9. A dynamic systems approach to infant facial action

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What does it mean when a baby smiles? Is it an expression of enjoyment, a signal to a partner that rewards effective caretaking, or simply a muscular contraction? Do physically different types of smiles indicate different things? Should the social context in which an infant smiles inform our understanding of the smile? To address these questions, we apply insights and ideas from a dynamic systems perspective to anatomical, social interactive, and neurophysiological data on the development of infant facial action (Fogel, 1993; Fogel & Thelen, 1987; Thelen, 1995; Thelen & Smith, 1994).

Two methodological and theoretical approaches to the study of facial action and to our initial questions can be identified. The Differential Emotions approach postulates that certain facial displays are expressions of discrete emotions while others are not (Ekman, 1994). The approach has generated research investigating the production (Izard, Hembree, Dougherty, & Spizzirri, 1983b) and recognition (Ekman, Friesen, & Ellsworth, 1972) of a set of facial displays thought to be prototypical expressions of a limited set of discrete emotions. The research has productively explored the physiological (e.g., Levenson, Ekman, & Friesen, 1990), cerebral (e.g., Fox & Davidson, 1988), and situational (e.g., Izard et al., 1983b) correlates of these facial displays. Using this approach, however, the coordination inherent in complex facial displays is a reality to be accepted, not a puzzle to be explored.

Is there more to facial action than displays of discrete emotion? Camras (1992) argues that a key premise of the differential perspective is that discrete emotions are associated with distinct eliciting conditions. Certain situations, for example, should typically elicit sadness, while others should elicit anger. Among infants, however, anger displays response to all negative elicitors, and sad displays are not a predominant response to any elicitor (Camras, 1992). Michel, Camras, and Sullivan (1992) have also demonstrated that discrete displays may be part of larger action structures that may not be emotional. For example, brow raising is a component of what have been posited to be interest expressions (Izard, 1983). However, in an experimental paradigm, brow raising during such expressions was typically related to infants raising their heads and/or eyes to gaze at an object presented above their line of sight (Michel et al., 1992). Thus, questions have been raised about the accuracy of viewing prototypical displays as expressions of discrete emotions, and about nonemotional factors involved in the formation of these displays.

The Dynamic Systems Approach explored in this chapter emphasizes the description of co-occurring and sequential patterns of facial action in relatively spontaneous social interactions (see Fernández-Dols & Ruiz-Belda, chapter 11, this volume; Oster & Ekman, 1977; Oster, 1978). We explain these patterns in terms of the interplay of muscular, cerebral, neural, attentional, experiential, and interactive constituents of what can be broadly described as emotional phenomena. We see the effort to explain patterns of facial actions as part of a dialogue with functional (e.g., Barrett, 1993; Campos, Mumme, Kermoian, & Campos, 1994), ethological (e.g., Fridlund, 1991; Fridlund, chapter 5, this volume), and differential approaches (e.g., Ekman, 1994; Izard, chapter 3, this volume; Izard & Malatesta, 1987) to facial action and emotion.

From a Dynamic Systems perspective, the mutual influence of facial actions with neurophysiological and interpersonal factors constitutes a form of "bottom–up" self-organization. These mutual influences mean that facial actions index interrelationships between relevant constituents. In Dynamic System's terms, facial action is a collective variable. It is a key to ongoing changes in the system that it helps to constitute.

A dynamic systems approach to two types of smiles

The theme of this chapter is that organization emerges from the mutual influence of the constituents of a system. First we describe how our observations of infants led us to conceptualize different kinds of smiles as co-occurrences of independent facial actions. Next we discuss different types of mutual influence at work in the formation of these two types of smiling. We also review patterns of neural activity that interface with interactive patterns to support the development of these two types of smiling. We argue that top–down mechanisms alone are inadequate to coordinate these smiles. A more macroscopic perspective characterizes the final section that illustrates an application of a systems axiom: Complex configurations of facial action have properties different from the properties of their constituents. The conclusion explores the role of a Dynamic Systems perspective in integrating other approaches to facial action and emotion.

How did the Dynamic Systems Approach emerge in our own work? As students of infant emotional development, we were influenced by theoretical perspectives that argued for the importance of infant emotion as an organizer and motivator of infant behavior and development (Tomkins, 1962). As observers of social interaction, we watched many face-to-face interactions in which a parent (often the mother) played with a young infant (generally below 6 months of age). To our surprise, many of the infant facial actions that occurred during these sequences did not seem to be described – much less explained – by dominant theoretical perspectives. Infant facial expressions were often fleeting. They sometimes occurred on only one side of the infant's face or were stronger on one side than the other. Smiles sometimes seemed to emerge from and contain elements of grimaces that did not appear to be positive at all. Changes in infant facial action were fast-paced. Infant smiles and other actions would come during a sequence of parental entreaties and seem to change in response to equally swift reactions on mother's part. It was out of this fast-paced interactional matrix that more stable, recognizable expressions seemed to develop. How could we generate data that would reflect these observations?

The Facial Action Coding System (FACS) (Ekman & Friesen, 1978; Friesen & Ekman, 1992) provided an important strategy for understanding and then objectively measuring (via an application of FACS to infants) [Oster & Rosenstein, in press]) these observations (see Wagner, chapter 2, this volume). Other coding systems identify facial action as discrete emotions or blends of discrete emotions (e.g., AFFEX [Izard, Dougherty, & Hembree, 1983a]). That is, one codes "enjoyment" directly from an infant's facial action. FACS, on the other hand, identifies anatomically based action units that are the functional constituents of facial displays. One codes the action of the zygomatic major as it pulls the corners of the lips upward and to the side of the face to create a smile. Such a strategy allows one to analyze facial configurations or displays into their constituent actions.

We became interested in the different types of smiling created by the combination of lip corner raising with other facial actions. In the Duchenne smile (see Figure 9.1), the lip corners are raised; the contraction of the orbicularis oculi raises the cheeks and, in adults, typically crinkles

Figure 9.1. Lip corner raising due to zygomatic major contraction co-occurs with orbicularis oculi contraction raising the cheeks to form the Duchenne smile.

the eye corners (Ekman & Friesen, 1978). In the sections that follow, we critically review an emerging body of research indicating that when compared to smiles without orbicularis oculi contraction, Duchenne smiles occur in infants during positive interactive events and are associated with self-reported pleasure in adults (Ekman, Davidson, & Friesen, 1990; Fox & Davidson, 1988; Messinger, 1994).

In play smiles, the lip corners are raised and the jaw is dropped, opening the mouth (see Figure 9.2). Play smiles often occur during interaction that involves physical contact (Dickson, 1994; Messinger, 1994) or games (Dedo, 1991). In this chapter, we critically review research suggesting that play smiles emerge from games involving physical contact and tend to occur during boisterous, affiliative play (Dedo, 1991; Dickson, 1994; van Hooff, 1972; Messinger, 1994; Plooij, 1979).

From a Dynamic Systems perspective, we began to think of Duchenne and play smiles as constituted by the co-occurrence of potentially independent facial actions (Messinger, 1994). The co-occurrence of lip corner raising and cheek raising constitutes Duchenne smiling. The co-occurrence of lip corner raising and mouth opening constitutes play smiling. When these smiles are analyzed into their separate actions, several

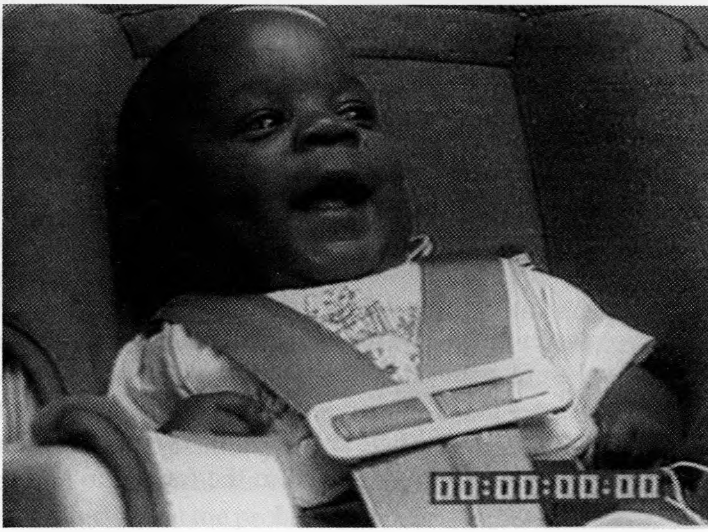

Figure 9.2. Lip corner raising due to zygomatic major contraction co-occurs with a lowered jaw to create a play smile.

questions emerge. Do the co-occurrences that create Duchenne and play smiles occur at greater than chance levels? Do these co-occurrences become more or less probable as infants grow older? Are these smiles more likely to come together during some interactive conditions than during others? To answer such questions, we could not measure the amount of Duchenne and play smiling as whole entities. Instead, we separately coded the three facial constituents – lip corner raiser, cheek raiser, and mouth opening – that co-occurred to form these smiles.[1]

To understand the relationship of Duchenne and play smiles to other co-occurring elements of the interaction, we separately coded (1) the position in which the infant was being held, (2) where the infant was gazing, and (3) whether the mother was smiling. Our data base consisted of observational data on a sample of a dozen middle-class mothers playing with their infants on their laps (Messinger, 1994). Because we were interested in the process of developmental change, mothers and infants were videotaped playing together *weekly* when infants were between 1 month and 6 months of age.

Our primary analysis strategies focused on finding which facial actions and social actions co-occurred for the group as a whole and how those patterns changed with age (Messinger, 1994). This was done with data-driven (hierarchical) loglinear analyses in which only terms that had Z scores significant at the .01 level for analyses by both duration and frequency were interpreted. We are currently replicating and expanding the results reported in different samples and in analyses that examine each mother–infant dyad individually (Messinger, 1995; Messinger, Fogel, & Dickson, in preparation).

Self-organization and mutual influence

From a Dynamic Systems perspective, facial actions are elements of self-organizing processes in which the mutual influence of relevant constituents creates a coherent pattern. In this section, we consider different self-organizing processes in the formation and development of the Duchenne and the play smile. In the following section, we describe what is known about the neural anatomy involved in the formation and development of these facial displays.

Duchenne smiling

Fridlund (1994) suggests that there is no intrinsic affinity between zygomatic and orbicularis oculi contraction. In contrast, we argue that there is a synergistic relationship between the action of the zygomatic major, which produces lip corner raising, and the action of that part of orbicularis oculi (the large orbital portion including pars lateralis) that raises the cheeks. Before 6 months of age, we found that orbicularis oculi contraction was almost 12 times more likely in the presence than in the absence of lip corner raising (Messinger, 1994). The original FACS manual (Ekman & Friesen, 1978) indicated that intense contraction of the zygomatic major necessarily involved contraction of orbicularis oculi because intense smiling is almost invariably associated with orbicularis oculi contraction. Although actions of the two muscles are potentially independent (Friesen & Ekman, 1992), intense contraction of the zygomatic major without orbicularis oculi contraction looks forced and artificial (cf. Blurton-Jones, 1972). Weak contraction of the zygomatic major, on the other hand, is rarely associated with orbicularis oculi contraction and, when it is, may give the impression of wincing (cf. Ekman & Friesen, 1978, exemplar photographs).

How do we account for these patterns? The first potential type of influence involved in the formation of the Duchenne smile is anatomical. As the zygomatic major lifts the corners of the mouth, it raises the cheek, functioning synergistically with (performing some of the same function as) the orbital portion of orbicularis oculi. The *decreased* downward pull on the orbital portion of orbicularis oculi (caused by the raising of the cheek by the zygomatic) may encourage increases in the resting tonus of orbicularis oculi, resulting in noticeable contraction. In addition, zygomatic contraction raises portions of the cheek over and adjacent to the orbital portion of orbicularis oculi surrounding the eye (Williams, Warwick, Dyson, & Bannister, 1989). The sensation of malar tissue (the cheek) rising next to and over the orbital portion of orbicularis oculi may also increase the probability of orbicularis oculi contracting.[2]

The presence of such anatomically based processes suggests several hypotheses. In general, the stronger the intensity of zygomatic contraction, the more likely should be orbicularis oculi contraction. In addition, zygomatic contraction should typically precede, perhaps be coincident with, but not follow, orbicularis oculi contraction. The influence of zygomatic major contraction on the probability of orbicularis oculi contraction would be seen most prototypically when zygomatic contraction slowly increases in intensity and is accompanied by the coordinated contraction of orbicularis oculi. However, this train of events may typically occur quickly, making relatively precise electromyographic or video observation techniques necessary to determine which muscle contracted first.

The physical effects of zygomatic contraction on orbicularis oculi contraction are one source of the coordination evident in Duchenne smiling. Another source involves the motor neurons in the seventh cranial nerve, the facial nerve, which travel from the facial nucleus in the brain stem and form five branches that innervate the face. Orbicularis oculi typically receives inputs from the temporal and zygomatic branches of this nerve, and the zygomatic major typically receives inputs from the upper portion of the buccal branch (Williams et al., 1989). There is, however, a considerable degree of interconnection between all these branches through a network referred to as the *parotid plexus* (Rinn, 1984). In an anatomical study of 100 faces, McCormack, Cauldwell, and Anson (1945) found that in 87 cases there were intersections between the buccal and zygomatic branches of the facial nerve after their initial division. The functions of these connections are unclear. However, they are a potential source of the coordination of the contraction of the zygomatic major and orbicularis oculi that leads to Duchenne smiling.

A coordinative structure is a functional linkage of *potentially* independent muscular actions into a basic motor unit (Thelen, 1995; Thelen & Smith, 1994; Turvey, 1990). Coordinative structures form out of the mutual influence of joints and muscles as they change rates of movement in a gravitational environment. These movements occur in coordination with patterns of neural innervation, but there is no one-to-one correspondence between the firing of effector neurons and a particular movement. The presence of both muscle linkages and overlapping patterns of neural innervation suggest that zygomatic and orbicularis oculi contraction typically function as a coordinative structure. It would be a *mistake*, however, to attempt to *reduce* the coordination of Duchenne smiling to a neuromuscular pattern. The presence of neural and muscular proclivities for co-action does not exhaust the possible explanations of the co-occurrence of zygomatic and orbicularis oculi contraction. Moreover, like the elements of other coordinative structures, zygomatic and orbicularis oculi contraction also occur independently. Links between the component actions of coordinative structures – such as the leg movements involved in taking steps (Thelen & Ulrich, 1991) – typically occur under particular environmental conditions.

Is Duchenne smiling likely in particular social contexts? The issue is theoretically important because Fridlund (1994) argues that the Duchenne smile is caused by zygomatic and orbicularis oculi contraction each being *independently* associated with particular environmental conditions. In our data, there were indeed significant individual associations between gazing at mother and zygomatic contraction on the one hand and orbicularis oculi contraction on the other (Messinger, 1994). However, in addition to these associations, there was a strong tendency for these facial actions to be *co-occurring* during mother smiling ($Z = 8.33$). This suggests that the Duchenne smile is an emergent configuration with properties above and beyond the properties of its constituents (see the later section, "Wholes and Parts").

What are the temporal characteristics of interactions involving Duchenne smiling? Preliminary results of research in progress suggest that half of infant Duchenne smiling at 3 months was accompanied by *maternal* Duchenne smiling (Messinger, 1995). Mothers tended to match infant Duchenne smiles with Duchenne smiles of their own. It is likely that infants become aware of this pattern and that at some point they also begin to match their mothers' Duchenne smiles. Fox and Davidson (1988) found that 10-month-old infants Duchenne smiled when their mothers smiled and approached the infant.

The meaning of infant Duchenne smiles cannot be known with certainty. Ekman et al. (1990) found that adults did more Duchenne smiling than non-Duchenne smiling in response to pleasant stimuli such as films of animals playing. In addition, the duration of Duchenne smiling was significantly associated with self-reported amusement, happiness, excitement, and interest (Ekman et al., 1990). Adult Duchenne smiling may arise from the adult's perception of puppies and gorillas enjoying themselves during play and their engagement with that perceived enjoyment. This process may begin with infants detecting contingencies when their Duchenne smiles are matched by their mothers' Duchenne smiles. Through such a process, Duchenne smiling may become tied to the visual perception of positive experience in one's interactive partner (the smiling mother) or one's imaginative partner (the film clip of the playful puppy, cf. Fridlund, 1994). This process is prototypically mutual, involving the simultaneous visual perception and communication of positive engagement.

This hypothesis underscores the idea that facial configurations are simultaneously experiential and social. It is not compatible with rigidly distinguishing Duchenne smiles as expressions of pleasure from non-Duchenne smiles as social signals (Fridlund, 1994). Such rigid distinctions are also not compatible with the empirical literature, which typically indicates probabilistic rather than deterministic associations between facial muscles, interactive processes, feeling states, and neurophysiological processes. More pointedly, a full account of the significance of Duchenne and non-Duchenne smiles must account for the fact that by contracting and relaxing the orbicularis oculi, infants move smoothly between these configurations. In our data, approximately one-half of Duchenne smiles were immediately preceded by non-Duchenne smiles, and approximately one-quarter of non-Duchenne smiles were immediately preceded by Duchenne smiles (Messinger, 1994; Messinger et al., in preparation). Additional research is clearly needed to determine what types of changes are associated with transitions between these facial configurations.

The development of Duchenne smiling. Despite provisions for social learning, Differential Emotion perspectives often indicate that the development of early emotion expressions is a maturationally controlled phenomenon (e.g., Izard & Malatesta, 1987). If this is the case, one might expect Duchenne smiles – at least insofar as they are a prototypical index of enjoyment (Ekman, 1994) – to emerge fully formed. That is, relevant neural circuitry would emerge at a certain point and coordinate a relatively mature form of the expression.

Data relevant to the development of Duchenne smiling are scarce and somewhat contradictory. Although Oster and Rosenstein (in press) have photographed Duchenne smiles in premature neonates, Duchenne smiling in full-term neonates is rare (Emde & Koenig, 1969). Wolff (1987) first observed the configuration in full-term infants at 3 weeks. Our hypothesis is that in full-term infants, zygomatic major contraction in the form of early smiling coexists with early orbicularis oculi contraction (during crying) without co-occurring. In response to unknown changes, these actions begin to come together as Duchenne smiling around the first month and with increasing strength through the first 6 months. Our data indicate that, comparing the period from 1 to 3 months to the period from 3 to 6 months, the proportion of time spent in Duchenne smiling increased from 6.4% to 10.5% (Messinger, 1994). Expressed differently, the strength of the association between zygomatic and orbicularis oculi contraction increased by almost three times. From a dynamic perspective, developmental changes are characterized by increases and decreases in the stability of certain system configurations. These data suggest that Duchenne smiling forms out of the co-occurrence of independent muscular actions that form an increasingly stable configuration in the first half-year of life.

Play smiling

Just as there are strong associations between the facial actions that constitute Duchenne smiling, there are strong associations between the facial actions that constitute play smiling. We found that infant mouth opening was about four times more likely during infant zygomatic contraction (smiling) than during its absence (Messinger, 1994). Unlike Duchenne smiling, however, there is not likely to be an anatomical explanation for the coordination evident in play smiling. The zygomatic major and the muscles responsible for opening the mouth (e.g., the lateral pterygoid, digrastic) have somewhat antagonistic functions (Williams et al., 1989). In addition, many of the muscles responsible for opening the mouth receive input from the trigeminal as opposed to the facial nerve (which innervates the zygomatic), making intranerve activity a less likely source of coordination. Instead, other concurrent actions of the infant and the infant's partner may be primarily necessary for the association of lip corner raising and mouth opening.

Our data-driven analyses suggested parallels between the independent occurrences of lip corner raising and mouth opening. Infant lip corner raising (smiling) and mouth opening occurred in similar interactive circumstances at similar ages (Messinger, 1994). Like lip corner raising, mouth opening was more likely after 3 months. Like lip corner raising (smiling), mouth opening was more likely while mother was smiling. These results replicate earlier findings of Kaye and Fogel, 1980. In addition, like lip corner raising, mouth opening tended to occur while infants were gazing at mother, particularly when infants were being held by mothers in more supported supine or cradled positions (Messinger, 1994).

What is the meaning of these parallel associations? An important index of the meaning of infant facial actions is how those actions are associated with ongoing interactive processes. As infant mouth opening and lip corner raising occur in conjunction with some of the same social actions, they may have similar functions in face-to-face interaction. Perhaps mouth opening communicates positive engagement in young infants. This challenges the view that culturally recognized "emotional expressions" have a special status as indices of infant affective engagement. That is, smiles may not be unique expressions of positive affect in young infants (Ekman, 1994; Izard et al., 1983b). Similarities between lip corner raising and mouth opening caution against a priori judgments of the emotionality of a given facial action. Open-minded descriptive research is needed to understand how different facial actions are associated with different interactive contexts.

Perhaps the most important aspect of the parallel associations described was a developmental increase of the likelihood of these facial actions coming together as a play smile in particular interactive contexts. Between 3 and 6 months of age, the likelihood of lip corner raising being associated (co-occurring) with jaw dropping increased in two interactive contexts: (1) when infants were being held in lying or reclining positions by mother, and (2) when infants were gazing at mother (Messinger, 1994). That is, relatively intense tactile and visual interchange with a partner became developmentally more strongly associated with the coordination of play smiling. In a separate sample of 12-month-olds, Dickson (1994) found that open-mouthed smiles predominated during play that involved physical contact with the infant's parent. Among nonhuman primates, van Hooff (1972) has reported that open-mouth displays similar in function to human play smiles were associated with social play and mock fighting.

How do play smiles form during interaction? Dickson (1994) hypothesized that infants who are already smiling may open their mouths (creating play smiles) immediately after physical contact with a partner.

Among infant chimpanzees, this reaction may have its roots in mouth opening as a response to perioral contact (Plooij, 1979). With experience, human infants may open their mouths in response not only to actual but to imminent physical contact. This would include infants preparing to suck on an object or on mother's hands; it would also include infants responding to an imminent hug or snuggle by dropping their jaws as if to mouth some part of the partner's body. If this mouth opening occurs when infants are already smiling or about to smile, a play smile would form. Fox and Davidson (1988) have hypothesized that *Duchenne* smiles are differentially associated with a motivation to approach. If physical contact plays a role in the formation of play smiles, it would also suggest investigating indices of approach motivation associated with open-mouthed (play) smiles.

The development of play smiling. How do play smiles develop? This section introduces Edelman's (1987) concept of neural reentry as part of an explanation of how the co-occurrence of *different* facial actions becomes a favored pattern of neural and motor activity. Reentry is a process in which neural information within and between motoric and sensory activities is integrated. How, for example, is neural information from visual and auditory sources integrated into the perception of a single stimulus? How is a unitary perception of smiling constructed from neural activity accompanying the contraction of the zygomatic major and from neural activity accompanying the afferent sensation of the lip corners rising? One clue is that efferent neural activity accompanying contraction of the zygomatic major is temporally synchronized with afferent neural activity stemming from the upward movement of the lip corners. A reentrant structure is a group of neurons that interface with two or more such sources of temporally linked information. Edelman (1987) suggests that neurogenesis is a dynamic process involving selection for populations of neurons that interface with two or more sources of coordinated neural activity. The presence of temporally coordinated but separate sources of neural activity strengthens the likelihood of a reentrant structure linking these sources. Through their reciprocal connections, populations of neurons that interface between simultaneously activated muscle groups in turn support the *sources* of neural activation with which they synapse.

Consider the coordination of different facial actions such as those involved in play (open-mouth) smiling. Gazing at mother is associated with both infant zygomatic contraction and mouth opening. Hence, gazing at mother will tend to be associated with co-occurring lip corner raising and mouth opening (i.e., play smiling). This will lead to neural change. There will be selection for reentrant structures that synaptically interface with the sources of neural efference associated with the production of zygomatic contraction and with mouth opening. There will be selection for neural connections associated with the *perception* of the area around the lip corners being raised by lip corner contraction and simultaneously pulled downward as the jaw opens. Patterns of neural activity associated with both production and perception will be integrated into the higher-level perception of play smiling.

How might coordinated facial action become a favored pattern? There would be a strengthening and selection for the activity of neural populations (reentrant structures) that synaptically link these two sources of synchronous neuronal firing. Reentrant structures have reciprocal influences on the neural activity associated with the performance of particular facial actions. They not only respond to synchronous neural activity but make the activity associated with synchronous patterns of movement more likely. We postulate that such interfacing neural groups will make the performance and perception of either zygomatic major contraction or mouth opening more likely to be linked to the performance and perception of the other action.

This scenario fits the data. Initially, play smiling should be dependent on the confluence of environmental events associated with *each* of its muscular constituents. Over the first 6 months of life, zygomatic contraction was associated with gazing at mother. In an independent association, mouth opening was also associated with gazing at mother (Messinger, 1994). Given a history of neural selection through activation of interfacing reentrant structures, the likelihood of the constituents of play smiling co-occurring should increase. This effect would be particularly clear in the interactive context with which each constituent of play smiling was associated. In fact, after 3 months of age, zygomatic contraction and mouth opening became more likely to co-occur as play smiling while infants were gazing at mother (Messinger, 1994).

The possibility that the emerging developmental coordination manifested in play smiling is structured by environmental events is attractive because there is no obvious neural or anatomical basis for the association of the constituents of play smiling. However, neural reentry is a generic process, an element in a more general theory of neurogenesis, that may support many types of coordinated action (see Thelen & Smith, 1994). In the case of the Duchenne smile, we have argued that muscular processes, the structure of the branches of the facial nerve, as well as joint positive visual engagement link the contraction of the zygomatic and orbicularis oculi. This would provide a primary basis for co-occurrence that would be further strengthened by reentry processes.

Alternate (top–down) explanations of facial coordination

The development of FACS (Ekman & Friesen, 1978) was accompanied by interest in the diversity of facial actions associated with zygomatic contraction (Oster, 1978). In order to resolve inconsistencies in the literature, however, empirical and theoretical attention turned first to distinguishing true from false smiles (Ekman & Friesen, 1982). For Ekman and his colleagues, zygomatic major contraction must be accompanied by orbicularis oculi contraction to index enjoyment (Ekman, 1994; Ekman et al., 1990; Ekman & Friesen, 1982). For Izard and his colleagues, the contraction of the zygomatic major alone is sufficient to index enjoyment (Izard, 1983; Izard et. al, 1983a). Both researchers seek to identify that smile which is an unambiguous signal of positive emotion. Mouth opening and other facial actions such as nose wrinkling are ignored (Dedo, 1991). Diversity in the form of smiling is not typically a focus of theoretical interest.

Given this overall perspective, how might a Differential Emotions approach account for the coordination evident in Duchenne smiling or other configurations of facial actions? Differential Emotions approaches have made use of the concept of sensory feedback from the face to the brain in the experience of emotion (Izard, 1981; Izard & Malatesta, 1987). Recent portrayals have steered clear of unidirectional causal accounts (Ekman, 1994) and emphasized nonlinear, systemic relations between emotion constituents (Izard, chapter 3, this volume; Malatesta, Culver, Tesman, & Shepard, 1989). However, a dominant perspective has been that unique patterns of neural activity produce distinctive and prototypical patterns of facial action in a relatively unidirectional fashion (cf. Panksepp, 1994). Izard and Malatesta (1987), for example, emphasize that genetically based neural processes lead to a specific facial expression.

Before examining difficulties with a unidirectional emphasis on facial action, it is helpful to review what is known about the neuroanatomy of such processes. The immediate source of innervation of the facial muscles is the motor nucleus of the facial nerve at the level of the pons in the brain stem (see Rinn, 1984, for a review). The facial nucleus receives inputs from two relatively distinct pathways. Neural activity from the cortical motor strip makes its way to the facial nucleus through the pyramidal system. This activity is thought to be associated with volitional facial actions. The second pathway stems from the extrapyramidal system involving subcortical as well as cortical structures including the basal ganglia and amygdala. Neural activity in these structures is thought to be involved in more spontaneous emotional displays. Although this distinction may not be absolute, it is the generally recognized neurological basis for several types of facial paralysis that affect one but not the other system (Rinn, 1984).

Why *not* conceive of central nervous system activity as a centrally organized plan that unidirectionally coordinates all facial action? One problem is the recognized diversity of neural processes – with cortical and subcortical points of origin – that are involved in the organization of facial activity. To the extent that top–down, relatively spontaneous, neural organizers of facial action exist (as in Differential Emotions approaches), they are one of a plurality of neural processes. During social interaction, more and less "volitional" neural processes may become dynamically related in the coordination of facial actions.

A more pervasive problem for the hypothesis of central organization is complexity. This discussion has focused on only three facial actions – lip corner raising, cheek raising, and mouth opening – whose presence or absence gives rise to eight (2^3) possible facial configurations. In fact, there are dozens of distinct facial actions and virtually no limit to the number of facial actions that can occur simultaneously (Ekman & Friesen, 1978). This potentially enormous set of combinations of facial actions to be coordinated is itself a *simplification* of how the face actually moves. In reality, facial actions are not simply present or not present. The degree of contraction of facial muscles is a continuous, not a categorical, variable.

In general, top–down solutions that hypothesize a central processor responsible for organizing the peripheral components simply displace the problem of complexity to the neurological system. This solution is workable if one attempts to explain only facial action patterns that have been defined a priori as prototypical expressions of discrete emotions. Researchers who confront the descriptive data must ask, for example, if there are separate neural programs for lip corner raising alone, for play smiles, Duchenne smiles, and combination Duchenne–play smiles. When one considers all possible combinations of all possible facial actions at all possible levels of contraction, the explanatory potential of preset neural programs falters.

Wholes and parts: Emergent properties

This section explores how the mutual influence of system constituents gives rise to patterns that are qualitatively different than the properties of their individual constituents. The contention here is that the coordination of facial actions creates emergent properties – social impacts, patterns of neural activity, and, potentially, feeling states – not present in the individual actions. The role of orbicularis oculi in raising the cheeks in a variety of facial configurations is offered as an illustration. For the sake of this argument, we accept Differential Emotions and approach–avoidance perspectives on the meaning of these facial configurations.

Fox and Davidson (1988) coded facial configurations identified as joy and anger by Izard's (1983) MAX in 10-month-old infants. They also coded the presence of orbicularis oculi contraction during smiles (joy expressions) and noted whether infants were crying during anger expressions. The onset of crying during these MAX-identified anger expressions was accompanied by the onset of orbicularis oculi contraction or by its extreme intensification.[3] Fox and Davidson (1988) also recorded frontal cerebral electrical activity during these facial actions.

The contraction of orbicularis oculi transforms a non-Duchenne into a Duchenne smile. In contrast with non-Duchenne smiles, Duchenne smiles are associated with self-reports of pleasurable emotions in adults and situations thought to involve enjoyment in infants (Ekman et al., 1990; Fox & Davidson, 1988). Fox and Davidson (1988) found that smiles with orbicularis oculi contraction (Duchenne smiles) were associated with greater relative left frontal activity than were smiles without. They interpreted this to indicate greater approach motivation during smiles with orbicularis oculi contraction (Fox, 1991; Fox & Davidson, 1984).

Next consider a description of what Differential Emotions perspectives have considered a prototypical anger expression. The brow is lowered, the upper lip is lifted to reveal the teeth, the corners of the mouth are drawn to the side, and the mouth is opened (Izard, 1983; Izard et al., 1983a). If orbicularis oculi now contracts, raising the cheeks and closing the eyes, this becomes a discomfort-pain (Izard, 1983; Izard et al., 1983a) or distress-cry (Camras, Oster, Campos, Miyake, & Bradshaw, 1992) configuration. The contraction of orbicularis oculi increases the negative signal value of anger configurations, transforming them into distress configurations. Fox and Davidson (1988) found that "anger" expressions with strong orbicularis oculi contraction (as indexed by crying) were associated with greater relative right frontal activity than the same anger expressions without orbicularis oculi (as indexed by the absence of crying). They interpret the presence of orbicularis oculi contraction during anger expressions as an indication of greater withdrawal orientation.

Orbicularis oculi contraction by itself has no recognized affective meaning, although Fridlund (1994) posits that it is an occluding response to strong stimuli. One might argue about the particular emotional meaning and motivational valences associated with the facial configurations discussed here. The point is that orbicularis oculi contraction is associated with contrasting patterns, depending on the other facial actions with which it occurs. Specifically, orbicularis oculi contraction may *intensify* the signal value, neurophysiological activity, and possibly affective significance associated with particular facial configurations. It may make positive expressions more positive and make negative expressions more negative.

To generalize, the meaning of facial configurations cannot be deduced by adding up the presumed valences or signal values of their components. The co-occurrence of facial actions reflects the mutual influence of muscular, neural, and interactive constituents. Out of the mutual influences involved in these configurations, *new properties emerge*. It is the task of future research to continue specifying the processes through which novel phenomena emerge from the coordination of facial actions in a neural and interactive milieu.

Conclusion: A metatheoretical framework?

To answer the questions posed at the beginning of the chapter, infant smiles and other facial actions are at once muscular contractions, social signals, and constituents of felt processes. Their meaning depends on interactive context, on the specific facial actions involved, and on how these constituents influence changes in each other over time. A facial action is a dynamic pattern whose meaning emerges out of the mutual influence of involved constituents.

In this conclusion, we attempt to demonstrate that acknowledging the mutual influences involved in the creation of emotional patterns exposes some debated dichotomies as more apparent than real. What, for example, is the association between facial action and feeling? Fridlund (1991, and chapter 5, this volume) argues that prototypical discrete emotion configurations function to alert or deceive a social partner as to one's social goals but do not necessarily reflect emotional states. Izard (chapter 3, this volume) argues, however, for a probabilistic association of infant facial actions and feelings. Our position is a synthesis. We regard infant facial actions not as unmediated expressions of emotions but as potential constituents of emotional processes. Infant facial actions come to function as social displays but are not reducible to social displays.

What is meant by feeling in Izard's account? The Differential Emotions position (see Izard, chapter 3, this volume; Izard & Malatesta, 1987) postulates a set of discrete feeling states. The complexity of emotional experience is thought to stem from links between these feelings and particular cognitions and perceptions. Although the distinction between abstractly defined feeling states and the rest of experience has a heuristic function, it contradicts fundamental systems principles. The mutual influence between an emotional feeling and a particular cognition or perception creates a unique gestalt. Pleasure in Duchenne smiling, the feeling of mutual positive involvement with a partner, and the sensation of tightened cheeks, all are inextricably combined. Each constituent transforms the experience of the other. The infant's experience of his or her embodied facial actions and his or her sensory experience of the partner are important constituents of the infant's emotional feeling (Fogel, 1993).

Broadening our conception of emotional experience has a theoretical advantage in accounting for the development of positive affect. Vygotsky (1978) has proposed that conventional communication develops because infants' gestures are treated as though they were intentional by the infants' social partners. A similar process may occur in the development of smiling. Face-to-face interaction is a social frame in which infants experience the influence of their facial actions on a partner. Mothers treat early infant zygomatic contraction as indices of pleasure. They smile back, comment, and try to elicit more smiles. Some of the feelings associated with zygomatic contraction such as an experience of engagement and mutuality may stem from such experiences. Part of the phenomenological experience of zygomatic contraction may develop from experiences of smiling while engaged with a smiling partner.

It is tempting to argue that infants' feelings are an internal reaction, a subjective summary of the meaning of an infant's actions in an interactive process. The difficulty with this position is that infant feeling ultimately becomes epiphenomenal. Subjective feeling may be a reflection of an ongoing process, but it is also a part of that process. Clearly, feeling states are on a different level of analysis than, say, cerebral activation. But constituents at different levels of analysis are rarely reducible to one another (Oyama, 1985). Like any other constituent of a process, infant feeling influences and is influenced by other constituents such as the infant's facial actions, his or her propensity to react to the social partner, and his or her state of sympathetic nervous system activation.

A recent debate concerns the temporal relationship of feeling to action. Izard (chapter 3, this volume) argues that emotional feelings are prior motivators of action. Campos et al. (1994) argue that emotional experience occurs just as a positive event is perceived. From a Dynamic Systems perspective, it seems unlikely that either possibility is exclusive. Positive feelings may motivate social actions such as gazing at a partner just as positive feelings may arise in the act of gazing at the partner. The principle here is that unidirectional cause–effect relationships between system constituents are unlikely. Mutual influence between infant facial and other actions, subjective feeling, and the response of a partner over the actual time span of an emotional interaction is likely to be a more productive assumption.

In this chapter, we have indicated how Dynamic Systems principles emphasizing the self-organization of complex systems can inform our understanding of facial action. We have identified how the mutual influence of neuromuscular, anatomical, neural, interactive, and affective processes can yield coordinated facial action. Finally, we applied the concept of mutual influence to problematics in emotion theory to achieve a more appropriately balanced understanding of these dynamic phenomena.

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Notes

1 These three constituents – lip corner raising, cheek raising, and jaw dropping – can all co-occur as a combined Duchenne–play smile. See Messinger (1994) for a discussion of this salient display.

2 These sensations may occur in the skin and connective tissue above the orbital portion of orbicularis oculi. There is much controversy as to whether the facial muscles themselves have sensory neurons that provide information on their movement and contraction (for reviews, see Elliot, 1969; Rinn, 1984).

3 In MAX (Izard, 1983), several configurations of facial actions lead to anger

codes but do not involve cheek raising. In the anger configurations that do involve cheek raising, it is described as "incidental" to a drawn brow and squarish mouth (Izard, 1983, p. 33).

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