Emotion, Development, and Self-Organization

Dynamic Systems Approaches to Emotional Development

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4 Surprise! Facial Expressions Can be Coordinative Motor Structures

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This chapter presents a dynamical systems perspective on both facial expression specifically and emotion communication more generally. I have been developing this perspective in response to several interesting problems that have recently emerged in attempts to verify one currently popular theory of infant emotional expression. In this chapter, I will review these problems and discuss the limitations of extant theory. The dynamical systems view I will present is not a fully articulated alternative proposal. Instead, it is intended to represent a new direction for theoretical and empirical exploration in which solutions to the problems with the current theory may be found.

A Theory of Infant Emotional Expression

The currently popular view of infant emotional expression is most fully embodied in Izard's (1977, 1991) differential emotions theory. According to this theory, there is a species-specific set of human emotions that emerge during development according to a maturational timetable. In its original formulation (Izard, 1971; Izard and Malatesta, 1987; Izard et al., 1995), the theory proposes an innate concordance between infant emotions and a specified set of infant facial expressions (Izard, Dougherty, and Hembree, 1983). These expressions are direct readouts of their corresponding emotions, that is, they are automatically produced when the emotion is experienced and are not produced in other circumstances. Thus, facial expressions serve as veridical indices of infant affects and can be simply "read" by observers to determine the infant's emotional state. In recent years, Izard (1997; this volume) has begun to qualify his early assertions about the invariant relationship between infant affect and facial expression, adopting a position more consistent with empirical demonstrations of nonconcord-

ance (e.g., Camras, 1992). Nonetheless, the original view is currently represented in many developmental psychology textbooks, probably because of its straightforward nature and the simple solution it offers to the problem of understanding nonverbal infants.

Within the community of infant emotion researchers, challenges of two different types have been raised with respect to Izard's original "strong" formulation. First, some researchers (Camras, 1991, 1992; Lewis and Michalson, 1983; Oster, Hegley, and Nagel, 1992; Sroufe, 1996) have challenged the view that infant emotions correspond to the same set of discrete affects described for adults. For example, Camras (1992) has proposed that young infants may experience not discrete adultlike "anger" and "sadness," but instead a less differentiated state of "distress." Second, some researchers (Barrett and Campos, 1987; Camras, 1991; Matias and Cohn, 1993) have questioned the assertion that certain specified facial expressions are invariantly produced to accompany their corresponding emotions in early infancy. As part of their functionalist theory of emotion, Barrett and Campos (1987) have argued that emotional facial expressions may be expected to occur or not occur depending upon their utility in a particular emotion situation. Along similar lines, my colleagues and I (Camras, 1991, 1992; Camras, Lambrecht, and Michel, 1996; Michel, Camras, and Sullivan, 1992) have previously described several specific examples of noncorrespondence between emotions and emotional facial expressions and discussed their possible causal basis within the context of a dynamical systems framework.

The Relationship between Emotions and Emotional Facial Expressions

Three anomalous phenomena can be identified that challenge the direct-readout hypothesis with respect to infant emotional expression. First, some expressions have rarely been observed in situations that are commonly believed to elicit their corresponding emotion. For example, Hiatt, Campos, and Emde (1979) failed to find fear expressions in infants who showed other indications of fear when confronted by a stranger or placed on the "visual cliff." Second, facial configurations that meet coding criteria for some emotions have been observed in situations where the emotion is unlikely to occur. For example, codeable "surprise" expressions are often produced when infants open their mouths in anticipation of mouthing a nonsurprising object (Camras et al., 1996, to be described further here). Third, more than one "prototypic" expression has been described for some emotions (e.g., interest; Izard et al., 1983). Yet causal factors underlying the production of one of these variant expressions rather than another have not yet been proposed.

It is important to point out that similar phenomena have also been observed for adult emotional expressions. In fact, noncorrespondences of the first two types just described are acknowledged in virtually all contemporary discrete emotion theories (e.g., Buck, 1988; Ekman, 1972, 1992; Frijda, 1986; Izard, 1997; Plutchik, 1980; Tomkins, 1982). Such disjunctions are accounted for primarily by the notion of "display rules" (Ekman and Friesen, 1969). That is, spontaneously produced emotional expressions may be subjected to voluntary control such that an expression may be minimized, completely inhibited, or masked through substitution of a different (perhaps more socially appropriate) facial expression. In addition, adults may falsify their facial behavior by voluntarily producing an emotional expression when no genuine emotion is being experienced.

Display-rule-governed dissociations between emotion and emotional expression are thought to occur as the result of socialization processes. During the course of development, the individual comes to exert control over his or her expressive behavior in conformity with personal standards and/or sociocultural norms. In these cases, variation in expressive behavior involves altering the "natural course of events," that is, the spontaneous production of species-specific emotional facial expression. However, such alterations would not be expected in young infants because traditionally infants have not been thought to engage in intentional communicative behavior, at least during the first eight months. Even in older infants, it is often difficult to envision circumstances under which inhibition or nongenuine expression of some emotions (e.g., surprise) would be expected to occur.

Regarding the third anomalous phenomenon described earlier, current systems for identifying emotional expressions include a number of variant expressions for each emotion. For example, the FACSAID database (Ekman et al., 1998) used to interpret facial behavior coded using Ekman and Friesen's (1978) Facial Action Coding System currently contains over ten configurations identified as "surprise" expressions and over fifteen additional configurations identified as possible expressions of surprise. However, as for infants, the causal basis for such variability has not been fully explicated (but see Ekman, 1979, for some proposals).

Coordinative Motor Structures

The problem of variability among facial expressions in the same emotional category is interesting because it resembles a classic dilemma in movement science known as "Bernstein's problem" (Bernstein, 1967; Turvey, 1990). Movement scientists have long been confronted with the challenge of accounting for the fact that functionally equivalent actions are never completely equivalent topographically (e.g., one never walks twice from point A to point B in exactly the same way). Minor variability inevitably occurs due to numerous contextual particularities, such as initial position when starting out, slight unevenness in the surface underfoot, and so forth. One way of accounting for such variability is to posit a central planning agent who continually monitors the details of the organism's activity and makes continual adjustments to compensate for minor variations in the environmental context in which the activity takes place. However, movement scientists have deemed this solution inadequate because it places too great a burden on the central controlling agent. Instead, they have proposed that contextually sensitive adjustments are made at lower levels through synergistic relationships among neuromuscular action components (Kelso and Scholz, 1986; Kugler, Kelso, and Turvey, 1980; Michel, 1991). That is, groups of muscles are proposed to be synergistically linked such that the action of one member of the group may recruit the action of other members. These synergistically related groups of muscles are called "coordinative motor structures." Via such neuromuscular linkages, minor perturbations in a planned action sequence (due to contextual factors, such as occur when walking over slightly uneven ground) may be automatically compensated for via recruitment of compensatory movements. In addition, performance of some activities may be made more efficient because executive control can be implemented at the level of the grouping rather than at the level of the individual muscles themselves.

A Dynamical Systems Framework

Coordinative motor structures are a class of patterned activities that have been proposed to fall within the explanatory framework of dynamical systems (Kelso, 1995). The dynamical systems approach attempts to account for the organization of complex systems of various sorts, many of which involve a large number of components that might potentially be combined in a nearly infinite number of possible ways (Fogel et al., 1992; Fogel and Thelen, 1987; Kelso, 1981, 1995; Schoner and Kelso, 1988;

Thelen, 1989a). Despite this potential for infinite variability, such systems (e.g., human motor action) tend to assume a limited number of states or patterns (termed "attractor states"; Abraham and Shaw, 1982), although some degree of variability within these patterns often occurs. According to the dynamical systems perspective, these states are self-organized (Fogel et al., 1992; Kugler, Kelso, and Turvey, 1982; Thelen, 1989b; Turvey, 1990), for example, they may involve constrained coordinative relationships among lower-order components rather than being fully dictated in detail by a higher-order command program. The system assumes one or another of its attractor states depending upon a number of factors. These include the value of some identified "control" parameter as well as the initial condition of the system when the control parameter changes value. For example, in an elegant set of experiments, Kelso and his colleagues (Kelso, 1995) have demonstrated that rhythmic multijoint arm movements (involving flexions and extensions of the elbow and wrist) will assume different patterns depending upon the initial position of the arm and the speed at which the arm is moved. Shifts from one pattern to another (termed "phase shifts") tend to occur relatively abruptly at the point at which the control parameter reaches its critical value. For example, when wrist and elbow movements accelerate beyond a certain velocity, they may switch from a pattern involving simultaneous wrist flexion and elbow extension to a pattern in which the wrist and elbow are constrained to flex (and extend) simultaneously. As the control variable (e.g., movement velocity) approaches its critical value, increasing fluctuations in the current pattern may occur, indicating loss of stability. Furthermore, when the system is perturbed (by some outside factor such as tapping the arm or an uneven spot on the ground), pattern recovery is slower if a control variable is near the critical value at which a change from one organized pattern to another will be catalyzed. Within this framework, the coordinative structures proposed as a solution to Bernstein's problem of motor coordination may be considered a class of dynamical systems "attractor states."

Dynamical systems models offer an attractive alternative to theories that attempt to explain systems that involve considerable variability solely by means of a central controlling agent (Fogel and Thelen, 1987; Kugler, Kelso, and Turvey, 1980; Oyama, 1989). According to the dynamical systems perspective, a system's activity takes place within a larger context that critically influences its component structure and thus produces such variability (Fogel et al., 1992; Thelen, 1989a). This important idea is expressed in the popular dynamical systems dictum: the task dictates the behavior.

Although its applications in psychology have been limited thus far, a dynamical systems perspective potentially might successfully explain the organization of any type of complex system. Furthermore, it might be applied to several different behavioral systems that operate at different levels of behavioral analysis, that is, microsystems embedded within macrosystems (see Vallacher and Nowak, 1994, for examples in social psychology). Herein, I will explore the possibility that a dynamical systems approach might be used to explain the anomalies of infant facial expression described earlier. To do this, I will argue that human emotions and human facial expressions may constitute overlapping but partly separate dynamical systems. To explain emotional facial expression, both systems must be examined as well as their points of overlap and integration. My approach shares considerable common ground with recent work by Fogel, Messinger, Dickson, and their colleagues (e.g., Fogel, 1985; Messinger, Fogel, and Dickson, 1997), who have primarily focused on infant smiling. Much of my discussion will be speculative in nature, but I will also review and present new data to support the ideas proposed herein.

Emotions, Expressions, and Dynamical Systems

Within this volume, the several chapter authors are applying dynamical systems approaches to the study of emotion in a variety of creative and productive ways (see also Fogel et al., 1992). Emotions are obvious candidates for explanation in terms of dynamical systems because they are highly complex and involve the coordination of multiple components. Furthermore, emotion-related behavior is patterned and yet variable across emotion episodes.

As applied to infant emotional facial expressions, a dynamical systems approach might be used to account for the first anomalous phenomenon described earlier, that is, the absence of emotional facial expressions in some emotion situations. This noncorrespondence might be expected to occur if emotional expressions are recruited for display in a selective task-specific manner. Facial expressions are viewed as being similar to other emotion-related behaviors (i.e., instrumental responses) whose occurrence within an emotion episode is dictated by the situational context rather than being automatically mandated by a central control system. Interestingly, this perspective is gaining some prominence within the area of animal communication. For example, Marler and Evans (1997) have recently found that several avian species may or may not produce vocal communication signals depending upon contextual factors, rather than upon presumed alterations in their own internal state. Of significance, Marler interprets his findings as requiring a revision of traditional theories in which animal communication signals have been viewed as direct readouts of the animal's motivational tendencies. However, consistent with the perspective proposed herein (and in contrast to other proposed alternatives, e.g., Fridlund, 1994), Marler does not relinquish the notion that animal communication signals may be considered to be expressions of emotion.

Related to this last idea, the dynamical systems perspective might also be used to account for the second anomalous phenomenon of infant facial expression described here: production of a codeable "emotional" expression in circumstances where it is unlikely that emotion is being experienced. This phenomenon might be explained by incorporating nonemotional (as well as emotional) facial expressions into the dynamical systems framework. Even discrete emotion theorists acknowledge that many facial expressions are not manifestations of emotion. Starting from this acknowledgment, facial expression itself may be viewed as a complex behavioral system presenting just those sorts of problems for which dynamical systems approaches attempt to provide a solution. The face can produce numerous muscle actions that potentially occur in a nearly infinite number of combinations. Nonetheless, only a limited number of combinations appear to occur (although these do exceed the number described as being emotional expressions). Dynamical systems proponents might propose that the face can assume only a limited number of patterned states due to constraints imposed by lower-order synergistic relationships among muscle actions (i.e., coordinative motor structures). Such coordinative structures might be activated in several different ways. One source of activation might be the experience of an emotion itself (e.g., surprise). However, the same facial action ensemble might also be activated if one of its components were produced as an instrumental action (e.g., opening the mouth widely to incorporate an object). In this case, the activated component (mouth opening) might recruit other facial actions (e.g., brow raising) that are elements of a common coordinative motor structure. Such recruitment would take place via lower-order synergistic relationships among facial muscle actions. As a consequence, the emotion-relevant facial configuration might sometimes be produced when no emotion is being experienced.

A dynamical systems model might also be used to account for the third anomalous facial expression phenomenon: variability among the several facial configurations that are all considered to be expressions of a particular emotion. First, particular components of a complete prototypic expression might occur or not occur depending upon their functional utility within the situational context in which the emotion is being experienced. This argument is similar to that advanced when discussing the first anomaly. Going back as far as Darwin (1872/1998), the functional value of certain facial actions has been recognized (e.g., widening the eyes and raising the brows increases the visual field). However, both Darwin and later ethologists have argued that such movements may become divorced from their functional origins (e.g., when they become "ritualized" or specialized as communicative signals; Tinbergen, 1952, but also see Andrew, 1963). Nonetheless, to account for the presence or absence of a particular facial action in an instance of emotional expression, perhaps its utilitarian instrumental value within a particular expressive context should be reconsidered and empirically investigated (see Ekman, 1979, for some examples).

Nevertheless, utility alone probably could not fully account for variability among emotional expressions within the same emotional category. This is because the instrumental value of many facial movements involved in emotional expression is not clear. However, it may also be the case that some components of the prototypic emotional expression may or may not occur because of their involvement in certain coordinative motor structures relevant to aspects of the situation other than the emotion in and of itself. For example, as I will elaborate later, muscle actions involved in raising the head, gaze, and brows may be part of a coordinative motor structure such that deliberately raising the head and/or gaze may recruit brow raising, a component of surprise and interest expressions. Thus brow raising might occur in surprise or interest episodes in which lifting the head and/or gaze takes place but might not occur in other instances of these emotions.

Commentary

Developmental scholars have been reluctant to acknowledge these anomalies of emotional expression because their existence might appear to make it impossible for us to understand and adaptively respond to nonverbal infants. However, I will argue that accurate emotion communication does not require an innate concordance hypothesis for infants. Just as we are capable of understanding adult emotion despite the operation of display rules, so are we able to understand infants' emotion even if there is no unique one-to-one relationship between specific facial expressions and specific affects. Toward the end of this chapter, I will tentatively suggest how a dynamical systems perspective might provide a framework in which we might account for such a communicative phenomenon. For now, I will simply suggest that, by the same token, if subsequent research with adults demonstrates disjunctions between expression and emotion beyond those attributable to display rules, a dynamical systems perspective might also help us account for the preservation of effective emotion communication among adults.

Empirical Observations of Infant Brow Raises and Surprise Expressions

In the remainder of the chapter, I will further pursue a dynamical systems approach with respect to two forms of infant facial expressions: brow raises and surprise expressions. Brow raising is a facial action that may occur alone or in combination with other facial movements. Within Izard's AFFEX coding system (Izard et al., 1983) it is included as a component of both the expression of interest and the expression of surprise. More specifically, according to AFFEX, interest expressions may involve either raised brows or horizontally knit brows, and either slightly pursed lips or slightly parted lips. The expression of surprise involves raised brows, widened eyes, and an open, rounded mouth. However, in using AFFEX, surprise may be coded if only two of the three surprise components are present (i.e., open mouth accompanied by raised brows or widened eyes). Thus, variability in the expression of both emotions is acknowledged within the AFFEX system, although a causal basis for this variability is not presented.

Beyond this acknowledged variability, previous observations and several empirical studies have indicated that mismatches between emotion and these expressions may occur during infancy. My original observations of these disjunctions were made during a systematic study of my own daughter's expressive behavior in her first two and a half months (Camras, 1992). During this time, I observed a striking association between her looking upward and raising her brows. Sometimes this occurred with slightly parted lips, producing a codeable "interest expression." While the association between looking up and brow raises might be attributed to a common emotional basis (i.e., the emotion of interest underlying both the facial movement and head/gaze lifting), the appropriateness of such an attribution seemed uncertain because visual regard in the upward direction was often fleeting rather than sustained. Thus, if anything, the raised brow movement appeared more closely related to visual searching than to the kind of sustained attention usually considered characteristic of interest as an emotion.

With respect to surprise, an initially important observation was merely that surprise expressions indeed occurred quite often during the course of the study. This observation was striking because very few surprise expressions had previously been observed in laboratory investigations in which the emotion of surprise has been assumed to be evoked. For example, studies of object permanence and other investigations utilizing expectancy-violation procedures (e.g., Baillargeon, 1986) evoke surprise expressions so infrequently that such expressions cannot be used as indices of a surprise response. By contrast, my daughter Justine often produced prototypic surprise expressions, but she produced them in familiar rather than surprising circumstances. For example, when placed beneath the familiar softly glowing kitchen lamp, she would invariably look upward at the light, become visibly excited, wave her arms in the direction of the lamp, raise her brows, widen her eyes, and open her mouth. Rather than as an indication of surprise in this context, her expression might be more reasonably interpreted as an example of a spreading appetitive sensory reaction described by the Austrian physiologist Albrecht Peiper (1963). As proposed by Peiper, Justine's facial reactions appeared to occur in the service of facilitating desirable sensory input. Similarly, Justine often showed the surprise expression as she opened her mouth in preparation for nursing. Taken together, these observations suggested that facial configurations codeable as interest and surprise expressions might occur in infants when these emotions were not actually present and that alternative systemic factors underlying their production might be identified.

Further empirical support for these ideas was produced in two systematic follow-up studies involving a larger number of infants. In one study (Michel, Camras, and Sullivan, 1992), five- and seven-month-old infants were presented with attractive toys at either above or below eye level. Raised brow movements significantly co-occurred with head-up and/or eyes-up movements at both ages. Presumably infants were equally interested in the toys irrespective of their presentation trajectory. Nonetheless, raised brows (a key component of the interest expression) occurred more often when looking at the toys required raising the head and/or gaze. Based on these findings, we proposed that raised brows is part of a coordinative motor structure involving actions of the head, eyes, and brows. The operation of this coordinative motor structure may determine whether infants produce a variant of the interest expression involving raised brows when they are displaying their emotion. Furthermore, we suggested that raised brows may sometimes be produced when head and/or gaze are lifted but the emotion of interest is not present. Thus, converging sources of evidence may be required before emotion can be inferred from the brow actions of infants.

With respect to surprise facial configurations, we reached similar conclusions in a study examining the facial actions of five- to seven-month-old infants as they carried nonsurprising objects toward their mouths in order to orally explore them (Camras, Lambrecht, and Michel, 1996). This study found that the facial action of moderately or widely opening the mouth was accompanied by brow raising and trace levels of eye widening. Thus, infants produced codeable "surprise" expressions in a nonsurprise situation. Again, these results suggest that coordinative motor structures are available for recruitment for a variety of purposes and that unique and exclusive ties may not be formed between some emotions and their corresponding facial expressions.

Surprise and Interest Expressions in Two Expectancy-Violation Procedures

More recently, my colleagues and I have begun to examine infants' facial behavior during procedures designed to elicit the emotion of surprise by means of expectancy violation. These procedures were administered as part of a collaborative cross-cultural investigation of infant expressive behavior. In this project, we studied eleven-month-old infants from the United States, Japan, and mainland China in stimulus situations designed to elicit mild anger/frustration and fear as well as surprise (see Camras et al., 1998, for a report of the anger and fear situations). Herein, I will present some preliminary analyses of the surprise-eliciting procedures.

We employed two different procedures in order to assess the situational specificity of infants' surprise reactions. Both procedures have been previously employed in other investigations and are expected to evoke surprise in infants of the age we studied. Both procedures involve violating notions of object permanence and constancy that are believed to develop well before eleven months.

In the first procedure, *vanishing object*, a small barking toy dog that the infant is watching suddenly appears to vanish instantaneously. This illusion is created with a large two-field tachistoscope having a one-way mirror in the center. The dog is placed behind the mirror. When the light is changed from one wing to the other, the dog appears to vanish while its barking can still be heard. In the second procedure, *toy switch*, the infant sees a toy covered by a cloth during a series of trials. After removing the cover and finding the same toy during the first four trials, the infant inexplicably finds a different toy on the fifth trial. This illusion is created by utilizing a table with a shallow well in which the toy is placed before covering. The well contains two compartments that can be rotated from under the table during the fifth trial so that the second compartment holding a different toy is exposed when the infant removes the cover.

The infants' facial behavior was coded using a modified version of BabyFACS (Oster and Rosenstein, 1995), an anatomically based scoring system for infant facial behavior based on Ekman and Friesen's (1978) adult-oriented Facial Action Coding System (FACS). In both BabyFACS and FACS, the basic scoring units are discrete, minimally distinguishable actions of the facial muscles (termed action units or AUs). One virtue of BabyFACS is that facial behavior is objectively described without making a priori assumptions about its emotional meaning. However, using this system, we were able to identify facial configurations that are interpreted as expressing surprise within Izard and colleagues' (1983) AFFEX system as well as in Ekman and colleagues' (1998) FACSAID (FACS Affect Interpretation Database).

Because facial coding is extremely labor-intensive, we selected a ten-second baseline episode and a ten-second stimulus episode to be coded for each procedure. For the vanishing object procedure, the baseline episode was the ten-second period preceding the first disappearance of the barking dog, while the stimulus episode was the ten-second period initiated by the disappearance. For the toy switch procedure, the baseline episode was the ten-second period preceding the baby's uncovering the unexpected object, while the stimulus episode was the ten-second period initiated by the baby's uncovering the unexpected object.

In addition to coding movements of the facial musculature, we also coded head and gaze movements. This allowed us to follow up on our previous studies examining relationships between these movements and the infants' production of raised brows. Since surprise expressions involve a raised brow movement, we wished to determine whether surprise expressions might also be selectively related to upward head and gaze movements occurring during our surprise procedures. Our coding categories were: (a) head/gaze – UP45 (i.e., head and/or gaze direction shifts upward from its initial position by at least 45 degrees), (b) head/gaze – control (i.e., head and/or gaze direction shifts horizontally or shifts upward but by less than 10 degrees), and (c) other head/gaze movements (e.g., downward movements or upward shifts of less than 45 degrees but more than 9 degrees). Because head and gaze movements for the Japanese babies have not yet been coded, our data analyses include only the American and Chinese infants whose faces were visible (not facing away from the camera or obscured by their hands) during some part of the coding interval. This produced a sample size of 24 American infants and 23 Chinese infants for the vanishing object procedure, and 24 American infants and 16 Chinese infants for the toy switch procedure.

We identified surprise expressions based on the criteria found in FACSAID (the FACS-based database for emotion interpretations) and AFFEX (Izard and colleagues' emotion-oriented coding system for infants). Only four infants showed a facial configuration identified with certainty as "surprise" by FACSAID. These configurations involved raised brows (AU 1+2), eyes widened via raising of the upper eyelid (AU 5), and moderately to widely open mouth (AU 26b/27). However, substantially more infants (n = 46; 53%) produced a facial configuration identified as "hypothesized" or "questionable" surprise by FACSAID. This expression involved raised brows and moderately open mouth but did not include a codeable raising of the eyelid. Instead, the eyes were slightly widened by the pulling of the skin below the brows, or the lids were lifted only to a "trace" level, that is, not enough to be coded with certainty. Nonetheless, based on the movements of the brows and mouth, this facial configuration would be codeable as "surprise" by the AFFEX system. Herein, I will refer to this facial configuration as the BROM (brow raise open mouth) configuration.

We compared the number of infants who produced the BROM configuration during baseline versus stimulus episodes for each procedure. Surprisingly, almost as many infants showed the configuration during baseline as during stimulus episodes (40 percent during baseline and 49 percent during stimulus for vanishing object; 28 percent for baseline and 33 percent for stimulus for toy switch; see Table 4.1). Chi-square analyses failed to show that more infants produced the BROM configuration during stimulus than during baseline episodes for all infants combined into a single group or for

Table 4.1. *Percent of infants producing BROM configurations in baseline and stimulus episodes*

		Episode	
Procedure	Culture	Baseline	Stimulus
Vanishing object	American (*N* = 24)	37.5	45.8
	Chinese (*N* = 23)	43.5	52.2
Toy switch	American (*N* = 24)	37.5	37.5
	Chinese (*N* = 16)	12.5	25.0

Note: *N* = number of infants

the American and Chinese infants examined separately. These results suggested that the BROM configurations were not selectively produced when the infants were presumably experiencing the emotion of surprise during the particular experimental procedures we examined.

Based on our earlier research on relationships among brow, head, and gaze lifting, we hypothesized that if BROM configurations were not serving as surprise expressions during our procedures, they might instead be selectively related to the infants' raising of their head and gaze. To assess this possibility in a preliminary fashion, we conducted several analyses. In these analyses, we treated individual instances of facial, head, and gaze movements as independent scores, irrespective of which or how many movements came from each individual infant. This decision was made in order to generate a larger sample size. Consequently, the results of these analyses must be viewed with some caution, although we believe that they have produced an interesting pattern of results that can be pursued more rigorously in future studies.

For the first analysis, we identified all BROM configurations in each of our two procedures as well as all facial configurations that did not involve brow raising (no-brow-raise configurations; henceforth NBRO configurations). For each configuration, we examined the infant's accompanying head and gaze direction (see Table 4.2). Combining across infants from both cultures and across the baseline and stimulus procedures, we conducted chi-square analyses comparing the distribution of BROM versus NBRO configurations across two categories of head/gaze movements: HG–UP45 and HG–control. Results showed that BROM configurations were more likely to be accompanied by HG–UP45 than were NBRO configurations, $\chi^2 = 5.95$, $df = 1$, $p < .02$, for the vanishing object procedure, and $\chi^2 = 6.38$, $df = 1$, $p < .02$ in the toy switch procedure. We also conducted follow-up chi-square analyses comparing American and Chinese infants' distribution of BROM configurations across the two head/gaze positions and comparing these distributions in the baseline versus stimulus episodes. No significant results were obtained in these analyses, suggesting that the relationship between BROM configurations and HG–UP45 holds for infants in both cultures and during both episodes of each procedure. These data suggested that BROM expressions (or some components thereof) may be part of a coordinative motor structure involving upward head and/or gaze movements. While BROM configurations may express the emotion of surprise in some situations, in our procedures they appeared to be components of a larger motoric ensemble that operated during both the baseline and stimulus episodes.

Table 4.2 *Number of BROM, BRO, and NBRO configurations accompanied by head/gaze up or control position*

			Facial configuration and head/gaze position					
Procedure	Episode	Culture	BROM HG–UP45	BROM HG–CON	BRO HG–UP45	BRO HG–CON	NBRO HG–UP45	NBRO HG–CON
Vanishing object	Baseline	American	1	5	4	11	6	36
		Chinese	6	12	4	18	3	37
		Total	7	17	8	29	9	73
	Stimulus	American	9	4	12	6	15	24
		Chinese	6	9	15	1	11	18
		Total	15	13	27	7	26	42
Toy switch	Baseline	American	4	6	17	0	8	27
		Chinese	1	0	14	4	6	17
		Total	5	6	31	4	14	44
	Stimulus	American	6	4	13	6	15	35
		Chinese	3	1	5	6	1	12
		Total	9	5	18	12	16	47

Note: BROM = Brow raised + open mouth configuration (AU26B/27)
BRO = Brow raised + other = raised brow ± any facial actions other than open mouth
NBRO = No brow raised + other configuration = any facial configuration without raised brows
HG–UP45 = Head and/or gaze raised at least 45°
HG–CON = Head and/or gaze control position (10° or less above horizontal)

In addition to examining the surprise-related BROM configuration, the present study afforded the opportunity of replicating previous findings (Michel et al., 1992) regarding the relationship between the raised brows action itself and raised head and/or gaze. To do so, we began by identifying all brow raise (BR) configurations. These included both BROM configurations and BR configurations (defined as configurations involving brow raise that were not BROM configurations). Conducting analyses similar to those already described, we found that BR configurations were accompanied more often by HG–UP45 than were NBRO configurations, $\chi^2 = 14.99$, $df = 1$, $p < .001$ for the vanishing object procedure, and $\chi^2 = 35.21$, $df = 1$, $p < .001$ for the toy switch procedure. Again, we conducted follow-up chi square analyses comparing American and Chinese infants' distribution of BR configurations across the two head/gaze positions and comparing these distributions in the baseline versus stimulus episodes. For the vanishing object procedure, results indicated that BR configurations occur with HG–UP45 more often in the stimulus episode than in the baseline episode. Informal inspection of the videotapes showed that at the onset of the baseline coding interval for this procedure, infants often were already looking intently at the visible barking dog with raised brows and unmoving level head/gaze. Thus their BR configurations may have resulted from previous encoded HG–UP45 movements or may be related to some other factor (see further discussion to follow). Overall, however, the analyses replicated the results of Michel and colleagues (1992), who also found a relationship between raised brows and raised head/gaze occurring during a (nonsurprising) toy presentation procedure.

In interpreting their findings, Michel and colleagues (1992) proposed a recruitment hypothesis, suggesting that the instrumental actions of lifting head and gaze recruited the accompanying brow raise movement. To assess this possibility more directly in our study, we conducted additional chi square analyses in which we began by identifying the onset of all HG–UP45 and all HG–control movements. We then determined whether each head/gaze movement was accompanied by or followed (within .5 second) by the onset of a BR configuration. Head/gaze movements occurring when the brows were already raised were eliminated from the data analysis. Results showed that HG–UP45 was accompanied (or followed) by raised brow significantly more often than were HG–control movements, $\chi^2 = 14.67$, $df = 1$, $p < .001$ for vanishing object, $\chi^2 = 84.54$, $df = 1$, $p < .001$ for toy switch. Follow-up analyses failed to show differences between the American and Chinese infants or between the baseline and stimulus episodes for either of the two procedures. The results provide stronger evidence supporting the hypothesis that brow raises can be recruited by raising the head and/or gaze and are part of a coordinative motor structure.

We also conducted similar analyses in which we looked only at the BROM configurations to determine whether HG–UP45 recruited these specific surprise-related configurations more often than did the HG–control movements. Significant results were not obtained for the vanishing object procedure. However, in the toy switch procedure, HG–UP45 was accompanied or followed by BROM configurations significantly more than HG–control movements, $\chi^2 = 13.05$, $df = 1$, $p < .001$. Thus there was some weak evidence that head/gaze raises selectively recruited BROM configurations, but only in the toy switch procedures. This further suggests that BROM configurations may sometimes be produced by causal factors other than the emotion of surprise.

Discussion

The results of these analyses revealed statistically significant associations between BROM and BR configurations and HG–UP45 movements in infants. Both facial configurations were accompanied by HG–UP45 movements more often than by HG-control movements. Conversely, HG–UP45 movements were accompanied or followed by brow raise configurations more often than were HG–control movements. In addition, HG–UP45 movements were accompanied or followed by BROM configurations more often than were HG–control movements in the toy switch procedure, but this did not occur statistically more often in the vanishing object procedure. How strongly do these data suggest that raised brows, head, and gaze are components of a coordinative motor structure in which upward movement of the head and/or gaze will tend to recruit brow raising and/or BROM expressions?

Brow Raise Configurations

Despite their tendency to co-occur with HG–UP45, data inspection (see Table 4.2) showed that many BR expressions were produced with HG–control and that many HG–UP45 movements were produced without recruiting (i.e., being accompanied or followed by) BR expressions. However, the fact that these movements did not *always* co-occur does not itself disprove the coordinative motor structure hypothesis. According to a dynamical systems perspective, components of a coordinative motor structure do not always operate in unison. Individual motor actions are multifunctional, available for a variety of tasks. Furthermore, the operation of a CMS depends upon a variety of factors, including the initial state of the organism and the values of other "control" parameters.

Viewed conservatively, our data suggest that further investigation is required to confirm the hypothesis that upward movements of the head, gaze, and brows constitute a coordinative motor structure in which raising the head and/or gaze may recruit brow lifting. Such investigations might involve procedures similar to those employed in studies of nonfacial coordinative structures (see Kelso, 1995). In investigations of this type, candidate control parameters are varied experimentally in order to determine whether a phase shift (i.e., an abrupt switch from one coordinative pattern to another) occurs when a parameter assumes some critical value.

In the present study, initial position of the head/gaze and speed of upward head/gaze movement might be proposed as control parameters. Regarding initial head/gaze position, we observed that this variable tended to differ across the two procedures, with the infant initially looking down at the object during toy switch and across at the display apparatus during vanishing object. Correspondingly, 82% of HG–UP45 movements were accompanied or followed by brow raises in the toy switch procedure, while 41% of the HG–UP45 movements were accompanied or followed by brow raises in the vanishing object procedure. Possibly the difference in initial head/gaze position produced the stronger recruitment of brow raising by HG–UP45 in the toy switch procedure. Velocity of head/gaze lifting may also have differed between the procedures and may be related to the recruitment of brow raising. In several studies of nonfacial movements (summarized in Kelso, 1995), movement velocity has been found to be an important control parameter underlying phase shifting. Further investigation is necessary to determine if movement velocity is a control variable determining whether HG–UP45 recruits brow raising. This might be achieved by experimentally inducing head/gaze movements of different speeds (e.g., in the context of a visual "following" task) and determining whether brow raising begins to occur when movement velocity reaches a particular value. Further tests might also examine other dynamical systems characteristics such as the changing effects of perturbing the system (e.g., gently touching the forehead) as the control parameter approaches its critical value.

While the discussion thus far has focused on possible factors determining whether brow raising is recruited by HG–UP45, we must also consider instances in which brow raising may occur with HG–control movements. Brow raising occurred with 12% of HG–control movements in the vanishing object condition and 3% of the control movements in the toy switch condition. Although these figures are low, they suggest that brow raises are sometimes produced by factors other than the coordinative motor structures we have identified. This possibility is again consistent with a dynamical systems interpretation of facial behavior positing that individual facial actions are available for recruitment by a variety of structures in a task-specific manner.

BROM Configurations

Regarding the surprise-related BROM configurations, when these occurred, the infant's head tended to be in the HG–UP45 position significantly more often than when other (NBR) expressions occurred. However, BROM expressions occurred relatively infrequently following HG–UP45 (11% of the time in the vanishing object and 16% in the toy switch procedures, respectively). Finally, in the vanishing object procedure, BROM expressions were not produced significantly more often after HG–UP45 than after HG–control movements.

Overall, these data do not strongly suggest that BROM expressions themselves are recruited by raising the head and/or gaze. More likely, when HG–UP45 movements recruit brow raising, the infant's mouth may sometimes open for other reasons. In the toy switch procedure, mouth opening and BROM configurations may occur as the infant brings the toy to his or her mouth for oral exploration (as was found by Camras et al., 1996). In the vanishing object procedure, mouth opening may occur as the jaw is relaxed while the infant sustains attention to the stimulus. This proposal is similar to one presented by Darwin (1872/1998) in his discussion of surprise and astonishment. However, it might also be used to account for the occurrence of BROM configurations in the nonsurprise baseline episodes of our procedures.

BROM Configurations as Surprise Expressions

Earlier in the chapter, I rejected the possibility that BROM configurations are invariably expressions of the emotion of surprise because they occurred equally often in the nonsurprise baseline and surprise-inducing stimulus episodes. However, possibly BROM configurations are *sometimes* produced when the infant is surprised, and in these cases the emotion itself is the underlying causal factor. If BROM configurations sometimes express

surprise and sometimes do not, how would an observer be able to use these facial configurations to read emotion?

One possibility is that our codeable BROM configurations differ in some crucial way depending upon whether or not they are expressions of surprise. This line of argument is similar to Frank, Ekman, and Friesen's (1993; Frank, 1997) proposal that genuine and nongenuine smiling may differ in their temporal profiles (e.g., smoothness of onset, duration of apex). Although the BROM configurations did not vary in terms of their action-unit components, possibly these configurations varied in some dynamic feature (e.g., intensity of mouth opening, speed of facial action onset) depending upon whether they reflected surprise or merely the operation of a coordinative motor structure (cf. Scherer, this volume). We are currently attempting to examine this possibility by comparing dynamic features of BROM configurations occurring in the nonsurprise baseline episodes to those occurring in the surprise-producing stimulus episodes.

A second possibility is that surprise and nonsurprise BROM configurations are identical morphologically and can be distinguished only by their context of occurrence. For example, BROM configurations occurring in a context where surprise is plausible will be interpreted as expressing surprise, while BROM configurations occurring when surprise is not plausible will be discounted or attributed to something other than genuine emotion. Theories of social cognition (e.g., Kelly, 1973) propose that such discounting processes routinely take place when observers attempt to make causal attributions regarding other persons' behavior. Such processes are also implicated in attempts to explain children's and adults' understanding of display-rule-dictated facial behavior. From a dynamical systems perspective, identical facial configurations might sometimes be expected to flow from different causal bases because (as indicated earlier) motoric actions may be recruited for a variety of purposes. Furthermore, this need not interfere with accurate emotion perception on the part of the observer. Within a dynamical systems framework, perception itself is viewed as a "synergetic pattern forming process" (Kelso, 1995, p. 187) in which observers will "sort a continuously changing signal into an appropriate category, whether it be of objects, emotions, or events" (Kelso, 1995, p. 201).

A third possibility is that none of our codeable BROM configurations are legitimate expressions of emotion and that this is why their frequency of occurrence did not differ in the baseline and stimulus episodes. As indicated above, according to FACSAID, the status of this configuration is questionable, that is, the BROM configuration has not been strongly confirmed as a surprise expression in adult recognition or production studies. Future investigations may show that only facial expressions that include more distinct raising of the eyelids are genuine expressions of this emotion. However, I believe it is equally plausible that some – but not all – BROM configurations are genuine expressions of surprise and that these are not morphologically distinguishable from BROM configurations produced via other causal pathways. Although such inconsistency in their causal basis may appear to threaten the ability of these configurations to serve as effective communication signals, as I have indicated previously, this need not be the case. According to a dynamical systems perspective, emotion communication should involve a process of pattern formation in terms of perception as well as expression production. Thus observers read emotion from the entire pattern of received information rather than from the presence of any one component.

Conclusion

In this chapter, I have described three phenomena of infant facial expression that are difficult to accommodate within theories that assume an invariant concordance between discrete emotions and specific infant facial expressions. As an alternative, I proposed that infant facial expressions may be viewed as patterned activities available for recruitment by either emotional or nonemotional dynamic behavioral systems. This alternative perspective differs importantly from other critiques recently launched against traditional discrete emotion theories. Such critiques (e.g., Fridlund, 1994; Ortony and Turner, 1990; Russell, 1997) attempt to dethrone discrete emotions as the causal basis for human facial expressions but replace discrete emotions with other unitary causal systems (e.g., social motives or emotional dimensions). That is, they still propose an invariant concordance between facial expressions (or facial expression components) and some underlying state, thus merely substituting one type of unitary controlling agent for another. Furthermore, these componential models fail to consider self-organizing anatomical synergies as an important factor determining the assemblage of facial components into both emotional and nonemotional facial configurations. Adopting a dynamical systems perspective, by contrast, allows us to retain the idea that facial behavior may express discrete emotions but to view these emotions as a "softly assembled" dynamic system in which no one component is required. According to the dynamical systems approach, facial expression may serve many masters, both affective and nonaffective, but this in no way jeopardizes our capacity to engage in effective interpersonal emotion communication.

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5 The Dynamic Construction of Emotion: Varieties in Anger

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Within psychology and other disciplines, discussions of emotion have traditionally drawn upon a series of dualisms. Theorists and researchers debate the extent to which emotions are best understood as universal or context-dependent, innate or acquired, dependent or independent of cognition, and so on. Current systems approaches in the social and physical sciences provide innovative frameworks that may enable theorists to break out of such polarizing dichotomies (Barton, 1994; Fischer and Bidell, 1998; Fogel, Lyra, and Valsiner, 1997; Fogel and Thelen, 1987; M. D. Lewis, 1996; Thelen and Smith, 1994; van Geert, 1994). In what follows, we outline a component systems approach to emotional development (Mascolo and Harkins, 1998; Mascolo, Pollack, and Fischer, 1997). At its most basic level, a component systems view holds that although individuals are composed of multiple distinct subsystems (e.g., affective, cognitive, overt action), component systems necessarily modulate each other in the production of emotional action and experience. An analysis of how component systems coregulate each other within social contexts can reveal both striking order and emergent variability in the production of emotional states.

Contemporary Approaches to Emotion

In recent decades, models that depict basic emotions as discrete and innate neuromuscular responses have been highly influential (Ekman, 1984; Izard, 1977, 1991; Tomkins, 1962). In their *differential emotions theory*, Izard and Malatesta (1987) define emotions as "a particular set of neural processes that lead to a specific expression and a corresponding specific feeling" (p. 496). As such, emotions consist of discrete states that are distinct from other psychological processes (e.g., cognition and instrumental action). Izard and his colleagues have proposed ten discrete emotions,