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Emotion Review 2010 2: 120 originally published online 19 February 2010
DOI: 10.1177/1754073909352529

emotion review

Emotion Review
Vol. 2, No. 2 (Apr. 2010) 120–129

ISSN 1754-0739
DOI: 10.1177/1754073909352529
er.sagepub.com

Emotional Facial Expressions in Infancy

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Abstract

In this article, we review empirical evidence regarding the relationship between facial expression and emotion during infancy. We focus on differential emotions theory's view of this relationship because of its theoretical and methodological prominence. We conclude that current evidence fails to support its proposal regarding a set of pre-specified facial expressions that invariably reflect a corresponding set of discrete emotions in infants. Instead, the relationship between facial expression and emotion appears to be more complex. Some facial expressions may have different meanings in infants than in children and adults. In addition, nonemotion factors may sometimes lead to the production of "emotional" facial expressions. We consider alternative perspectives on the nature of emotion and emotional expression in infancy with particular focus on differentiation and dynamical systems approaches.

Keywords
dynamical systems, emotion, facial expressions, infancy

Understanding infant emotions is important to scholars, pediatric professionals and parents alike. Because infants cannot verbally report on their emotions, understanding their affect has been considered by many to present a significant problem. Differential emotions theory (DET; Izard, 1971, 1991; Izard & Malatesta, 1987) is a highly influential contemporary theory of emotion that offers a solution to this problem by presuming that infants experience discrete basic emotions (defined as motivational assemblies of expressive, neurophysiological and phenomenological responses), and that infant emotions are indexed by their facial expressions (principle of innate concordance; Izard & Malatesta, 1987). While some alternative theories (e.g., Barrett & Campos' [1987] functionalist perspective) emphasize the relational and motivational aspects of emotions more than does DET, many developmentalists share the notion that discrete emotions in some form develop during infancy and are represented by a set of corresponding facial expressions. Thus, current researchers often use facial expressions as their sole measure of infant affect, focusing on those expressions considered to represent discrete emotions according to differential emotions theory (e.g., Lewis, Ramsay, & Sullivan, 2006; see Zeman, Dougan-Klimes, Cassano, & Adrian, 2007). Nonetheless, questions have been raised about the soundness of this approach and the evidence on which it is based (e.g., Camras, 1992; Camras, Malatesta, & Izard, 1991). In this article, we will review that evidence in an attempt to evaluate the advisability of relying exclusively on a pre-defined set of facial expressions for the measurement of infant emotions. We conclude that the complex relationship between expression and emotion in infancy may best be captured by an emerging model that draws upon both earlier differentiation theories of emotional development and contemporary dynamical systems approaches to conceptualizing behavioral organization.

Because infants are presumed to exert no voluntary control over their expressive behavior (e.g., they do not adhere to cultural display rules), developmental studies have been considered ideal for demonstrating DET's theoretically important principle of innate concordance. In their highly influential early paper, Izard and Malatesta (1987) made several assertions regarding infant emotional expressions that they considered to provide evidence for this principle. First, they argued that the morphology of infant emotional expressions is the same as the morphology of adult expressions for the same discrete emotion (p. 517). Second, they contended that infant facial expressions are identified as discrete emotional expressions by adults (p. 504) and adults respond differently and appropriately to these expressions (p. 517). Third, they cited covariance between infant expressions and emotion-appropriate incentive events (pp. 517–518). Fourth, they maintained that infant expressions and appropriate nonfacial emotional behaviors also covary (p. 518). We will begin by evaluating the currently extant research related to each of these assertions.

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Morphology of Infant and Adult Emotional Expression

As indicated above, morphological similarity between infant and adult emotional expressions has been proposed to imply a correspondence in their emotion meaning (i.e., the emotion that they represent). This line of reasoning has its roots in the ethological tradition of using structural similarities between communicative and instrumental behaviors to aid in the interpretation of animal signals (see Camras, 1980). With respect to human emotional expression, however, the utility of this argument for the purposes of differential emotions theory has been compromised in recent years by theoretical debates regarding the nature of adult emotions and the meaning of adult facial expressions (Barrett, 2006; Fridlund, 1994; Russell, 1994). Thus, even if infant and adult expressions correspond to each other morphologically, they might not represent discrete emotions as conceptualized within DET. Furthermore, even if scholars agreed that adult expressions do represent discrete emotions as defined by DET, the meaning of these expressions when produced by infants might differ. Nonetheless, if infant expressions correspond morphologically to proposed adult emotional expressions, this would strengthen the justification for further investigation of their own affective meaning. Therefore, despite the caveats just described, we examine the question of morphological similarity.

According to Izard, the muscle movements and configurations of infants' emotional facial expressions are "identical to those of adults" (Izard, Hembree, & Huebner, 1987, p. 106). In order to formally describe and score infants' emotional facial expressions, Izard and his colleagues developed the Maximally Discriminative Facial Movement Coding System (MAX; Izard, 1979, 1995). MAX is an anatomically-based system in which coding units represent actions of the facial musculature with a specific focus on those movements involved in infants' emotional expressions as proposed within DET. Providing an alternative approach to the earlier AFFEX system (Izard, Dougherty, & Hembree, 1983), the most recent version of MAX also delineates a set of rules for determining the emotion meaning of MAX-code combinations. In addition, the affect-related drive state of physical discomfort/pain is included in the system (and for simplicity's sake we henceforth include physical discomfort/pain under the umbrella term of "negative emotion"). While positive and negative affect expressions have been described by other investigators of infants (e.g., smiles and cry faces; Oster, 2007), MAX constitutes the only currently existing coding system intended for infant expressions of discrete emotions.

According to the MAX manual (Izard, 1995), the emotion configurations that are described were derived by examining adult emotional expressions used in previous studies as well as observing infant expressions in a "wide variety of affect-eliciting conditions" (p. 30). In addition, the original manual (Izard, 1979) states that the infant configurations specified in MAX were identified as expressions of their predicted emotions using a preliminary adult expression coding system. Such consistent classification would indeed suggest morphological identity between the infant and adult facial expressions. However, though anatomically-based, MAX is not anatomically-comprehensive. Thus, infant and adult expressions that differ in the details of their morphology might be categorized as the same emotion.

In an exemplary investigation, Oster, Hegley, and Nagel (1992, Study 3) addressed this concern as part of a larger set of studies examining the validity of the MAX-specified infant expressions. Using BabyFACS (2007), Oster et al. (1992) recoded a number of infant expression photographs obtained from Izard's training materials as well as other photographs that fit the MAX-specified criteria for emotional expressions. BabyFACS (2007) is Oster's infant-oriented version of Ekman, Friesen, and Hager's (2002) anatomically-comprehensive Facial Action Coding System (FACS). The infants ranged from 2 weeks to 21 months of age. After re-coding the expressions using BabyFACS, Oster et al. submitted these configurations to FACSAID, an emotion-interpretation database compiled by Ekman, Hager, Irwin, and Rosenberg (1998). Results showed that all MAX-specified happiness slides and two out of three MAX-specified surprise slides were identified by FACSAID as representing their predicted emotions. However, only three out of 19 negative expressions were identically interpreted by both MAX and FACSAID. For example, none of the four MAX-specified anger slides were interpreted by FACSAID as representing the emotion of anger. Oster et al. also noted that the MAX-specified infant discomfort/pain expression does not correspond to pain expressions described for adults (a point later acknowledged by Izard et al., 1995).

One potential explanation for the discrepancies obtained in Oster's investigation is that some photographs she used (including those taken from the MAX training materials) were poor representations of the prototype expressions specified in MAX itself. In fact, subsequent to Oster's study, Izard et al. (1995), re-coded several of the photographs and modified their emotion interpretation. However, an alternative—and more direct—approach to addressing the issue of morphological similarity involves comparing adult and infant prototypes as described within the coding systems themselves. These represent the "ideal" expressions of the emotions that may or may not have been captured in the MAX training photographs (or indeed in real-life expressive behavior). Although the FACSAID database is no longer available, the current FACS Manual (Ekman et al., 2002) presents a set of formulas that represent adult expression prototypes and "major variants" for six of the emotions described in MAX (i.e., happiness, surprise, anger, sadness, fear, and disgust). Using the anatomical information provided in both the FACS and MAX manuals, coders trained in both systems (such as this article's authors) can make comparisons between formulas representing the six emotions included in both systems.

Inspection of the MAX and FACS formulas for these emotions reveals both similarities and potentially significant differences. MAX-based formulas for the complete expression of happiness (enjoyment/joy), surprise, and fear would be interpreted as representing these same emotions by FACS. However, expressions of some negative emotions are not completely isomorphic. For example, as pointed out earlier by Oster et al. (1992), the MAX-specified expression of anger includes contraction of obicularis oculi (the muscle encircling the eye, i.e., MAX AC 33 or FACS AU 6) which does not appear in any of the FACS formulas for anger. Furthermore, all of the FACS anger expressions include either a lip tightening (AU 23) or lip press (AU 24). Neither facial action is included in any of the MAX-based anger formulas. Similarly, all the MAX-specified expressions of disgust include both contraction of obicularis oculi and also a tongue-showing movement (an element of MAX AC 59b or FACS AU 19). These actions do not appear in any of the FACS-specified adult disgust expressions. For sadness, only one of four complete MAX-expressions of sadness corresponds exactly to a FACS prototype. Three MAX-specified sadness expressions include contraction of obicularis orculi (i.e., MAX AC 33 or FACS AU 6), a movement which does not appear in those FACS formulas that otherwise correspond to the three infant expressions. Thus, none of the infant anger and disgust expressions and only some of the infant sadness expressions as described in MAX would fit the formulas for corresponding adult emotional expressions as presented in FACS.

In summary, several infant emotional expressions described within MAX are not morphologically identical to adult expressions for the corresponding emotions as described within the most current, state-of-the-art adult expression coding system. However, as noted above, even if one could successfully identify a set of infant expressions that are isomorphic to consensually-acknowledged adult expressions of emotion, further evidence for their emotion meaning in infants would be required. Thus, we proceed to consider such evidence.

Judgment Studies of Infant Expressions

Judgment studies form the principal basis for contemporary theories of emotional expression (Russell, 1994). Izard and Malatesta (1987) have argued that adults' ability to accurately judge the emotion content of infant facial expression is adaptive, allowing them to effectively respond to infants' needs. However, as pointed out by Oster (2005), effective responding need not rely on infants' expression of discrete emotions (rather than more general states of positive or negative affect). Because the adaptational demands of the environment differ for infants and adults, Oster maintains that their emotional and expressive repertoires may also differ. Thus, whether adults indeed interpret infant expressions using adult discrete emotion categories becomes an empirical question rather than an evolutionary necessity.

In an early series of studies, Izard, Huebner, Risser, McGinnes, and Dougherty (1980) investigated observer judgments (i.e., the "social validity") of eight infant emotional facial expressions as defined by differential emotions theory. Stimuli were still photographs and dynamic video clips of infants ranging in age from 1 to 9 months. Stimulus expressions were selected to be high quality exemplars of the respective emotional expressions. No effort was made to use same-age infants for all emotions and no more specific information regarding infant age was provided. In several conditions, judges selected an emotion label (forced choice recognition) or produced their own emotion word (free-response labeling) for each infant expression. Some judges were tested both before and after being trained to identify the emotional expressions. Although the authors found above-chance levels of agreement with the predicted emotions (with "chance" equaling 12.5%), inspection of the data showed that the mean scores for untrained judges were not exceptionally high. In fact, forced-choice recognition "accuracy" exceeded 60% for only three out of the eight emotions (i.e., for joy, surprise, and sadness but not interest, anger, disgust, contempt, or fear).

In a later study, Emde, Izard, Huebner, Sorce, and Klinnert (1985) found significant correlations across two laboratories in rater judgments of infant expression photographs. However, identification "accuracy" (i.e., whether judges produced the theoretically predicted emotion label) was not investigated. Similarly ambiguous results were obtained in Huebner and Izard's (1988) investigation of mothers' responses to MAX-specified sadness, anger, physical discomfort, and interest expressions displayed by 2–15-month-old infants. Although mothers reported different reactions to several different expressions, as pointed out by Oster et al. (1992), their responses often did not appear particularly appropriate for the predicted discrete emotion.

Because of these unclear findings, Oster and her colleagues (Oster et al., 1992) conducted an important set of judgment studies as part of their larger investigation of infant emotional facial expressions. As indicated above, stimulus pictures were of infants ranging from 2 hours to 21 months of age. In addition to offering discrete emotion labels as response options, Oster et al. used the nondiscrete emotion term "distress," a term "encompassing both mental as well as physical pain or suffering" (p. 1117). Distress was included to explore the possibility that judges actually perceive at least some infant expressions to represent less differentiated negative affect (as also proposed by Bridges, 1932; Camras, 1992; Camras, Sullivan, & Michel, 1993; Oster, 1982; Sroufe, 1996) rather than discrete negative emotions.

Using a forced choice procedure, Oster et al. (1992) found that judges selected the predicted emotion more often than chance for all of the MAX-specified joy, surprise, and interest expressions. In fact, the predicted emotion was chosen by over 70% of judges for five of the six expression stimulus slides for these three emotions. Thus, overall the results for the nonnegative emotions were consistent with the claims of differential emotions theory. However, results for the MAX-specified negative expressions were not similarly supportive. Judges selected the predicted emotion significantly more often than chance (with "chance" equaling 12.5%) for only 10 of the 16 negative stimulus slides. The predicted emotion was chosen by over 60% of judges for only one negative emotion stimulus (one of five sadness slides). Similar results were obtained when adults were asked to rate the infant emotional expressions on each of eight emotion scales. For the fear, anger, sadness, and disgust pictures, the predicted emotion received the highest mean rating for only 2 out of 17 stimuli (both being sadness expressions). However, distress was rated significantly higher than the predicted emotion for four (out of four) anger pictures, one (out of four) fear picture, and two (out of three) disgust pictures. In summary, Oster et al.'s findings raised important questions about the social validation of the MAX-specified negative emotional expressions.

Camras et al. (1993) also explored the possibility that judges often interpret infant emotional behavior as expressing distress rather than discrete negative emotions. Judges were presented with videotape segments that included a 4- to 9-week-old infant's facial, vocal, and body behaviors. During each segment, the baby displayed the MAX-specified expression of either discomfort/pain, anger, or sadness. Results showed that distress was rated higher than the other negative emotions irrespective of the baby's facial expression (which was clearly visible but occupied only 6–15% of the video screen).

In response to Oster et al.'s (1992) and Camras et al.'s (1993) findings, Izard et al. (1995) revisited the issue of observer judgments by conducting an additional set of forced-choice recognition studies. Again he and his colleagues presented context-free stimulus photographs of infants under 10 months of age showing MAX-specified emotional expressions. However, nondiscrete emotion labels (including distress) were now included as response alternatives in some experimental conditions. In addition, they corrected the coding for several pictures used in previous studies (considering these now to be emotion blends). In one procedure (Study 3), the investigators again found that the predicted emotion was chosen significantly more often than expected by chance (12.5%) for all of the MAX-specified negative emotional expressions. However, as before, levels of recognition "accuracy" were not high; the predicted emotion was chosen by over 60% of judges for only three of the eight negative emotion stimulus slides. Distress was also chosen significantly more often than expected by chance for four of the eight negative infant slides. In a subsequent procedure (Study 4), Izard et al. included "distress," "pain," "frustration," and "pride" as response alternatives. Once more, the predicted emotion was selected significantly more often than expected by chance (9%) for all expression stimuli, but "accuracy" rates for the negative expressions were still relatively low. In this case, the predicted emotion was chosen by over 60% of judges for only one of the 11 negative slides. At the same time, distress was chosen more often than the predicted emotion for only two of the negative stimulus expressions.

Taken together, the results of these judgment studies suggest that observers identify the MAX-specified expressions as predicted with above-chance frequency when they are presented in isolation. However, recognition rates are unimpressive for the negative emotions. Consequently, the social validity evidence for interpreting these facial configurations as expressions of discrete emotions is not strong. At the same time, the evidence that judges interpret the negative expressions as expressions of distress when they are presented in isolation also is not impressive. Instead, observers may be uncertain as to the interpretation of these expressions when they are presented with no additional cues. However, the Camras et al. (1993) study suggests that when some of these negative expressions (i.e., pain, anger, sadness) are viewed in conjunction with the infant's body actions and vocalizations, then observers may indeed tend to interpret the entire constellation of behavior as an expression of distress rather than a discrete negative emotion. One intriguing (and plausible) possibility is that if given additional cues about the social context, observers would use this information to make a more specific interpretation of the infant's emotional experience. Nonetheless, such findings could not serve as social validity evidence for the invariant discrete emotion meaning of the infant's facial expressions.

Another interesting possibility is that expressions produced by older infants would be "recognized" as representing discrete emotions more often than those of younger infants. However, although formal analyses of age effects have not yet been conducted in the context of judgment studies, an informal inspection of relevant data (reported in Oster et al., 1992 and Izard et al., 1995) suggests that a significant relationship would not be found. Furthermore, such a relationship would actually argue against the innate concordance hypothesis by suggesting that recognition depends on infant age and not solely on the type of expression produced by the baby. Nonetheless, future research should address the question of age effects in the judgment of infant facial expressions.

Eliciting Circumstances

Covariance between infant expressions and emotion-appropriate incentive events has been considered an important source of evidence for the emotion meaning of the facial expressions (Izard, 1995, p. 34; Izard & Malatesta, 1987, pp. 517–518). According to Izard et al. (1995, p. 998), "the development of MAX was guided by observations of young infants in a variety of emotion-eliciting situations" and "several studies of infants have shown predictable relations between particular incentive events and specific expressions." For example, Izard and his colleagues (Izard, Hembree, Dougherty, & Spirrizi, 1983; Izard et al., 1987) found that 2- to 18-month-old infants showed MAX-specified expressions of physical discomfort and anger in response to painful inoculation. These findings are considered evidence for the principle of innate concordance.

At the same time, more comprehensive reviews of the literature conducted in the early 1990s also revealed several phenomena that are inconsistent with this principle (Camras, 1991; Camras et al., 1991). Three of these anomalous phenomena will be highlighted here. First, some infant facial expressions (both positive and negative) occur in situations in which the predicted emotion is not generally presumed to be present. For example, neonatal smiles have been linked to REM sleep states, a circumstance not typically associated with happiness (Emde & Koenig, 1969). Similarly, Camras (1992) observed her 4-week-old daughter produced MAX-specified surprise expressions when she appeared to be excited but not surprised (e.g., in response to attractive but very familiar stimuli). Camras also observed her daughter to show surprise expressions when bringing an object to her mouth for oral exploration, a finding later confirmed in a more systematic study of 5- to 7-month-old infants (Camras, Lambrecht, & Michel, 1996). Regarding the emotion of interest, Michel, Camras, and Sullivan (1992) demonstrated that infants' production of one variant of the MAX-specified interest expression (involving raised brows) depended on the infant's head and gaze position (i.e., looking up rather than down at an attractive stimulus). With respect to the negative emotions, MAX-specified expressions of physical discomfort/pain have been observed in situations during which physical discomfort/pain was unlikely to be experienced (e.g., cessation of a pleasant swinging motion [Camras, 1992], or face-to-face interaction with mother [Matias & Cohn, 1993]).

The second anomalous phenomenon involves researchers' failure to find MAX-specified emotional expressions in situations during which the corresponding emotion is widely believed to be present. For example, surprise and fear expressions are seldom seen in situations generally viewed as eliciting surprise or fear for infants well past the neonatal period (e.g., 10- to 12-month-old infants on the visual cliff or in expectancy violation procedures, see Camras et al., 2002; Camras et al., 2007; Hiatt, Campos, & Emde, 1979). At the same time, infants will sometimes show nonpredicted emotional expressions in these same situations (e.g., physical discomfort/pain expressions on the visual cliff).

The third anomalous phenomenon involves the observation that several configurations purported to express different discrete negative emotions often occur in close temporal proximity during bouts of crying by young infants. Thus, Camras (1992) observed that when her daughter was 4–9 weeks of age she often went through a cycle of MAX-specified expressions of pain, anger, and sadness as the intensity of her crying waxed and waned. Rather than reflecting discretely different emotions, these expressions appeared to correspond to the intensity of her distress. In a related proposal, Oster (1982, 2005) has suggested that some forms of the MAX-specified sadness expression reflect the infant's attempt to modulate distress or regulate crying. Interestingly, Darwin made a similar suggestion for some forms of adult expressions.

Reports of these anomalies produced an energetic response by proponents of differential emotions theory. For example, Izard and his colleagues have acknowledged that some fleeting facial expressions observed in the first two months of life may not be expressions of emotion but instead may reflect random CNS activity (Ackerman, Abe, & Izard, 1998; Izard & Abe, 2004). However, this would not be true for older infants. To explain researchers' failures to observe predictable expressive responses in some emotion situations (e.g., absence of fear expressions on the visual cliff), Izard (2004) has argued that the expressive impulse sometimes may be too weak to produce observable expressive behavior. Presumably this might result in the absence of the predicted facial expression—but not the production of other facial configurations (e.g., physical discomfort/pain expressions on the visual cliff). Proponents of DET also have emphasized that expression production may be regulated by older infants, children, and adults according to social and personal display rules that are acquired over the course of development. However, post-neonatal infants younger than approximately 1 year of age are presumed not to exert such voluntary control over their facial behavior (Izard, 1995). Lastly, Izard and his colleagues have highlighted the fact that there are individual differences in emotion responding. Therefore not all infants will experience (and thus express) the same emotion in any particular situation. In summary, despite the anomalous phenomena described above, proponents of differential emotions theory continue to maintain the principle of innate concordance.

Such debates highlight the scientific importance of establishing systematic criteria and procedures for using eliciting circumstances as evidence for the emotion status of infant facial expressions. Ironically, such criteria were proposed almost three decades ago by Hiatt et al. (1979). According to these scholars, demonstrating both intersituational specificity and intrasituational specificity would provide compelling evidence that particular configurations of facial movements are expressions of particular infant emotions. Intersituational specificity means that infants show different facial configurations in situations believed to evoke different emotions. For example, a facial configuration hypothesized to be a fear expression is shown more often in fear situations than in anger situations while a facial configuration hypothesized to be an anger expression is shown more often in anger than in fear situations. Intrasituational specificity means that within each situation, the target facial configuration is produced more often than expressions linked to other emotions. For example, the hypothesized "anger" expression would be produced more often than "fear" expressions in a situation that elicits primarily anger, while "fear" expressions would be produced more often than "anger" expressions in situations that elicit primarily fear.

Two features of the procedures for establishing intersituational and intrasituational specificity are worth noting. First, the procedures require investigating at least two emotional expressions simultaneously so that true specificity can be established. For example, if the hypothesized "anger" expression is produced most often in both anger- and fear-eliciting situations, then its status as a specific expression of anger would be questionable. In fact, to establish the unique emotion meaning of a facial configuration, comparing the target expression to the full range of other expressions is required, although this need not take place in a single study. Second, situational contexts that evoke the target emotions in most infants must be utilized. At the same time, it is not necessary (or even possible) to use situations that will elicit the target emotion in *all* infants. Because individual differences in emotion responding exist even for babies, demonstrating specificity requires showing relative rather than absolute differentiation.

In their own study, Hiatt et al. (1979) used the criteria of intersituational and intrasituational specificity to evaluate 10- to 12-month-old infants' facial responses in happiness, surprise, and fear situations. Because MAX was not available when the study was conducted, facial coding was based on Ekman and Friesen's (1975) descriptions of adult prototypic expressions. However, as indicated above, there is close correspondence between the MAX and FACS codings for these particular emotional expressions. Babies' nonfacial instrumental behaviors were scored to validate the overall effectiveness of the emotion-eliciting situations. The investigators' findings yielded evidence for both intersituational and intrasituational specificity for happiness, intrasituational but not intersituational specificity for surprise, and neither intrasituational nor intersituational specificity for fear expressions.

Surprisingly, only three subsequent investigations have utilized the criteria of intersituational and intrasituational specificity in attempting to validate the emotion status of infant facial expressions. Bennett, Bendersky, and Lewis (2002) used MAX to code 4-month-old infants' expressive responses in situations theoretically predicted (and widely utilized) to elicit happiness (tickling), surprise (jack-in-the-box), disgust (sour taste), anger (arm restraint), and fear (masked stranger). Replicating Hiatt et al. (1979), the investigators found both intersituational and intrasituational specificity for happiness expressions, intrasituational specificity but not intersituational specificity for surprise expressions, intersituational specificity but not intrasituational specificity for disgust expressions, and neither intersituational nor intrasituational specificity for anger or fear expressions. Of particular note, this study was the first to report a predominance of sadness expressions in an emotion-eliciting situation, but ironically the situation (sour taste) was predicted to evoke disgust rather than sadness. Surprise expressions were shown equally often in the surprise, anger, and fear situations, thus failing to demonstrate intersituational specificity. The number of babies showing fear expressions did not differ across the three negative emotion situations while the number of babies showing anger expressions in the anger and disgust situations also did not significantly differ, thus again failing to demonstrate intersituational specificity. In both the anger and fear situations, more babies showed anger expressions than fear expressions. Because the pattern of intrasituational specificity should be unique for each emotion (e.g., anger expressions most common in anger situations but not in fear situations), Bennett et al.'s (2002) study did not provide evidence for the discrete emotion status of the MAX-specified anger and fear expressions.

In a subsequent investigation, Bennett, Bendersky, and Lewis (2005) examined developmental changes in the infants' production of MAX-specified joy, disgust, anger, and fear expressions by comparing babies at 4 and 12 months of age. They reported that the number of babies producing happy, disgusted, and angry expressions in the appropriate eliciting situation increased with age while the number producing these expressions in other situations either decreased or remained the same. In contrast, specificity for the fear expression did not increase as infants grew older. However, data inspection suggested that few 12-month-old infants expressed any negative emotion in the fear situation (masked stranger). Therefore, examining a more powerful fear elicitor would be important.

Towards this end, Camras and her colleagues (Camras, Oster, Campos, & Bakeman, 2003; Camras et al., 2007) conducted a collaborative cross-cultural study of 11-month-old European-American, Japanese, and Chinese infants in situations designed to elicit anger, surprise, and fear. Intersituational and intrasituational specificity of the infants' facial behavior were examined in two procedures: arm restraint (designed to elicit anger/frustration) and presentation of a disembodied growling toy gorilla head (designed to elicit fear). Observer judgments of infants' nonfacial behavior as well as objective coding of their instrumental behavior confirmed that the intended emotions were differentially produced in the two situations. Facial behavior was coded using BabyFACS (an anatomically-based coding system; Oster, 2007) rather than MAX. However, combinations of BabyFACS codes corresponding to the MAX-specified expressions of anger and fear were examined in some analyses. Neither intersituational nor intrasituational specificity was found in this study. Instead, infants showed MAX anger-related patterns more often than MAX fear-related patterns in both the arm restraint and growling gorilla situation. In addition, when a larger set of BabyFAC-coded expressions was examined, a significant correlation ($r = .50$) was found between their rank orderings in the anger and the fear situations. Camras et al. (2007) interpreted these findings as indicating the MAX-specified anger and fear configurations expressed nonspecific negative affect (i.e., distress) rather than the discrete emotions of anger and fear in these 11-month-old infants. Also, although the babies clearly experienced anger and fear (as indicated by their nonfacial behaviors), they produced similar facial responses in the two different emotion situations.

While no other studies have further explored the situational specificity of anger versus fear expressions, Lewis and his colleagues have developed a uniquely creative variant of this approach to investigate anger versus sadness expressions. Using a contingency learning procedure in which infants can produce a desirable audiovisual stimulus by moving their arm, these investigators have compared expressive behavior produced by infants in several different conditions (e.g., contingency followed by extinction, partial contingency, or noncontingent stimulation). Their results have shown that 4- to 6-month-old infants who can control the desirable stimulus produce more positive and less negative expressive behavior than infants who are given equivalent exposure to the stimulus but are not able to control it with their arm movements (Sullivan & Lewis, 1989). However, the frequency of anger expressions exceeds the frequency of sadness expressions in all conditions (Sullivan & Lewis, 2003).

In summary, studies examining infants' expressive behavior in various eliciting circumstances suggest that MAX-specified positive and negative emotional expressions are differentially evoked by positive and negative emotional events in post-neonatal infants. However, research attempting to more specifically link different MAX-specified negative expressions to different negative emotional events has had mixed success. Summarizing across studies that have used the criteria of intersituational and intrasituational specificity, both standards have been met by 4-month-old infants only for happy expressions and by 12-month-old infants only for happy and disgust expressions. Thus these studies have provided little evidence that the MAX-specified negative emotional expressions reflect discrete negative emotions.

Nonfacial Emotion Responses

As indicated above, Izard and his colleagues have reported covariance between some MAX-specified infant facial expressions and nonfacial responses as evidence for the expressions' emotion meaning (e.g., decreased heart rate and MAX-specified interest expressions; Langsdorf, Izard, Rayias, & Hembree, 1983). However, other investigators (e.g., Saarni, Campos, Camras, & Witherington, 2006) have cited the principle of equipotentiality in cautioning against an exclusive reliance on this approach. According to this principle, individuals may employ different responses to achieve the same emotion-related outcome and thus covariance between pairs of specific responses might not always occur. Nevertheless, investigating facial and nonfacial covariance can provide important data relevant to our understanding of the relationship between infant facial expressions and infant emotion.

In their contingency learning procedure, Lewis and his colleagues (e.g., Lewis, Alessandri, & Sullivan, 1990; Sullivan & Lewis, 1988, 1989) also explored individual differences and covariance between infants' facial and nonfacial behaviors during the first year of life. For example, Lewis et al. (1990) found concordance between increased arm pulling and increased production of MAX-specified anger expressions by 2- to 8-month-old infants during the extinction phase of their procedure. However, in a subsequent experiment (Sullivan & Lewis, 2003), the researchers found an inverse relationship (i.e., a decrease in arm pulling and increase in MAX-specified anger expressions) when contingent learning was followed by loss of the contingency (i.e., losing control of stimulus presentation) rather than extinction (i.e., complete loss of exposure to the rewarding stimulus). Thus, covariance between facial and behavioral responding disappeared when arm pulling was discovered no longer to be functional in the emotion-evoking situation.

In addition to studying arm pulling, Lewis and his colleagues (Lewis & Ramsay, 2005; Lewis et al., 2006) have explored the relationship between facial expression and nonobservable physiological response measures (e.g., heart rate, respiratory sinus arrhythmia, cortisol). Most recently, Lewis et al. (2006) reported that MAX-specified anger expressions were associated with increased heart rate while MAX-specified sadness expressions were associated with increased cortisol responding when 4-month-olds experienced contingency learning followed by extinction. Their finding with regard to the MAX-specified sadness expression is particularly noteworthy because no previous study has identified a nonfacial response that correlates selectively and positively with sadness expressions but not anger expressions (e.g., see Camras et al., 1991; Weinberg & Tronick, 1994, for further discussion).

Lewis et al.'s (2006) findings provide indirect support for an interpretation of the MAX-specified sadness expression as indeed reflecting the emotion of sadness in the context of their experimental procedure. In the human adult and nonhuman animal literature, several researchers have proposed that cortisol response is a reaction to situations in which goal attainment is perceived as uncontrollable (see Dickerson & Kemeny, 2004). Many emotion researchers link sadness with the perception of goal unattainability or loss and this might well include loss of stimulus control (see Barrett & Campos, 1987; Ekman & Friesen, 1975; Lazarus, 1991). Thus, infants who perceived that they had lost control of the stimulus in Lewis et al.'s (2006) study (as possibly indicated by their increased cortisol) might be predicted to experience sadness, and thus the expression that they showed might be interpreted as an expression of this emotion. Although Lewis et al. failed to indicate whether cessation of arm movements (another indication of perceived loss of control) was also linked to cortisol response and sadness expressions, their conclusions may still be legitimate within the context of their investigation.

At the same time, other evidence suggests that the MAX-specified sadness expression may not invariably indicate sadness in all situations. As described earlier, two studies of infants during the first four months of life have found MAX-specified sadness expressions in situations that do not involve either uncontrollability or other forms of loss (e.g., Bennett et al., 2002—observation of sadness expressions in response to sour tastes; Camras, 1992—observations of sadness expressions during bouts of crying that occurred in a variety of negative situations). Correspondingly, while cortisol increase has been linked to uncontrollability in adults, it also is associated more broadly to social-evaluative threat (Dickerson & Kemeny, 2004). In fact, in the adult literature, the emotions of shame (Dickerson, Gruenewald, & Kemeny, 2004) and anxiety (Abelson, Young, & Khan, 2005) have been linked to cortisol responding rather than the emotion of sadness. These findings indicate that the relationship between MAX-specified sadness expressions and the discrete emotion of sadness may not be invariant as stipulated in differential emotions theory. Nonetheless, further developmental studies of both sadness and other emotions should focus on relationships between facial and nonfacial responses both within and across emotion-eliciting contexts.

An Alternative Perspective

As indicated in our review, research conducted in the past several decades has failed to provide convincing evidence to support the idea that the MAX-specified emotional expressions invariably index their proposed corresponding discrete emotion in infants. What type of model might more easily accommodate the body of research on infant facial expressions? In several earlier papers, Camras and her colleagues (1991, 1992; Camras & Fatani, 2008; Camras & Witherington, 2005) have proposed that a dynamic systems perspective on infant emotions might offer an alternative to current discrete emotion models of infant facial expression and emotional development (see also Fogel & Thelen, 1987). Herein, we take the opportunity to briefly review that proposal and elaborate on some aspects that relate particularly to developmental changes in the emotion meaning of infant facial expressions.

As indicated above, several investigators of infant emotional development (e.g., Camras, 1992; Camras et al., 1993, 2003, 2007; Oster, 2005; Oster et al., 1992; Sroufe, 1996) have suggested that some MAX-specified negative expressions may actually reflect a more general state of distress. This proposal originates in a seminal theory of infant emotions proposed by Bridges (1932) who described emotional development as proceeding via the related processes of differentiation and integration. According to Bridges, infant emotions originate in a state of diffuse excitement that first differentiates to generate delight and distress and then more distinct emotion states such as fear, anger, elation, and affection. Correspondingly, other researchers have found that young children's emotion categories also may be broad at first (e.g., distinguish only positive vs. negative emotion) and later become more differentiated during development (Widen & Russell, 2003, 2008). Consistent with these theories, we propose that the concept of differentiation may indeed describe developmental changes in the affective meaning of certain of the MAX-specified emotional facial expressions. For example, the MAX-specified surprise expression may originally represent an intense level of excitement but later become more specifically tied to the discrete emotion of surprise. Similarly the MAX-specified anger expression may originally represent a moderately intense level of general distress but later become more specifically tied to the discrete emotion of anger. During development, minor changes in morphology also may occur for some expressions (e.g., for anger) such that they now correspond more closely to the emotion prototypes described for adults. Because the relevant convincing data are sparse, we are reluctant to make specific proposals regarding the age at which such differentiation (i.e., the linking of expressions to discrete rather than generalized emotions) may take place. However, we note that the most relevant data (reviewed above under "Eliciting Circumstances") suggest that it has not yet occurred by 12 months for surprise, anger, and fear. In contrast, there is some evidence that the MAX-specified expression of disgust is selectively linked to its predicted emotion by the end of the first year (Bennett et al., 2005). The evidence with respect to sadness is more ambiguous. Thus, differentiation may occur at different ages for different emotions.

One important corollary of this proposal is the idea that the development of emotions themselves can be independent of the development of their corresponding prototypic facial expressions. For example, infants may demonstrate anger versus fear in their nonfacial behaviors before they show distinct negative facial expressions for these emotions (Camras et al., 2007).

It is also the case that the concept of affective differentiation alone may not be adequate to explain developmental changes in emotion meaning for all expressions. For example, infant smiles may originally reflect a purely nonemotion state (e.g., REM sleep; Emde & Koenig, 1969) rather than any form of positive emotion (Emde, 1980; Messinger & Fogel, 2007). Subsequently smiles may become associated with positive affect. Current evidence suggests that this occurs early, almost certainly by 4 months (Bennett et al., 2002) and most probably well before that age (e.g., during the second month when smiles are regularly observed under eliciting conditions that might plausibly be related to happiness; Messinger & Fogel, 2007; Wolff, 1987). In addition, smiles themselves may be "differentiated" with different variants (e.g., open-mouth vs. closed-mouth smiles) and reflect different forms of happiness or positive emotion (Messinger, 2002; Messinger & Fogel, 2007; Messinger, Fogel, & Dickson, 2001).

Bridges (1932) also proposed that the progressively differentiated elements of emotion become integrated into more specific (i.e., discrete) emotion systems over the course of development. We propose that dynamical systems approaches provide a framework within which we can understand this integration process. According to the dynamical systems perspective, emotions may be conceived of as "attractor states" (i.e., frequently observed organizations of emotion system components; Fogel & Thelen, 1987). A dynamical system will shift into an attractor state when some key component (i.e., termed a "control parameter") reaches a critical threshold. For example, as suggested by several scholars (e.g., Barrett, 2006; Holodynski & Friedlmeier, 2006), during the course of development, socializing agents may impose new organizational structures on infants' and children's emotion responding by promoting linkages between specific appraisals, emotion-related goals, and culturally-sanctioned means of achieving those goals, including the production of specific emotional facial expressions. Thus, discrete emotions might emerge in children's repertoire once these socialization efforts have taken effect. From a dynamic systems perspective, adult socialization strategies might serve as "control parameters" stimulating the reorganization of emotion systems during the course of development. However, while theoretically and intuitively plausible, this proposal remains to be systematically investigated in future research.

Dynamical systems attractors may exhibit considerable variability in their details because contextual factors play an important role in shaping any particular behavioral episode. Thus, according to this perspective, any specific emotion episode may or may not include a particular behavioral component (e.g., a prototypic facial expression). As a result, expressions may never come to be associated with emotion states in a unique one-to-one invariant relationship—even in adults. The dynamical systems perspective thus may make a unique contribution to describing emotional development by providing a single framework within which we can explain both variability among emotion episodes and changes in emotion organization across development.

Conclusion

This article has reviewed empirical evidence regarding the relationship between facial expression and emotion during infancy. We focused on differential emotions theory's view of this relationship because of its current theoretical and methodological prominence. We concluded that current evidence fails to support DET's proposal that the MAX-specified emotional expressions invariably reflect a corresponding discrete emotion in infants. Instead, the relationship between facial expression and emotion is variable and complex. Infant emotions may sometimes be accompanied by non-predicted facial expressions because such expressions have different meanings in infants as opposed to children and adults. In addition, nonemotion factors may sometimes engender "emotional" facial expressions. Thus, measuring emotions in infants requires more than recording only their facial expressions. A more desirable approach would be to incorporate facial expressions into a contextually-appropriate emotion measurement system that also includes other components of behavior.

Because the relationship between facial expression and emotion would appear to change during the course of development, we conclude by reiterating our proposal that the concepts of differentiation and integration can be used to describe this developmental progression. The process of differentiation may explain changes in the emotion meaning of some infant facial expressions while the dynamical systems perspective may explain the integration process through which facial expressions are combined with other elements of an emotion episode. More specifically, emotional expression may become differentiated in that some facial configurations take on more specific emotion meanings over the course of development, eventually serving to sometimes (but not always) indicate discrete emotions (e.g., anger, surprise) rather than general states of distress or excitement. At the same time, emotion components (including facial expressions) may become organized (i.e., integrated) into systems that sometimes represent discrete emotions. The dynamical systems perspective potentially can provide a framework for modeling more fully these developmental and organizational processes.

Several directions for future research can be identified that would provide additional evidence relevant to the proposals presented above. First, the differentiation hypothesis might be further investigated in studies involving older infants and children in a wide range of emotion-eliciting circumstances. These studies could determine whether greater intersituational and intrasituational specificity of facial expression develops at later ages. While some efforts have been made in this direction (e.g., Buss & Kiel, 2004), the expression coding systems used in this research have not been entirely appropriate. Second, the integration hypothesis presented above might be further investigated in studies of the relationship between facial and nonfacial emotion responses. Again, examining such relationships across a broad range of ages and in a broad range of eliciting contexts would be important. In addition, examination of adult behaviors that might promote such relationships (e.g., through reinforcement or modeling) might be included in these investigations. Such studies could provide evidence regarding factors (i.e., dynamical systems control variables) that produce associations between components of emotion systems at various points in development. Lastly, more comprehensive facial coding systems (e.g., BabyFACS and FACS rather than MAX) should be utilized in future studies. This would allow for the investigation of a wider range of expressive configurations across development, including the configurations identified for adults within Ekman and colleagues' (2002) FACS. Such an approach would enable us to determine whether facial expressions of any type come to be associated with emotion states in a unique one-to-one invariant relationship in either children or adults.

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