Debates

Social process theory of emotion: A dynamic systems approach

Alan Fogel* University of Utah, Eva Nwokah and Jae Young Dedo, Purdue University, Daniel Messinger, K. Laurie Dickson, Eugene Matusov and Susan A. Holt, University of Utah

Abstract

In this paper we apply a dynamic systems perspective to infant emotional development. We propose that emotions are not states but self-organizing dynamic processes intimately tied to the flow of an individual's activity in a context. We review data on the relationship between emotional actions and the social context, in particular the development of smiling and laughter. These data are more adequately explained by our perspective than by other theories of emotional development. We provide a model for how emotional processes in early infancy become embedded into sociocultural systems, and suggest new avenues of research on emotional development.

Keywords Emotional development; dynamic systems; nonverbal communication; self-organization

The current state of theory and research on emotional development

In this paper we propose a social process theory of emotion and its development in the social context. We suggest that emotions are neither states nor programs but self-organizing dynamic processes that are created with respect to the flow of the individual's activity in a context. This paper is an extension to emotional

development of a previous theoretical analysis of the development of communicative and expressive action in the social context from a dynamic systems perspective (Fogel & Thelen, 1987).

We begin by reviewing current theories of emotional development. Next, we review recent empirical findings that are inadequately explained by existing theories and we outline a social process theory of emotion in the form of three propositions. The theory uses dynamic systems principles and poses an alternative to the prevailing theories of emotional development. Finally, we give specific suggestions for research strategies that illuminate the dynamics of emotion in the social context.

A large number of processes are thought to be involved in emotion, including patterns of central nervous system (CNS) activation, patterns of autonomic nervous system (ANS) arousal, actions of the face, body and voice, psychological processes (such as feelings, drives, motivations and evaluations), and processes related to the transaction between individual and environment. Current theories of emotion postulate that one or another of these processes has primacy in the organization and development of emotions. In this section, we have grouped otherwise diverse theories by the type of process to which they accord primacy in explaining emotional phenomena. Our purpose is to both acknowledge the insights of these perspectives and to indicate their limitations.

Discrete emotion theory

One current view of emotions is discrete emotion theory (Emde, Gaensbauer & Harmon, 1976; Fridlund, Ekman, 1982; Izard, 1990; Izard & Malatesta, 1987; Tomkins, 1962; 1981), which suggests that emotions organize and motivate action such that "a discrete emotion can be defined as a particular set of neural processes that lead to a specific expression and a corresponding specific feeling" (Izard & Malatesta, 1987, p. 496). Approximately nine different basic emotions reflecting correspondences between specific patterns of CNS activity, facial expression and subjective experience are generally postulated as part of a core emotion program. The emotion program is believed to be phylogenetically adapted with respect to the basic functions of survival. According to Tomkins, patterns of neural stimulation cause associated changes in feeling, and are associated with "distinct sets of facial, vocal, respiratory, skin and muscle responses" (Tomkins, 1981, p. 325).

Development of the emotions is presumed to be controlled by the maturation of the CNS, causing corresponding changes in expression. In addition, display rules may be learned that modify and modulate the expression of the core programs, such as restricting sadness to only a brow movement in one culture or changing its duration of expression in another (Fridlund et al., 1987; Zivin, 1982). Although emotions can be expressed using the whole body, discrete emotion theorists tend to focus primarily on the face. According to Demos' interpretation, "facial expressions in young children represent the primary, the most precise, and the clearest indicators of affective states" (Demos, 1982, p. 128).

Functionalist theories of emotion

The functionalist theory places emotions squarely at the interface between the individual and the environment so that emotions reflect the ecology of organism-

environment relationships (Barrett & Campos, 1987; Campos & Barrett, 1984; Fridlund, in press; Frijda, 1987; Gianino & Tronick, 1988; Lazarus, 1991; Leventhal, 1980; Trevarthen, 1977). "We conceive of emotions as bi-directional processes of establishing, maintaining, and/or disrupting significant relationships between an organism and the (external or internal) environment" (Barrett and Campos, 1987, p. 558). Each form of individual-environment relationship is reflected by a "family" of different emotions. Enjoyment, for example, would be defined as moving toward aspects of the environment in order to experience or take part in them, and might be expressed by "action tendencies" such as smiling, laughing, hugging, or approaching. According to some functionalists (Darwin, 1872; James, 1890; Leventhal, 1980), the form of the action contributes to the subjective quality of the emotion. In other words, if the action context demands that one run away rather than show a facial expression of fear, the subjectively experienced emotion will differ in each situation.

For functionalist theory, emotional development begins with a core set of CNS emotion programs (Campos & Barrett, 1984; Lazarus, 1991). These programs are defined with respect to basic functional or survival relationships between the individual and the environment and involve action tendencies of the entire body. Trevarthen (1977) believes, for example, that emotions are part of innate routines for social communication and serve to initiate and maintain contact with others. Development must therefore occur with respect to the relationship between the individual and the environment and thus one's attention is directed to changes in the sequences of action involved in adaption to the environment (Lazarus, 1991).

Cognitive theories

Another approach to emotion can be found in theories that emphasize the evaluative and appraisal aspects of emotion (Cicchetti & Sroufe, 1978; Fischer, Shaver & Carnochan, 1990; Kagan, 1978; Lazarus, 1991; Lewis & Brooks-Gunn, 1979; Schachter & Singer, 1962; Sroufe, 1979). Sroufe (1979) suggests, for example, that the infant can only experience the emotion of enjoyment if there is some "psychological processing of the stimulus content" (p. 481). Following Piaget (1952), cognitive developmental theory posits that cognition in infants need not be a purely mental activity, but is part of the individual's active engagement with the environment (Fischer et al., 1990, Lewis & Brooks-Gunn, 1979, Sroufe, 1979). In this sense, cognitive theory is similar to functional theory in the emphasis on the relationship between individual and environment, and stresses continuous interactions between emotion and cognition during development (Cicchetti & Sroufe, 1978; Sroufe, 1979).

From a developmental perspective, cognitive theories of emotion assume a reflexive neonate whose expressions are innately activated by unlearned and unregulated CNS and ANS processes. Emotions per se do not emerge until particular cognitive developmental milestones are reached and allow for cognitive appraisal of the innate physiological response (Lewis & Brooks-Gunn, 1979; Sroufe, 1979). Developmentally, emotions are increasingly influenced by cognition and by the sociocultural context.

Theories of emotion in the social context

Social theories of emotion emphasize the role of social interaction in the development and display of emotion. This perspective includes theories of the social construction of the emotions (Averill, 1980; Gordon, 1990; Harre, 1986), theories of adult guidance (Rogoff, 1990; Vygotsky, 1978), and theories in which social learning plays a role (Malatesta et al., 1989; Lewis & Michaelson, 1982; Tomkins, 1962). In these views, development occurs by means of the social transfer of categorical linguistic labels or as the result of guidance, modeling or reinforcement processes.

From a developmental perspective, social theories of emotion also assume a biological core of emotions out of which infants and their partners construct culturally defined emotions. It is not clear how this happens before the emergence of cognitive and linguistic skills necessary for the comprehension of labels and categories. In any case, once infants acquire the necessary cultural tools, constructivist theories have provided a number of models by which children acquire culturally specific display rules. In some versions of this theory (Averill, 1980; Gordon, 1990; Harre, 1986), the constructed emotions are entirely dependent upon cultural definition.

Issues in emotional development

In spite of their differences in emphasis, our review of current theories suggests a convergent view of early emotional development. Infants are thought to begin life with a rudimentary but organized set of innate emotion programs. These programs are thought to have a phylogenetic origin and are structurally embodied in the physiology of the CNS, ANS and motor system. During development, individuals acquire the ability to regulate their expression by self-control and cognitive processing, and to adapt to culturally imposed display rules. Thus, social and cognitive factors enter emotion from the outside but do not alter the biological core of programs.

What's wrong with this developmental scenario? We argue that this conceptualization of emotional development is incomplete in three major areas. These points are each developed in the next three sections of this paper covering the topics of self-organizing systems, sequential patterning of emotion, and gradient and categorical emotional information. In each section we offer a response in the form of a theoretical proposition based on the dynamic systems perspective.

First, there is a rich array of emotional phenomena – especially those pertaining to their variability and context-specificity – that are explained inconsistently by existing theories. Even in infancy, the variability of patterning of emotion-related actions may not be consistent with the notion of a core set of hard-wired emotions or blends of those emotions. *Proposition 1* states that emotions are dynamic self-organizing systems.

Second, the way in which emotions develop within social relationships and in relation to the functions and demands of daily living is poorly understood. The dynamics by which those relationships contribute to emotional development, and conversely, the ways in which emotions affect relationships, has not been well

established. According to *Proposition 2*, sequences of action in the social context are conceptualized as an integral feature of the emotion system.

Third, current conceptualizations of the acquisition of cultural display rules fail to explain observations on the cultural variability of displays in early infancy. We need a theory of emotional development that does not rely on categorical emotions that require advanced linguistic and cognitive skills to perceive and produce. In *Proposition 3*, we suggest that emotions are perceived and produced using intensity and timing information available to young infants not only in the face, but also in vocalizations and body movements.

The social process theory of emotion reflected in Propositions 1, 2 and 3, is based on a dynamic systems perspective suggesting that action and its development – including perception, cognition, motor skill, social behavior and emotion – is a constructed and emergent process that is related to physiological factors, to the demands of a task, and to the broader context in which the action takes place. Although we believe our approach to be generalizable to the entire life course and to the entire spectrum of emotions, the following discussion focuses on positive emotions in infancy and early childhood.

Emotions as self-organizing systems

Although not all emotion theorists attempt to account for infant emotions, those that do assume that there are a small number of discrete emotions from birth, a set of core programs that develop at first by a highly canalized maturation of the CNS. These early emotions are thought to be relatively reflexive and un-modulated by the environment. Only later are these emotions thought to become socialized and variable according to learned display rules. In this section we make two main points: (1) The empirical evidence for this position is not convincing. (2) From the first weeks of life data suggest that there are more instances of contextual modulation and expressive variability than has been predicted.

Neuro-developmental considerations

In current views of brain functioning (Skarda & Freeman, 1987; Singer, 1986), the brain acts as a cooperative system in which many structures must be concurrently activated. Previous views conceived of the brain as composed of different areas, each having a dedicated function, such as the presumed sub-cortical location of the basic emotion programs. Current views suggest, however, that even a simple emotional expression would be inconceivable without the active cooperation of the sensory cortical and sub-cortical structures, the motor cortex, and the feedback from the motor effector system whose anatomical connections impose constraints on neural processing at all levels (Leventhal, 1980).

Existing theories of early emotional development are at odds with new data on the development of the brain showing that brain structures are neither preformed nor maturationally driven. *Many aspects of brain structure, including patterns of neural activation, are developmentally constructed in relation to the experiences of the individual* (Gottlieb, 1991; Greenough, 1991; Greenough, Black & Wallace, 1987). The brain, like the rest of the body, is a phenotype and requires active transaction with an environment in order to develop.

Because active transaction with the environment is required for the normal development of neurological structures (physiological maturation is not sufficient), it may be more accurate to assume that emotions are not hard-wired but rather a soft or flexible initial assembly of elements, each of which may developmentally affect the others. In animals and humans who have been exposed to stress or to extra handling in infancy, their CNS and ANS processes and structures are measurably different from controls (Gunnar, Magelsdorf, Larson & Hertsgaard, 1989). Could this mean that culturally mediated construction processes serve to re-organize the entire emotion system, including both central and peripheral behavioral features? We know little about neurphysiological development in this regard (Fridlund, et al., 1987) and research on the biological components of emotions should be open to such alternative hypotheses.

Variability in patterning of facial actions

What is the evidence for a core set of reflexive and un-modulated expressions in early infancy? A careful examination of the research suggests that investigators have been premature to conclude that such a core exists. First, most studies only code facial expressions and not other possible emotion-related facial, vocal and body actions. Second, with few exceptions, only facial expressions that are recognizable as members of the proposed discrete emotion categories are recorded in widely used discrete emotion coding systems such as AFFEX (Izard, 1977): non-standard facial movements and other body actions are ignored. Finally, data are typically reported as average rates of occurrence, thus ignoring the sequential and context specificity of expressions and their variants (Fogel & Reimers, 1989).

By contrast, Ekman and Friesen's (1978) Facial Action Coding System (FACS) and Oster and Rosenstein's (in press) adaptation of FACS for infants are anatomically-based systems for coding facial action units. These researchers suggest that examination of the organization of elementary muscle actions, rather than the study of facial gestalts, allows for the discovery of emerging patterns in emotional processes. Indeed, less than one-third of a corpus of 6,000 adult facial expressions can be classified on the basis of a priori emotional categories, and not all facial expressions are clearly associated with ANS and other indices of emotional processing (Fridlund et al., 1987).

Research on infants reveals a number of such non-classifiable expressions. Oster and Ekman (1978) examined a non-standard infant facial expression, the "horseshoe" mouth. This configuration was systematically accompanied by motor quieting and by direct, prolonged and unbroken visual fixation of the social partner. This configuration, similar to a pout, typically is not followed by crying. Oster (1978) found that brow knitting, typically thought to be a component of discrete negative emotions, often immediately precedes but never coincides with smiling. More recently, Camras (in press, a, b) reports that infant negative expressions surrounding similar situational events are highly variable, showing an unpredictable mixture of "sadness" and "anger" expressions even in the same bout of crying. In some cases, tickling a crying baby induces a complex and changing mixture of facial actions and vocalizations that bear some resemblance both to cry and to laugh (Nwokah et al., 1990). We found that laughter can be categorized into at least ten distinct types (Nwokah, Davies & Fogel, 1990). The "comment laugh,"

for example, has one main vocal peak, "chuckles" have two peaks, and "rhythmical laughs" have three or more. Rhythmical laughs are the most frequently occurring, followed by comment laughs and then chuckles, and there are individual differences in the frequency of laughter types. These findings are analogous to the different patterns discovered for cry vocalizations in young infants (D'Odorico, 1984; Wolff, 1987).

These findings suggest that there are coherent patterns of facial and vocal action, but that even young infants display a wide variety of patterns that would be difficult to classify on the basis of discrete emotions or blends of discrete emotions. In lieu of a more complete natural history of facial action, one should regard with caution claims for a small, universal, or core set of emotions and their facial concomitants.

Context specificity of facial actions

Are these non-standard patterns of expression random or transient phenomena? Not only do many such patterns occur with a relatively high frequency, there is evidence that many of these patterns occur systematically with respect to context. Ekman, Davidson & Friesen (1990), for example, differentiated Duchenne smiles in which the lip corners are raised by the zygomatic muscle (action unit AU12 in FACS) and in which the orbicularis oculi raises the cheeks and crinkles the corners of the eye (AU6), from non-Duchenne smiles that involve only lip corner raises. Duchenne smiles are more likely to occur in contexts associated with genuine feelings of pleasure while non-Duchenne smiles occur in contexts not associated with pleasure. For infants playing with an attentive adult, open-mouth smiles are more common, while in toy-centered non-social play closed-mouth smiles occur more frequently (Demos, 1982; Holt, 1984, 1990; Jones & Raag, 1989). Very similar relationships between social context and facial actions are reported in other primates (Blurton-Jones, 1972; Chevalier-Skolnikoff, 1973; van Hooff, 1972).

Dedo (1991) examined mouth opening and lip corner retraction, as well as the presence of other facial actions when AU12 (lip corner raise) was present for infants between 10 and 18 months. Smiles with less pronounced lip retraction (AU12x or AU12y) and a relatively closed mouth (AU 25 or closed) occur more often during object exploration. During mother-infant games, infant smiles are more likely to have more intense lip corner retractions (AU12z and cheek raising, AU6; a Duchenne smile) and moderate or wide mouth opening (AU26 or AU27). Other facial movements – such as nose wrinkling, tongue showing and lip sucking – systematically accompany AU12. Nose wrinkling most often occurs in the game context, appearing with long lip retractions and wide open mouths. Lip sucking with short lip retractions are more related to the context when mother requested the infant to do something. In addition to patterns found to occur across infants, there were also individual differences in patterns (see also, Demos, 1982).

There are linkages between social context and different types of laughter. It was found that low intensity laughs are associated with infant actions such as object exploratory play while high intensity laughs are significantly related to maternal games (such as tickling and bouncing) and infant's movements (such as going down the slide) (Nwokah, et al. 1990). In the third year, the ways in which infants display and hide smiles also show context specificity, depending on the instructions in a social task (Reissland & Harris, 1991).

Proposition 1: *Emotion is a self-organizing system constituted by the interaction of many components related to individuals in their social and physical context.*

The preceding review of the literature suggests that the CNS may develop in relation to emotional experiences, that there is variability in the patterning of facial actions, and that many of these variants are systematically related to social contexts. How can we explain the variety of emotional phenomena described above? We postulate that emotion is not felt experience alone, nor a pattern of neural firing, nor an action such as smiling. Emotion is the process that emerges from the dynamic interaction among these components as they occur in relation to changes in the social and physical context.

According to dynamic systems approaches, organized and repeated patterns can arise from the mutual constraints imposed by components of a complex system on each other. There is no need, theoretically, to assume that there is an executive center or core program that imposes order, nor even that one component is the organizer of the others. The dynamic systems alternative to these views is the principle of *self-organization* (Haken, 1977; Kugler, Kelso & Turvey, 1982).

Some theorists postulate neurologically based emotion programs as the primary organizer that creates a set of patterned expressions. Others suggest that the primary organizer of patterned families of emotion is the individual's relationship to the environment, the motivational system or the cognitive system. From a dynamic systems perspective, coherent emotions can be conceived of as relatively stable patterns that are continually constructed by a complex and dynamic process of interaction among the components (Camras, in press, b).

What does a dynamic systems perspective offer that existing theories do not? According to a dynamic systems view, there are no elements that are more central or important than any others. One need not assume that each time enjoyment occurs it is elicited and maintained by a similar causal mechanism. There may be many starting points, and many different types of interactions among the components that eventually coalesce into a stable positive emotion. We need not speak of emotion-related facial actions as "expressions" or even as "displays" since these terms imply a linear pathway of causation from inner process to behavior (Hinde, 1985). A dynamic systems view directs one's attention to the process by which emotions become organized into coherent patterns, and opens this process to empirical investigation.

The variability of the linkages between emotion components may be one reason for the inconsistent support for the facial feedback hypothesis (Leventhal, 1980). Moreover, there are interactions between emotion components that do not involve facial feedback, such as the interdependence of cognitive and affective processes in emotional development (Cicchetti & Sroufe, 1978; Sroufe, 1979). The common use of multiple indices (cf. Fridlund et al., 1987) – such as facial and other action, physiological measures and the context – to measure emotion implicitly invokes an interdependent view of the emotional process. Fridlund et al. (1987) conclude that emotions should be treated as "soft" constructs, like intelligence and personality, not indexed by a single component. Multiple indices are necessary if there is interdependence between components such that the action of one component influences but does not determine the others in ways that are not precisely predictable.

In existing theories, facial action variants that do not fit neatly into one or

another discrete emotion have been assigned non-emotional, pre-emotional, or blended emotional status (Fridlund et al., 1987; Lazarus, 1991; Izard & Malatesta, 1987; Sroufe, 1979). The emotion program is presumed to be the source of the patterns that are differentially reinforced with respect to variations in the social context. Thus, blends are evidence of "conflict" or "masking," and actions following intense emotions are "coping." The emotion program is the ghost in the machine: it is always there regardless of how much it is civilized, modulated or disguised. Implicit in these theories is the view that this core set of emotions becomes sublimated, overruled, or transformed by social interaction: a view not much different from a Freudian energetic conception of emotional development.

Emotions that we commonly describe as "conflicted" or "masked" reflect unique self-organizing processes of many components. Their characterization as a battle for primacy of expression, or a blend between two or more core programs, is mere metaphor. The actual physiological and psychological processes that enter into the experience of ambivalence or deceit are likely to bear little resemblance to their supposed discrete poles of conflict since the notion of self-organization suggests that the poles (the components) continuously affect each other to create a unique emergent pattern. This view does not deny that emotions are experienced as motivating, that they are accompanied by cognitions and goals, or that they are supported by neural processes. What we mean is that none of these components is the sole cause of emotion, nor is any component fully defined and structured in the absence of interaction. The essence of a dynamic system is that each component is not self-contained and inviolable, but flexible and open to transactions that may fundamentally alter its pattern of action.

The developmental implications of this view are fundamentally different than in other views of emotion. Most emotion theories predict that the common core of emotions, although somewhat flexible and open to contingent environmental shaping, is invariant across the life course and universal across the human population. *The dynamic systems perspective predicts a greater developmental malleability of the emotions.* To the extent that a carefully done cross-cultural and longitudinal natural history of the emotions may reveal developmental and cross-cultural invariants, a dynamic systems view would seek explanations based on universal processes and universal dynamics, rather than based on universally fixed programs.

A research agenda freed from treating motivations, cognitions, or neural programs as primary organizers that are not fundamentally influenced by their interactions can lead to a new perspective on emotional phenomena. What is the range of possible combinations of organized patterns of facial and other action that we see at different ages and in different cultures? Are the individual's patterns of organized action systematically related to context? How do developmental changes in emotion processes interface with changes in motivation and cognitions, and to the individual's changing relationship to the context? The research agenda focuses on the temporal dynamics of process rather than on the statics of correlations between independent measures.

Sequential patterning of emotions

How does the ongoing pattern of action, context and feeling contribute to the evolution and dissolution of emotions? Tomkins (1962) suggests that affects are activators of themselves, creating longer term moods, and that reduction of either negative or positive affect tends to lead to the appearance of an affect of the opposite valence. Solomon and Corbit (1974) report that the removal of electric shock is inherently reinforcing to an animal. Some research suggests that the prior context or induced emotion influence an individual's response to "emotional" material presented in films (Krupat, 1974; Masters, Barden & Ford, 1979). Izard (1971) suggests that emotions might amplify or attenuate each other, as in the attachment-exploration system in which interest in the environment alternates with anxiety over separation from the mother, and Malatesta, et al. (1989) recognize the need to expand research on emotional sequences.

Research on infants and children shows that actions by a social partner, as well as the flow of the subject's own action, are sequentially related to changes in emotion. Infants have been observed to make sudden changes from crying to laughing as the result of a simple intervention like maternal tickling (Nwokah et al., 1990; Nwokah & Fogel, in press), although tickling does not always end a crying episode (Wolff, 1987). Similarly, the onset of laughter in a game can be triggered by a single change of action on one occasion, but not on another. Whether an action elicits laughter seems to be related to the ongoing dynamics of the emotion in the social context, although considerably more research is needed to specify these processes (Fogel, Nwokah & Karns, in press; Nwokah & Fogel, in press).

Research indicates that the timing of social events also has a significant impact on infant emotion. Responses that are contingent on infant's behavior are likely to be followed by smiles and laughs, while non-contingent responses are likely to be followed by infant avoidance and crying (Emde, Gaensbauer & Harmon, 1982; Field, 1982; Koester, Papousek & Papousek, 1989; Maltesta et al., 1989; Tronick & Cohn, 1989; Watson, 1972). Smiling has been related experimentally to timing factors involved in the expectation generated by a series of repeated contingent events (Miller & Bryne, 1984; Sroufe & Waters, 1976; Watson, 1972), to the timing of the stimulus presentation vis-a-vis the infant's state of arousal (Field, 1982; Fogel, 1982; Wolff, 1987), and to the synchronization and repair of interactive sequences (Tronick & Cohn, 1989).

A number of studies have shown marked changes in emotional action following either the mother's abrupt cessation of action, the "still-face" situation (Cohn & Elmore, 198; Gusella, Muir & Tronick, 1988; Mayes & Carter, 1990; Murray & Trevarthen, 1985; Tronick, Als, Adamson, Weise & Brazelton, 1978), the mother's changes in tempo or simulated depression (Cohn & Tronick, 1983; Field, 1987; Field, Healy & LeBlanc, 1989), and maternal departure as early as two months of age (Field, Vega-Lahr, Scafidi & Goldstein, 1986; Fogel, 1980). In a variant of the still-face situation, we found that the still-face was less distressing to the infant if we asked the mother to initiate it while the infant was smiling, compared to when the infant was merely gazing at her (Fogel, Diamond, Langhorst & Demos, 1981), a finding that was later replicated with both behavioral and physiological data (Stoller & Field, 1982). This work demonstrates that there is at least a short-term sequential effect of prior emotions on later emotional responses

to the same contextual event. This interpretation is also supported by lower levels of smiling and higher levels of crying in a resumed spontaneous interaction following the still-face condition, compared to the spontaneous interaction that occurred before the still-face event (Fogel et al., 1981; Mayes & Carter, 1990; Stoller & Field, 1982).

Finally, the occurrence of smiling during a naturalistic session of mother-infant interaction was found to depend on a variety of sequential factors that changed with age (Fogel, 1982; Kaye & Fogel, 1980). In 6 and 13 week-olds, smiling was most likely to occur near the beginning of an interaction and following a mother's smile. By about three months, infant smiles were likely to be followed by repeated smiles in the context of maternal smiling and vocalizing with infant gazing at mother. By six months, bouts of repeated smiling co-occurred with episodes of laughter. In addition, infant smiles were more likely to precede mother smiles at six months, and infants continued smiling as they gazed away from the mother, or smiled while gazing away and then turned to look at the mother (Fogel, 1981).

Thus, by six months, smiles are embedded in increasingly complex sequences of action in systematic ways. Some students of the infant's behavior during social interaction prefer to code at the level of the sequences in which the facial actions are embedded, attaching more functional significance to these than to specific expressions. Examples are the monadic phase coding system (Tronick & Cohn, 1989), temporal hierarchies of infant action (Fogel, 1977; Stern, 1974), and the "packages" of interactive behavior described by Beebe & Gerstman (1980).

Proposition 2:   *Emotions are related to the continuously evolving sequences of action in a context.*

The systematic relationship between emotion and the infant's ongoing action may not have been recognized because emotions have typically been studied in highly intense or traumatic situations, such as following maternal separation or medical injections. These intense events may create responses that seem disconnected from the flow of action prior to the occurrence of that event. On the other hand, if emotion is studied in its everyday context it becomes more difficult to assign unique causal roles to any prior action or event. Rather, emotions are related to a complex sequence of prior and concurrent events. Although one can find theoretical justification for examining sequential emotional processes in theories that emphasize the individual's relationship to the environment – functional, cognitive and social theories – the fact remains that there are only a handful of existing studies of temporal sequencing that have been inspired by an explicit theory of emotion. Studies of sequential processes of infants interacting with social partners, oddly, have not been viewed as relevant to the mainstream of emotion research.

Dynamic systems perceptives offer a principled way to understand sequences and stability of emotional patterns as part of a larger process of change and re-organization in a complex system. This view is especially applicable to the study of how transitions occur between stable patterns of organization, particularly the concepts of *dynamic stability* and *linear and non-linear transitions* (Fogel & Thelen, 1987; Kugler et al., 1982; Thelen, 1989). Dynamic systems, including both physical and biological systems, spend most of their time in some stable pattern that is recognizable and repeatable. Dynamic stability refers to the observation that these

patterns are never static structures, but rather the result of each component of the system actively constraining all the others, that is, by self-organization.

Once a stable pattern is established, it often persists in the face of changes in some or all of the components. Systems may make transitions out of stable patterns, however, when a new component is added to the system, or when one or more of the existing components of the system is changed. If the system's stability is altered continuously as the components are changed, the system is said to be linearly dependent on changes in the component. In many cases, linear changes in one or more components do not change the system initially, but at a certain point the stable pattern suddenly breaks up and the system reorganizes into a new pattern. In this case, the behaviour of the system as a whole is a non-linear function of the changes in the components (Kelso, Scholz & Schoner, 1986; Thelen, 1989). In non-linear systems, the duration of the transition between stable patterns is considerably less than the duration that system exhibits any stable pattern. Thus, transitions between stable patterns are relatively brief with the system appearing to jump discontinuously from one stable process to another.

Because dynamic systems thinking predicts that the factors that are implicated in emotional changes are also the factors implicated in emotional stability, this view points to transitional phenomena as an important window on emotion dynamics. Either by observing emotions changing in the natural context, or experimentally perturbing emotion systems by changing one component at a time to probe their stability and patterns of change, we can learn about the dynamics of the emotional process (Fogel & Thelen, 1987; Kelso, Scholz & Schoner, 1986).

In our view, emotions are continuous and always present. Periods of time that are often called "emotional" reflect particular dynamic processes that motivate a change in the individual's relationship to the context. These intense periods cannot be isolated from prior and subsequent periods of relative relaxation, characterized by low levels of engagement. These are merely different patterns of organization of the components of the same emotion system.

The tendency in other theories is to highlight the more motivationally charged phases of action, attempting to explain sequentially linked action as pre-emotional preparation or as post-emotional coping (Lazarus, 1991; Leventhal, 1980). Because a dynamic systems view offers tools for conceptualizing sequences and transitions, it seems premature to decide a priori which parts of an otherwise continuous stream of action are more significant than others. This is especially true for infants, where the boundries between different emotions are less clear and the transitions between extremes less modulated.

If there are periods that are non-emotional, that would suggest the individual is no longer linked to the environment in any meaningful relationship, a position that seems absurd from a functionalist perspective. It makes more sense to talk about sequentially related phases in an emotional process, differences in intensity, variations in motivational attitude between the self and the environment, all from the perspective of how each of these variations makes a transition from one pattern to another.

Gradient and categorical emotional information

One important developmental issue that has been relatively unexplored is how young infants are able to relate events in the environment to changes in their own emotions. Do infants perceive facial expressions and respond to them in culturally appropriate ways? Emotion theorists that postulate a set of core emotion programs may assume that infants are genetically endowed with an ability not only to produce a discrete set of emotions, but to perceive certain environmental events, including the discrete facial expressions of social partners, as emotionally meaningful.

Infants tend to smile with a higher probability following adult smiles than in the absence of adult smiles (Kuchuk, Vibbert & Bornstein, 1986; Malatesta & Haviland, 1982). Does this mean that infants are responding to smiles by matching them with innate categorical representations of smile gestalts? This is unlikely. Research on facial perception shows that the infant's recognition of facial expressions develops slowly over the first years of life and is still rudimentary by age two years, particularly in research paradigms in which faces are presented as static two- or three-dimensional images. The evidence for discrimination of facial expressions in the first six months is controversial (Nelson, 1987). The use of adult facial expression to alter infant action, social referencing, does not begin until eight or nine months and at this time only infrequently and primarily with respect to negative rather than positive expressions (Hornik & Gunnar, 1988; Nelson, 1987).

So how can we account for the contingency between adult and infant smiling? One answer is that in everyday situations, maternal vocalizations accompany smiles. Even at the end of the first year of life, infants prefer and are better able to detect differences between facial expressions when those expressions are paired with appropriate vocalizations (Caron, Caron & Myers, 1982; Walker, 1982). Research shows that when adults smile, the fundamental frequencies of their speech are higher than during non-smiling periods. These changes may result from alterations in the vocal tract during smiling, and suggest that smiling has a characteristic vocal signature (Tartter, 1980).

Another way in which infants may perceive differences between adult facial actions is with respect to the dynamics of facial movement. Infants are considerably more accurate in discrimination of facial expressions, even at three months, if the expressions are presented in live motion, rather than as static images (Kaufmann & Kaufmann, 1980; Stucki, Kaufmann-Hayoz & Kaufmann, 1987). Even in adults, judgements of categorical changes in emotion related to smiling are based on the rate of change of movement in the face being perceived (Leonard, Voeller & Kuldau, 1991). Infants may be better at detecting invariant features of moving rather than static images.

There is also evidence that infants are sensitive to a wide variety of subtle differences in biological motions (Bertenthal, Proffitt, Spetner & Thomas, 1985). While there is very little research on this for infants, adults are able to detect emotions from information in a variety of body movements such as speed and direction of movement, openness of posture, gracefulness of movement, lean of head and trunk toward or away from the perceiver, and gait (Frey, Hirsbrunner, Florin, Daw & Crawford, 1983; de Meijer, 1989; Montepare, Goldstein & Clausen, 1987).

Findings such as those reviewed here suggest that infants are probably using

dimensional or gradient cues related to temporal or spatial contours, rather than processing social information categorically (Fogel, in press; Gibson, 1979; Leventhal, 1980; Stern, 1985; Tomkins, 1962). Tomkins (1962), for example, describes emotions as dynamic changes in neural intensity that are elicited in the presence of environmental events with similar contours of intensity. According to Stern's (1985) theory of vitality affects, the young infant's affective world is made up in part by continuous dynamic changes in intensities of arousal, rather than categorical affect states. Infants appear to be sensitive to different patterns of event intensity changes over time, such as events that build slowly to a peak of intensity, events that are abrupt, or events that are gently modulated. The intonation contour of an adult's voice contains all the emotionally relevant information for the young infant, regardless of whether the adult uses language or nonsense sounds (Fernald, 1989; Papousek, Papousek, & Bornstein 1985).

How would infant perception of gradient cues function in social interaction? Adult's cross-modal matching of infant intensity contours, such as the matching of maternal vocalizations to the timing and intensity of infant body movements, has been found to enhance infant positive engagement. (Stern, 1985; Gianino & Tronick, 1988). Among adults, motor and postural matching leads to judgements of closeness, caring and empathic rapport (Bavelas, Black, Lemery & Mullett, 1986; La France & Ickes, 1981; Maxwell & Cook, 1985; Trout & Rosenfeld, 1980). Thus, there is converging evidence that infants and adults perceive emotion from the dynamics of action and use this information to regulate their behavior in social contexts.

Proposition 3: *Emotional development depends on the construction of categorical information out of gradient information, and the changing relationship between information and action.*

Infants develop from using emotional gradient information embodied in non-verbal action to using categorical information about emotions in lexical codes. As shown by the research on non-verbal communication that we reviewed, the lexical categorical aspect of emotion does not replace the gradient aspect, it simply adds another layer of complexity to emotional processes. With both of these forms of emotional information in mind, we can now address the problem of infant emotional development.

At birth, it is likely that the neonate has the ability to perceive invariant patterns in complex temporal contours of events and to relate such patterns to specific forms of action and motivation (Gibson, 1979). Developmental change is therefore likely to occur with respect to changes in sensitivity to different types of information available in the context, and also with respect to changes in motor, sensory and cognitive abilities linked to that information. Development of a perception-action system occurs by virtue of its activity, with perception and action mutually influencing each other and contributing to each other's change (Kugler et al., 1982; Reed, 1982).

At first, the infant is not likely to be affected by the categorical aspects of culture during social interaction. Does this mean that the infant must await the acquisition of lexical categories to develop cultural emotions? We propose that there are cultural differences in the gradient features of emotional information that are available to the infant in the first days of life. Some cultures, for example, protect the infant against extremes of excitement and distress, while other cultures expose

the infant to wide variations in arousing stimulation. Western infants who spend most of their time out of physical contact with mother display more intense patterns of crying than infants from cultures where continuous parent-infant physical contact is the norm. There are also cultural differences in the allowed intensity of face-to-face play, and the extent to which positive emotions are elicited and recognized. From the first days of life, therefore, one can speak of cultural differences in emotions (Dixon, Tronick, Keefer & Brazelton, 1981; Fogel, in press).

We suspect that via processes related to cross-modal matching of intensity contours, infants perceive and produce culturally regulated intensity contours from an early age, and thus participate in the culture of emotion well before their acquire language (Fogel, in press; Stern, 1985). Because the intensity dynamics of adult actions are embedded in sequences of discrete, categorical and culturally conventional facial expressions, gestures and words, infants may easily acquire the ability to translate freely between gradient and categorical features of emotion perception and production. More research is needed on how this process develops.

In this perspective, infants come to produce culturally conventional forms of emotion by regulating the dynamic parameters that enter into the creation of those actions. Thus, infants are not merely displaying an automatic "read-out" of an innate emotion program, nor are they learning the contingencies of when to exhibit a particular emotion program or suppress another. By detecting dynamic invariants of emotion in jointly constructed social routines, infants are developing the tools for re-creating the culture of emotion for themselves (cf. Fogel, in press, for a more detailed treatment; and Lock, 1980, for a similar perspective on language development), rather than having culture imposed from "outside" on the regulation of "inner" emotional programs.

Conclusions

The social process theory is an attempt to construct a theory of emotion that is consistent with recent evidence from neurophysiology and social developmental psychology. Social process theory rests on the assumptions of a fundamental connectedness between organism and environment, of the self-organizing nature of biosocial processes, and of the developmental plasticity in all components of emotion.

In this paper we have taken the basic assumptions of a dynamic systems approach and pursued some of their logical consequences for explaining emotion and its development. Dynamic systems concepts related to the stability and instability of emotion were used to explain the variability of emotions and the sequences of emotions that occur in everyday situations. Finally, we proposed that the acculturation of emotions is a socially co-constructed process that arises out of each infant's detection of invariants in emotional gradients that are embedded in social routines.

With respect to a systems research agenda, one line of new research involves the careful description of infant actions, particularly facial actions, descriptions that are not bound by an assumption of discrete emotions. The development by Oster & Rosenstein (in press) of an infant version of the adult FACS coding system should be a major impetus to the charting of infant facial actions in all their complexity.

Future studies should couple behavioral observations with CNS and ANS measures to determine whether these variants of action are tied to unique patterns of physiological activity (cf. Ekman, Davidson & Friesen, 1990; Fox & Davidson, 1988).

Another line of work is to link detailed observation of infant actions related to emotions and correspondingly detailed observations of everyday social contextual events. If infant emotional actions are studied in isolation, or only in response to intense or traumatic events the picture of normal infant development is likely to be skewed. Our current state of knowledge about normal emotional processes in infancy is incomplete and is analogous to trying to understand adult emotions primarily from studies of adult responses to intense emotional stresses, such as following the loss of a job or winning a lottery. In addition to our work, we can point to the careful descriptive studies of variations in infant emotion in the social context currently being done by both psychologists and ethologists.

Explorations of timing and intensity factors related to emotions and emotional development are needed. Investigators can select and compare from spontaneous interaction sequences that contrast with respect to their timing or intensity parameters that are hypothesized to influence emotional processes. Moreover, the investigation of timing and intensity factors lends itself to experimental manipulations that would be particularly revealing. Caution needs to be exercised however, since major disruptions of the flow of everyday social processes would lead to a distortion of the emotional process. Interventions can be designed to alter the timing and intensity of particular events or sequences within the context of otherwise normal interaction. An example is Eckerman's (Eckerman, in press; Eckerman & Stein, 1990) study of toddler positive affect and play behavior in the presence of an imitative or non-imitative adult, Field's (1982) study of imitation intervention with early mother-infant interaction, and Stern's (1985) research on attunement processes. Alternatively, investigators can select and compare sequences of spontaneous interaction that differ with respect to timing or intensity factors.

Research on infant emotion has prematurely departed from the natural history period of science, usually characterized by detailed descriptive analysis of the phenomenon, and only a sketchy portrait of emotional process has been drawn. We suggest that by temporarily reversing this trend and by subjecting the patterns discovered to careful experimental analysis, we will develop a science of emotional development that is grounded in an empirically accurate knowledge base, sensitive to the actual range of individual and group variation, and theoretically integrated with other related processes. Research, application and intervention in emotional processes – both normal and pathological – will benefit as a result.

References

Averill, J. R. (1980). A constructivist view of emotion. In *Emotion: Theory, research, and experience, Vol. 1: Theories of emotion*, (pp. 305–339). Academic Press.
Barrett, K. S., & Campos, J. J. (1987). Perspectives on emotional development II: A functionalist approach to emotions. In J. D. Osofsky (Ed.), *Handbook of infant development, Second Edition*, (pp. 555–578). NY: John Wiley & Sons.
Bavelas, B. J., Black, A., Lemery, C. R., & Mullett, J., (1986). "I *show* how you feel": Motor mimicry as a communicative act. *Journal of Personality and Social Psychology, 50*, 322–329.

Beebe, B., & Gerstman, L. J. (1980). The "packaging" of maternal stimulation in relation to infant facial-visual engagement: A case study at four months. *Merrill-Palmer Quarterly*, *26*, 321–339.

Bertenthal, B. I., Proffitt, D. R., Spetner, N. B., & Thomas, M. A. (1985). The development of infant sensitivity to biomechanical motions. *Child Development*, *56*, 531–543.

Blurton-Jones, N. G. (1972). Non-verbal communication in children. In R. A. Hinde (Ed.), *Nonverbal communication*. Cambridge, MA: Cambridge University Press.

Campos, J. J., & Barrett, K. C. (1984). Toward a new understanding of emotions and their development. In C. E. Izard, J. Kagan, & R. B. Zajonc (Eds.), *Emotions, cognition, and behavior* (pp. 229–263). New York: Cambridge University Press.

Camras, L. A. (in press a). A dynamic systems perspective on expressive development. In K. Strongman (Ed.), *International review of studies on emotion*. NY: Wiley.

Camras, L. A. (in press b). Expressive development and basic emotions. *Cognition and Emotion*.

Caron, R. F., Caron, A. J., & Myers, R. S. (1982). Abstraction of invariant face expressions in infancy. *Child Development*, *53*, 1008–1015.

Chevalier-Skolnikoff, S. (1973). Facial expression of emotion in nonhuman primates. In P. Ekman (Ed.), *Darwin and facial expression*. NY: Academic Press.

Cicchetti, D., & Sroufe, L. A. (1978). Facial behavior in child development, *Minnesota Symposium on Child Psychology*, *11*, 231–276.

Cohn, J. F., & Elmore, M. (1988). Effect of contingent change in mothers' affective expression on the organization of behavior in 3-month-old infants. *Infant Behavior and Development*, *11*, 493–505.

Cohn, J. F. & Tronick, E. Z. (1983). Three-month old infants' reaction to simulated maternal depression. *Child Development*, *54*, 185–193.

Darwin, C. R. (1872). *The expression of the emotions in man and animals*. Murray, London.

Dedo, J. Y. (1991). Smiling during later infancy: Relationships among facial expressions, contexts, and other communicative behaviors. Doctoral Dissertation. Purdue University.

de Meijer, M. (1989). The contribution of general features of body movement to the attribution of emotions. *Journal of Nonverbal Behavior*, *13*, 247–268.

Demos, E. (1982). Facial expressions of infants and toddlers: A descriptive analysis. In T. Field & A. Fogel (Eds.), *Emotion and early interaction* (pp. 127–160). Hillsdale, NJ: Erlbaum.

Dixon, S. Tronick, E., Keefer, C. & Brazelton, T. B. (1981). Mother-infant interaction among the Gusii of Kenya. In T. Field, A. Sostek, P. Vietze & P. Leiderman (Eds.), *Culture and early interaction* (pp. 149–169). Hillsdale, NJ: Erlbaum.

D'Odorico, L. (1984). Non-segmental features in prelinguistic communications: An analysis of some types of infant cry and non-cry vocalizations. *Journal of Child Language*, *11*, 17–27.

Eckerman, C. O. (in press). Toddlers' achievement of coordinated action with conspecifics: A dynamic systems perspective. In L. B. Smith & E. Thelen (Eds.), *Dynamical systems in development: Applications*. Cambridge, MA: Bradford Books, MIT Press.

Eckerman, C. O., & Stein, M. R. (1990). How imitation begets imitation and toddlers' generation of games. *Developmental Psychology*, *26*, 370–378.

Ekman, P. (1982). *Emotion in the human face*. Elmsford, NY: Pergamon.

Ekman, P., Davidson, R. J., & Friesen, W. V. (1990). The Duchenne smile: Emotional expression and brain physiology II. *Journal of Personality and Social Psychology*, *58*, 342–353.

Ekman, P., & Friesen, W. (1978). *The Facial Action Coding System*. Palo Alto: Consulting Psychologists Press.

Emde, R. N., Gaensbauer, T. J., & Harmon, R. J. (1976). Emotional expression in infancy: A biobehavioral study. *Monographs of Psychological Issues*, *10*, (1, Serial No. 37).

Fernald, A. (1989). Intonation and communicative intent in mothers' speech to infants: Is the melody the message? *Child Development*, *60*, 1497–1510.

Field, T. (1982). Affective and physiological changes during manipulated interactions of high-risk infants. In T. Field & A. Fogel (Eds.), *Emotion and early interaction* (pp. 101–125). Hillsdale, NJ: Erlbaum.

Field, T. (1987). Affective and interactive disturbances in infants. In J. D. Osofsky (Ed.), *Handbook of infant development* (2nd ed.) (pp. 972–1005). NY: Wiley.

Field, T., Healy, B., & LeBlanc, W. G. (1989). Sharing and synchrony of behavior states and heart rate in nondepressed versus depressed mother-infant interactions. *Infant Behavior and Development, 12*, 357–376.

Field, T., Vega-Lahr, N., Scafidi, F., & Goldstein, S. (1986). Effects of maternal unavailability on mother-infant interactions. *Infant Behavior and Development, 9*, 473–478.

Fischer, K. W., Shaver, P. R., & Carnochan, P. (1990). How emotions develop and how they organize development. *Cognition and Emotion, 4*, 81–127.

Fogel, A. (1977). Temporal organization in mother-infant face-to-face interaction. In H. R. Schaffer (Ed.), *Studies in mother-infant interaction* (pp. 119–152). New York: Academic Press.

Fogel, A. (1980). The effect of brief separations on two-month-old infants. *Infant Behavior and Development, 3*, 315–330.

Fogel, A. (1981). The ontogeny of gestural communication: The first six months. In R. Stark (Ed.), *Language Behavior in Infancy and Early Childhood* (pp. 17–44). Elsevier.

Fogel, A. (1982). Affect dynamics in early infancy: Affective tolerance. In T. Field & A. Fogel (Eds.), *Emotion and early interaction* (pp. 15–56). Hillsdale, NJ: Erlbaum.

Fogel, A. (in press). *Developing through relationships: communication, self and culture in early infancy*. London: Harvester-Wheatsheaf.

Fogel, A., Diamond, G., Langhorst, B., & Demos, V. (1981). Affective and cognitive aspects of the 2-month-olds' participation in face-to-face interaction with its mother. In E. Tronick (Ed.), *Joint regulation of behavior* (pp. 37–57). Baltimore: University Park Press.

Fogel, A., Nwokah, E., & Karns, J. (in press). Parent-infant games as dynamic social systems. In K. B. MacDonald (Ed.), *Parents and children playing*. Albany, NY: SUNY Press.

Fogel, A., & Reimers, M. (1989). On the psychobiology of emotions and their development. *Monographs of the Society for Research in Child Development, 54*, (serial no. 219) 105–113.

Fogel, A., & Thelen, E. (1987). Development of early expressive and communicative action: Reinterpreting the evidence from a dynamic systems perspective. *Developmental Psychology, 23*, 747–761.

Fox, N. A. & Davidson, R. J. (1988). Patterns of brain electrical activity during the expression of discrete emotions in ten-month-old infants. *Developmental Psychology, 24*, 230–236.

Frey, S., Hirsbrunner, H., Florin, A., Daw, W., & Crawford, R. (1983). A unified approach to the investigation of nonverbal and verbal behavior in communication research. In W. Doise & S. Moscovici (Eds.), *Current issues in European social psychology, Vol. 1*, (pp. 143–199). NY: Cambridge University Press.

Fridlund, A. J. (in press). Evolution and facial action in reflex, social motive, and paralanguage. In P. K. Ackles, J. R. Jennings, & M. G. H. Coles (Eds.), *Advances in psychophysiology*. (vol. 4). Greenwich, CT: JAI Press.

Fridlund, A. J., Ekman, P., & Oster, H. (1987). Facial expressions of emotion: Review of literature 1970–1983. In A. W. Siegman and S. Feldstein (Eds.), *Nonverbal behavior and communication* (pp. 143–224). Hillsdale, NJ: Erlbaum.

Frijda, N. H. (1987). *The emotions*. NY: Cambridge University Press.

Gianino, A., & Tronick, E. (1988). The mutual regulation model: Infant self and interactive regulation, coping and defense. In T. Field, P. McCabe & N. Schneiderman (Eds.), *Stress and coping across development* (pp. 47–68). Hillsdale, NJ: Erlbaum.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Gordon, S. L. (1990). Social structural effects on emotions. In T. D. Kemper (Ed.), *Research agendas in the sociology of emotions* (pp. 145–179). Albany, NY: State University of New York Press.

Gottlieb, G. (1991). Experiential canalization of behavioral development: Theory. *Developmental Psychology, 27*, 4–13.

Greenough, W. T. (1991). Experience as a component of normal development: Evolutionary considerations. *Developmental Psychology, 27,* 14–17.

Greenough, W. T., Black, J. E., & Wallace, C. S. (1987). Experience and brain development. *Child Development, 58,* 539–559.

Gunnar, M., Mangelsdorf, S., Larson, M., & Hertsgaard, L. (1989). Attachment, temperament, and adrenocortical activity in infancy: A study of psychoendocrine regulation. *Developmental Psychology, 25,* 355–363.

Gusella, J., Muir, D., & Tronick, E. (1988). The effect of manipulating maternal behavior during an interaction on three- and six-month-olds' affect and attention. *Child Development, 59,* 1111–1124.

Haken, H. (1977). Some aspects of synergetics. In H. Haken (Ed.), *Synergetics.* (pp. 1–17). New York: Springer-Verlag.

Harre, R. (1986). *The social construction of emotions.* New York, NY: Basil Blackwell.

Hinde, R. A. (1985). Expression and negotiation. In G. Zivin (Ed.), *The development of expressive behavior: Biology-environment interactions* (pp. 103–116). NY: Academic Press.

Holt, S. A. (1984, September). *The morphology and social context of toddler smiles: An ethological study.* Paper presented at the British Psychological Society, Developmental Section Meeting, Lancaster, UK.

Holt, S. A. (1990, April). *Toddler smile characteristics: Type and context similarities, sex and age differences.* Poster presented at The International Conference on Infant Studies, Montreal, Canada.

Hornik, R., & Gunnar, M. R. (1988). A descriptive analysis of infant social referencing. *Child Development, 59,* 626–634.

Izard, C. (1971). *The face of emotion.* NY: Appleton-Century-Crofts.

Izard, C. E. (1977). *Human emotions.* New York: Plenum.

Izard, C. E. (1990). Facial expressions and the regulation of emotions. *Journal of Personality and Social Psychology, 58,* 487–498.

Izard, C. E., & Malatesta, C. Z. (1987). Perspectives on emotional development I: Differential emotions theory of early emotional development. In J. D. Osofsky (Ed.), *Handbook of infant development, Second Edition.* (pp. 494–554). NY: John Wiley & Sons.

James, W. (1890). *The principles of psychology.* New York: Holt.

Jones, S. S., & Raag, T. (1989). Smile production in older infants: The importance of a social recipient for the facial signal. *Child Development, 60,* 811–818.

Kagan, J. (1978). On emotion and its development: A working paper. In M. Lewis & L. A. Rosenblum (Eds.), *The development of affect* (pp. 11–14). NY: Plenum Press.

Kaufmann, R., & Kaufmann, F. (1980). The face schema in 3- and 4-month-old infants: The role of dynamic properties of the face. *Infant Behavior and Development, 3,* 331–339.

Kaye, K., & Fogel, A. (1980). The temporal structure of face-to-face communication between mothers and infants. *Developmental Psychology, 16,* 454–464.

Kelso, J. A. S., Scholz, J. P., & Schoner, G. (1986). Nonequilibrium phase transitions in coordinated biological motion: Critical fluctuations. *Physics Letters A, 118,* 279–284.

Koester, L. Papousek, H., & Papousek, M. (1989). Patterns of rhythmic stimulation of mothers with three-month-olds: A crossmodal comparison. *International Journal of Behavioral Development, 12,* 143–154.

Krupat, E. (1974). Context as a determinant of perceived threat: The role of prior experience. *Journal of Personality and Social Psychology, 29,* 731–736.

Kuchuk, A., Vibbert, M., & Bornstein, M. H. (1986). The perception of smiling and its experiential correlates in three-month-old infants. *Child Development, 57,* 1054–1061.

Kugler, P. N., Kelso, J. A. S., & Turvey, M. T. (1982). On the control and co-ordination of naturally developing systems. In J. A. S. Kelso & J. E. Clark (Eds.), *The development of movement control and co-ordination* (pp. 5–78). New York: Wiley.

Lazarus, R. S. (1991). Progress on a cognitive-motivational-relational theory of emotion. *American Psychologist, 46,* 819–834.

Le France, M., & Ickes, W. (1981). Posture mirroring and interactional involvement: Sex and sex typing effects. *Journal of Nonverbal Behavior, 5,* 139–154.

Leonard, C. M., Voeller, K. K. S., & Kuldau, J. M. (1991). When's a smile a smile? Or how to detect a message by digitizing the signal. *Psychological Science, 2*, 166–172.

Leventhal, H. (1980). Toward a comprehensive theory of emotion. *Advances in Experimental Social Psychology, 13*, 139–207.

Lewis, M., & Brooks-Gunn, J. (1979). *Social cognition and the acquisition of self.* New York: Plenum.

Lewis, M., & Michaelson, C. (1982). The socialization of emotions. In T. Field & A. Fogel (Eds.), *Emotion and early interaction.* Hillsdale, NJ: Erlbaum.

Lock, A. (1980). *The guided reinvention of language.* NY: Academic Press.

Malatesta, C. Z., Culver, C., Tesman, J. R., & Shepard, B. (1989). The development of emotion expression during the first two years of life. *Monographs of the Society for Research in Child Development, 54*, Serial no. 219.

Malatesta, C. Z., & Haviland, J. M. (1982). Learning display rules: The socialization of emotion expression in infancy. *Child Development, 53*, 991–1003.

Masters, J., Barden, C., & Ford, M. (1979). Affective states, expressive behavior, and learning in children. *Journal of Personality and Social Psychology, 37*, 380–390.

Maxwell, G. M., Cook, M. W. (1985). Postural congruence and judgements of liking and perceived similarity. *New Zealand Journal of Psychology, 14*, 20–26.

Mayes, L. C., & Carter, A. S. (1990). Emerging social regulatory capacities as seen in the still-face situation. *Child Development, 61*, 754–763.

Miller, C., & Byrne, J. (1984). The role of tempo cues in the development of language and cognition. In L. Feagans, C. Garvey & R. Golinkoff (Eds.), *The origins and growth of communication.* Norwood, NJ: Ablex.

Montepare, J. M., Goldstein, S. B., & Clausen, A. (1987). The identification of emotions from gait information. *Journal of Nonverbal Behavior, 11*, 33–42.

Murray, L., & Trevarthen, C. (1985). Emotional regulation of interactions between two-month-olds and their mothers. In T. Field & N. Fox (Eds.), *Social perception in infants.* Norwood, NJ: Ablex.

Nelson, C. A. (1987). The recognition of facial expressions in the first two years of life: Mechanisms of development. *Child Development, 58*, 889–909.

Nwokah, E., Davies, P., & Fogel, A. (April, 1990). *Variations in the acoustic and contextual features of infant laughter.* International Conference on Infant Studies, Montreal, Quebec.

Nwokah, E., & Fogel, A. (in press). Laughter in mother-infant emotional communication. *Humor: International Journal of Humor Research.*

Oster, H. (1978). Facial expression and affect development. In M. Lewis & L. A. Rosenblum (Eds.), *The development of affect* (pp. 43–75). New York: Plenum Press.

Oster, H., & Ekman, P. (1978). Facial behavior in child development, *Minnesota Symposium on Child Psychology, 11*, 231–276.

Oster, H. & Rosenstein, D. (in press). *Facial action coding system for infants.*

Papousek, M., Papousek, H., & Bornstein, M. H. (1985). The naturalistic vocal environment of young infants: On the significance of homogeneity and variability in parental speech. In T. M. Field & N. A. Fox (Eds.), *Social perception in infants.* Norwood, NJ: Ablex.

Piaget, J. (1952). *The origins of intelligence in children.* New York: International Universities Press.

Reed, E. S. (1982). An outline of a theory of action systems. *Journal of Motor Behavior, 14*, 98–134.

Reissland, N., & Harris, P. (1991). Children's use of display rules in pride-eliciting situations. *British Journal of Developmental Psychology, 9*, 431–435.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context.* NY: Oxford University Press.

Schachter, S. & Singer, J. E. (1962). Cognitive, social, and physiological determinants of emotional state. *Psychological Review, 69*, 379–399.

Schoner, G., & Kelso, J. A. S. (1988). Dynamic pattern generation in behavioral and neural systems. *Science, 239*, 1513–1520.

Singer, W. (1986). The brain as a self-organizing system. *European Archives of Psychiatry and Neurological Sciences, 236*, 4–9.

Skarda, C. & Freeman, W. (1987). How brains make chaos in order to make sense of the world. *Behavioral and Brain Sciences*, *10*, 161–195.

Solomon, R., & Corbit, J. (1974). An opponent-process theory of motivation: I. Temporal dynamics of affect. *Psychological Review*, *81*, 119–145.

Sroufe, A. (1979). Socioemotional development. In J. Osofsky (Ed.), *Handbook of infant development* (pp. 462–516). NY: Wiley.

Sroufe, A., & Waters, E. (1976). The ontogenesis of smiling and laughter: A perspective on the organization of development in infancy. *Psychological Review*, *83*, 173–186.

Stern, D. N. (1974). Mother and infant at play: The dyadic interaction involving gaze, facial and vocal behavior. In M. Lewis & L. Rosenblum (Eds.), *The effect of the infant on its caregiver* (pp. 187–214). New York: Wiley.

Stern, D. N. (1985). *The interpersonal world of the infant*. New York: Basic Books.

Stoller, S. A., & Field, T. (1982). Alteration of mother and infant behavior and heart rate during a still-face perturbation of face-to-face interaction. In T. Field & A. Fogel (Eds.), *Emotion and early interaction*, pp. 57–82, Hillsdale, NJ: Erlbaum.

Stucki, M., Kaufmann-Hayoz, R., & Kaufmann, F. (1987). Infants' recognition of a face revealed through motion: Contribution of internal facial movement and head movement. *Journal of Experimental Child Psychology*, *44*, 80–91.

Tartter, V. C. (1980). Happy talk: Perceptual and acoustic effects of smiling on speech. *Perception & Psychophysics*, *27*, 24–27.

Thelen, E. (1989). Self-organization in developmental processes. Can systems approaches work? In M. Gunnar (Ed.), *Systems in development*, (pp. 77–118). Hillsdale, NJ: Erlbaum.

Thelen, E., & Ulrich, B. D. (1991). Hidden skills. *Monographs of the Society for Research in Child Development*, *56*, 6–97.

Tomkins, S. (1962). *Affect, imagery and consciousness*. Vol. 1. NY: Springer.

Tomkins, S. (1981). The quest for primary motives: Biography and autobiography of an idea. *Journal of Personality and Social Psychology*, *41*, 306–329.

Trevarthen, C. (1977). Descriptive analysis of infant communicative behavior. In H. R. Schaffer (Ed.), *Studies of mother-infant interaction* (pp. 227–270). London: Academic Press.

Tronick, E., Als, H., Adamson, L., Weise, S. & Brazelton, T. B. (1978). The infant's response to entrapment between contradictory messages in face-to-face interaction. *Journal of the American Academy of Child Psychiatry*, *17*, 1–13.

Tronick, E., & Cohn, J. F. (1989). Infant-mother face-to-face interaction: Age and gender differences in coordination and the occurrence of miscoordination. *Child Development*, *60*, 85–92.

Trout, D. L., Rosenfeld, H. M. (1980). The effect of postural lean and body congruence on the judgment of psychotherapeutic rapport. *Journal of Nonverbal Behavior*, *4*, 176–190.

van Hooff, J. A. R. A. M. (1972). A comparative approach to the phylogeny of laughter and smiling. In R. A. Hinde (Ed.), *Non-verbal communication* (pp. 209–241). Cambridge University Press.

Vygotsky, L. S. (1978). *Mind in society*, Cambridge, MA: Harvard University Press.

Walker, A. S. (1982). Intermodal perception of expressive behaviors by human infants. *Journal of Experimental Child Psychology*, *33*, 514–535.

Watson, J. S. (1972). Smiling, cooing, and "the game". *Merrill-Palmer Quarterly*, *18*, 323–339.

Wolff, P. H. (1987). *The development of behavioral states and the expression of emotions in early infancy*. Chicago: University of Chicago press.

Zivin, G. (1982). Watching the sands shift: Conceptualizing development of nonverbal mastery. In R. S. Feldman (Ed.), *Development of nonverbal behavior in children*. New York: Springer.