT TO SMILES AND GAZE AVERSION

Theoretical perspectives hailing from social psychology may be relevant to infant gaze aversion during smiles. One theoretical perspective holds that positive emotion occurs when an individual attains a goal faster than anticipated (Carver, 2001, 2003). Goals are desired end states. When goals are attained more rapidly than expected and positive emotion occurs, the individual is likely to attend to other features of the environment including other potential goals. This may be partially responsible for the broader, more creative cognitive set of adults after they have experienced positive affect (Fredrickson, 2001; Fredrickson & Joiner, 2002).

Although infants' goals are relatively inchoate, Carver's (2001, 2003) proposal may be relevant to infant's proclivity to gaze away from the parent's face during a smile. Infants are learning to expect peaks and declines in arousal associated with interactive smiling. The infant's growing tendency to gaze away from the parent's face during a smile may index the infant's developing comprehension that an affective climax has been reached; that is, in the most primitive sense, a goal has been achieved. In this sense the infant's smiling behavior may index the infant's affective and cognitive comprehension of their interface with the environment at a particular moment (Fogel, Bosma, & Kunnen, 2001).

VI. Smiling and Referential Communication

In this section, we examine infants' developing capacity to utilize smiles to communicate intentionally toward the completion of the first year of life. In the first 6 months, infant emotional expressions appear to reflect, for the most part, a primary, nonreflective communication of immediate experience (Kaye & Fogel, 1980). Infants engage in intricate communicative smiling exchanges at 6 months, but their smiles are the message. They do not clearly communicate *about* external events. Surprisingly, the form of infant smiling does not appear to change between 6 and 12 months (Fogel *et al.*, 2006). Instead, it is the timing of smiles and gazes at a social partner that changes as smiles become vehicles for referential communications about external objects and events.

By way of backdrop, between 8 and 12 months, infants begin to communicate desires and experiences intentionally to their communicative partners (Adamson & Bakeman, 1985). Infants create conventional or ritualized behavior patterns with the apparent intent of influencing another. Infant smiles are more likely to accompany protodeclarative communication, whose goal is showing or sharing, than protoimperatives, whose goal is obtaining an object or action (Kasari *et al.*, 1990; Messinger & Fogel, 1998).

Both smiles and protodeclarative gestures tend to occur in the context of coordinated joint engagement in which the infant actively shifts attention between a toy and a social partner (Adamson & Bakeman, 1985). These gestures and attentional patterns are often referred to as triadic communication in that the infant refers to an object or event outside the infant–partner dyad. Patterns of triadic joint engagement—both those that are accompanied by smiles and those that are not—increase substantially between 5 and 9 months (Striano & Bertin, 2005). Yet the percentage of infants who accompany a gaze between a toy and an adult with a smile is dramatically less than the percentage of infants who only coordinate gazing between the toy and the adult at 5, at 7, and at 9 months. This suggests that combining a smile with a gaze at an attentive adult indexes a more complex communicative achievement than gazing alone.

Anticipatory smiles are a specific temporal pattern of smiling and gazing at a partner that may have special intersubjective significance (see Figure 7) (Venezia *et al.*, 2004). Anticipatory smiles occur when an infant smiles at an interesting toy or event and then turns to gaze at another person while continuing to smile. We have studied anticipatory smiles during infant initiations of joint attention in which a tester places a windup toy on a table (Mundy, Hogan, & Doehring, 1996; Seibert, Hogan, & Mundy, 1982). In this context, the infant's smile while gazing between the object and social partner appears to communicating something like, "that was funny, wasn't it?"

Fig. 7. Anticipatory smile. A 15-month-old infant gazes at an object (left), smiles at the object (middle), and gazes at the experimenter while continuing to smile (right).

Developmental and associated evidence suggests infants use anticipatory smiles to communicate preexisting positive affect to another person. Infant anticipatory smiles—whether occurring in interaction with mother or an experimenter—increase between 8 and 12 months. This developmental increase is not seen in rates of initiating joint attention generally or in other patterns of smiling accompanying initiations of joint attention. The degree to which infants engage in anticipatory smiling is associated with separate measures of their level of intentional communication and understanding of means–end relationships (Jones & Hong, 2001). This suggests that, when engaging in anticipatory smiles, infants are coming to understand and refer to the relation of an adult and an object. During anticipatory smiles, infants smile and, in real time, reference an object to another. From a dynamic systems perspective, this real-time process suggests how positive affect may motivate the *development* of early referential communication (Adamson & Bakeman, 1985; Fogel & Thelen, 1987; Jones & Hong, 2005; Venezia *et al.*, 2004)

VII. Pragmatics: the Representativeness, Discriminant, and Predictive Validity of Infant Smiling

This section reviews literature on the representativeness of laboratory studies of infant smiling and differences in smiling between typically developing and at-risk infants. We then examine associations of infant smiling with developmental outcomes.

A. REPRESENTATIVENESS OF SMILING

Many of the studies reviewed in this chapter occurred in controlled laboratory settings. Interest in developmental outcomes, then, raises questions concerning the stability and representativeness of findings. In Western industrialized societies the quantity of infant smiling coded during the 3-min

face-to-face interactions with mother typically is correlated with infant affective state observed during 2–3 h home observations (Cohn *et al.*, 1990). Infant's positive smiling reactions to social stimuli such as peekaboo are associated with observed infant positive emotional tone during interactions with parents and with parent ratings of their children's day-to-day positive emotions (Aksan & Kochanska, 2004). From a broader perspective, however, frustratingly little is known concerning the frequency and duration of smiling outside of the structured face-to-face interactions that have been observed by researchers in the day-to-day life of infants in industrialized societies. Rates and types of smiling do, however, allow developmentalists to discriminate between typically and atypically developing infants.

B. SMILING IN ATYPICALLY DEVELOPING INFANTS

Patterns of smiling allow us to distinguish typically developing infants from infants at risk for different types of disturbed development. Infants at risk for autism exhibit lower levels of smiling than typically developing infants (Cassel *et al.*, in press; Zwaigenbaum *et al.*, 2005). Maternal depression and maternal depressive symptomatology, particularly when chronic, tend to be associated with less frequent infant smiling, at least during interactions with mother (Moore *et al.*, 2001). Smiles are more frequent among healthy infants than among those with a history of neurological complications or other illnesses related to preterm birth (Bigsby *et al.*, 1996).

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Infants at risk for developmental difficulties also show deficits in particular types of smiling. Premature infants, for example, engage in lower levels of high amplitude and/or open-mouth smiling during face-to-face interactions and exhibit fewer high-amplitude smiles during peekaboo games with a trained experimenter than do full-term infants (Eckerman *et al.*, 1999; Segal *et al.*, 1995). This difference is likely due to premature infants' reduced capacity to tolerate highly arousing positive affect. An opposite pattern is seen in infants with Down syndrome. These infants show a pattern of somewhat indiscriminate intense smiling. They tend to direct smiles with eye constriction and mouth opening both to the toys with which they are playing and to their mothers, whereas typically developing infants direct these smiles only to their mothers (Berger & Cunningham, 1986; Carvajal & Iglesias, 2001).

C. SMILING AND DEVELOPMENTAL OUTCOMES

Still-face studies are often the basis for investigations of the predictive validity of early smiling. Individual infants show consistency in smiling levels over the episodes of face-to-face/still-face, particularly between the interactive face-to-face

and reunion episodes (Carter, Mayes, & Pajer, 1990; Cassel *et al.*, in press; Moore *et al.*, 2001; Weinberg *et al.*, 1999). Surprisingly, smiling at the still-face does not increase after 1½ months of age (Bertin & Striano, 2006; Lamb, Morrison, & Malkin, 1987), nor does it show developmental stability within infants (Moore *et al.*, 2001). The possibility that smiles during the still-face can be positively characterized as bids for the parent's attention deserves increased attention from researchers.

There is some evidence that infant smiling in the face of the challenge of the parental still-face may index emotional resilience. Six-month-old infants who smile during the still-face are more likely to become securely attached at 12 months than infants who do not (Cohn, Campbell, & Ross, 1991). They are also perceived by their parents as having fewer externalizing behaviors at 18 months than infants who did not smile during the still-face (Moore *et al.*, 2001). Still-face smiling may reflect an infant's expectations of positive communication and be associated with dyadic patterns of harmonious interaction that subsequently lead to more optimal developmental outcomes.

Positive affect sharing indexed by anticipatory smiling may be one link between early social smiling and subsequent social expressivity and competence (Parlade, Messinger, & Mundy, 2006). Smiling by 6-month-olds in face-to-face interaction with a parent and in the subsequent still-face positively predicts mean levels of anticipatory smiling with a tester between 8 and 12 months. An infant's experience with early gratifying social interaction probably contributes to a continued tendency to share positive affect with an adult. In fact, affectively positive infant joint attention communications are, more generally, predicted by highly sensitive maternal caregiving (Hane & Fox, 2006). In addition, mean levels of anticipatory smiling predict parent-reported social expressivity and social competence at 30 months (Parlade *et al.*, 2006). Infants who share smiles with relatively unfamiliar adults may be more motivated than other infants to engage socially and emotionally with others.

Researchers motivated by a positive psychology perspective have become involved in investigating the impact of positive emotions—above and beyond the absence of negative emotion—on interpersonal competence and well-being. Positive emotional experience in infants may, as in adults, broaden the scope of attention and the behavioral repertoire and elicit positive responses from social partners (Fredrickson, 2001; Fredrickson & Joiner, 2002; Harker & Keltner, 2001). One longitudinal study relied on an extreme groups design in which infants were selected based on their emotional reactions to neutral stimuli at 4 months of age (Fox *et al.*, 2001). Infants who engaged in more smiling, neutral/positive vocalizations and motor movement were compared to infants who had negative reactions or were not responsive to the stimuli. The infants who showed earlier emotional positivity exhibited less behavioral inhibition in unfamiliar situations over the first 2 years of life than other infants. They continued to show a more exuberant temperamental style at 4 years when they were

more likely to talk and engage with peers (Fox *et al.*, 2001). Similar results have been reported among a normative sample of 18-month-olds observed during reunions with mother in the Strange Situation (Abe & Izard, 1999). Infant smiling involving eye constriction (Duchenne smiling) predicted parent ratings of extraversion and openness to experience when children were 3½ years of age.

Smiling interactions involve coconstructing processes of responsive engagement. Relationships characterized by this mutual positivity may have relatively enduring developmental effects. Caregiver positive emotional responsivity to the infant is associated with later internalization of social norms and committed compliance to maternal requests (Kochanska, 2002; Kochanska, Forman, & Coy, 1999). Experiences of affectively positive responsivity, participation in the ebb and flow of joyful engagement, may enable infants to experience their own joy as a mutual process. Joy is not only shared but created in such interactions. The delight of engaging in a positive process bounded by mutual expectations ultimately contributes to the creation and internalization of social norms.

VIII. Summary and Conclusions

Infant smiles emerge even in the absence of visual feedback, but their interactive development and intensification appear to be dependent on experiences of visually mediated interaction. Although neonatal smiling has no clear emotional content, social smiling emerges out of attentive engagement with an interactive caregiver. This process illustrates the dynamic systems postulate that real-time interaction is a window on developmental process.

On the one hand, specific dimensions of smiling may have qualitatively different psychologically meanings. On the other hand, different features of infant smiling may reflect linked indices of a single dimension of positive emotion that ebbs and flows in time. The resolution of this paradox will likely involve continued attention to the interactive flow of positive emotion communication. This will be facilitated by new methods for measuring smiling and positive emotion in time.

Smiling may simultaneously index a desire to interact and the dissipation of arousal associated with that interaction. Infants' capacity to become actively and vigorously caught up in emotionally positive smile-mediated interaction is linked to their ability to regulate that emotion by gazing away from their interactive partners. Ultimately, this attentional control paves the way for infant's tendency to use smiles to initiate early referential communication with a partner. These anticipatory smiles may provide a developmental bridge between early emotionally positive dyadic responsivity and later patterns of social competence.

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