BRIEF REPORT

The Eyes Have It: Making Positive Expressions More Positive and Negative Expressions More Negative

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Facial expressions frequently involve multiple individual facial actions. How do facial actions combine to create emotionally meaningful expressions? Infants produce positive and negative facial expressions at a range of intensities. It may be that a given facial action can index the intensity of both positive (smiles) and negative (cry-face) expressions. Objective, automated measurements of facial action intensity were paired with continuous ratings of emotional valence to investigate this possibility. Degree of eye constriction (the Duchenne marker) and mouth opening were each uniquely associated with smile intensity and, independently, with cry-face intensity. In addition, degree of eye constriction and mouth opening were each unique predictors of emotion valence ratings. Eye constriction and mouth opening index the intensity of both positive and negative infant facial expressions, suggesting parsimony in the early communication of emotion.

Keywords: emotional expression, facial action, infancy, valence, intensity, joy, distress

What is the logic by which facial actions are combined to communicate emotional meaning? Infant facial expressions communicate a range of negative and positive emotion from subtle displeasure to distress and from mild amusement to extreme joy (Camras, 1992; Messinger, Fogel, & Dickson, 2001). Infants have historically provided a basis for understanding the origins of facial expression meaning (Camras, 2011; Darwin, 1877; Izard, 1997). We propose that a given facial action, such as the Duchenne marker, can index the emotional intensity of both positive and negative infant expressions. This proposal has roots in several theories of emotion and facial expression.

Core affect theory emphasizes the primacy of positive and negative emotional valence—a focus of the current report—but does not propose facial actions that index this dimension of emotion (Feldman-Barrett & Russell, 1998). Componential models of emotion posit that facial actions have an invariant meaning in multiple expressive configurations (Ortony & Turner, 1990; Scherer & Ellgring, 2007; Smith, 1989). These models have not, however, suggested that facial actions can index the intensity of both positive and negative affect. Discrete emotion theorists emphasize the role of eye constriction—the Duchenne marker—in indexing the positive intensity of smiles (Ekman, Davidson, & Friesen, 1990). These theorists have also noted the presence of eye constriction in negative expressions (Ekman, Friesen, & Hager, 2002; Izard, 1982), but have not spoken to the possibility that eye constriction can index the intensity of both types of expressions. We synthesize the logic of these theoretical models in our investigation of facial actions involved in prototypic infant positive and negative emotional expressions.

Smiles are the prototypical expression of positive emotion in infancy. Eye constriction—with associated raising of the cheeks—has a well-established role in indexing the joyfulness of adult (Ekman et al., 1990) and infant (Fox & Davidson, 1988) Duchenne smiles. Recent research suggests that during infant smiles, mouth opening is associated with eye constriction, and that both are indices of positive emotion (Fogel, Hsu, Shapiro, Nelson-Goens, & Secrist, 2006; Messinger, Mahoor, Chow, & Cohn, 2009).

Infants do not reliably produce discrete negative emotion expressions in specific eliciting contexts. Instead, the cry-face—combining elements of anger and distress—is the prototypical infant expression of negative emotion (Camras et al., 2007; Oster, 2003; Oster, Hegley, & Nagel, 1992). Cry-faces can involve a set of actions—including brow lowering, tight eyelid closing, and upper lip raising—not involved in smiles. Nevertheless, ratings of photographs suggest that cry-faces involving greater mouth opening and stronger eye constriction with associated cheek raising are

perceived as more affectively negative than cry-faces with lower levels of mouth opening and eye constriction (Bolzani-Dinehart et al., 2005; Messinger, 2002; Oster, 2003).

Despite recent research, little is known about the dynamics of infant smiles and cry-faces, and their association with emotional valence. Smile dynamics—continuous changes in the intensity of facial actions—and perceived emotional valence have been investigated only in a series of brief video clips (Messinger, Cassel, Acosta, Ambadar, & Cohn, 2008) and in the face-to-face interactions of two pilot infants (Messinger et al., 2009). More strikingly, there have been no detailed investigations of the dynamics of infant negative expressions. One obstacle to such research has been a lack of efficient methods for measuring the intensity of facial actions and their perceived emotional intensity (Messinger, et al., in press). The current study addresses this difficulty using innovative measurement approaches.

We employed objective (automated) measurements of the intensity of infant facial actions as they occurred dynamically in time. These objective measurements were complemented with continuous ratings of the perceived emotional intensity of the infants' facial expressions (Figure 1). This approach was used to test the hypothesis that eye constriction and mouth opening index the positive emotional intensity of smiles *and* the negative emotional intensity of cry-faces (Figure 2).

Method

Infants and Procedure

Twelve 6-month-olds and their parents (11 mothers, 1 father) were video-recorded in the Face-to-Face/Still-Face (FFSF) proce- dure (Adamson & Frick, 2003). The FFSF was used to elicit a range of negative and positive infant emotional expressions. It involved 3 min of naturalistic play with the parent, 2 min in which the parent became impassive and did not respond to the infant (an age-appropriate stressor), and 3 min of renewed play. The 6-month-olds (M = 6.20, SD = 0.43) were 66.7% male, and ethnically diverse (16.7% African American; 16.7% Asian Amer- ican, 33.3% Hispanic American, and 33.3% European American).

Manual Coding

The metric of facial measurement was intensity coding of Action Units (AUs) of the anatomically based Facial Action Coding System (FACS; Ekman et al., 2002). AUs were coded by FACS-certified coders trained in BabyFACS (Oster, 2003). Smiles were indexed by the action of zygomaticus major (AU12), which pulls the lip corners laterally and upward; cry-faces were indexed by the action of risorius (AU20), which pulls the lip corners laterally; and eye constriction was indexed by the action of orbicularis oculi, pars orbitalis (AU6), which draws the cheeks and skin around the temples toward the eyes. These AUs were coded as 0 (absent) 1, 2, 3, 4, or 5 (FACS intensities A to E, trace to maximal (Ekman et al., 2002). Mouth opening was indexed using a combination of the actions of depressor labii (AU25), masetter (AU26), and the pterygoids (AU27). This produced a scale from 0 (mouth closed), to lips parted (1), and captured the cumulative inten- sity of jaw dropping (2 – 6, AU26) and mouth stretching (7–11, AU27) based on the FACS A to E intensity metric (Messinger et al., 2009). The purpose of this manual coding was to train and test the automated measurement system.

Figure 1. The measurement approach. (A) Video is recorded at 30 fps. (B) Appearance and shape features of the face are distinguished and tracked using an Active Appearance and Shape Model (AAM). (C) Nonlinear mapping is used to reduce the appearance and shape features to a set of 12 data points per video frame. (D) A separate support vector machine (SVM) classifies the occurrence and intensity of each FACS Action Unit (AU). (E) This yields information on the presence and intensity of AUs 6, 12, and 20 in each video frame. (F) Raters' view video in real-time. (G) Raters use joysticks used to continuously rate the infant's affective valence. (H) Individual ratings (I) are combined to produce a mean rating of affective valence for each video frame.
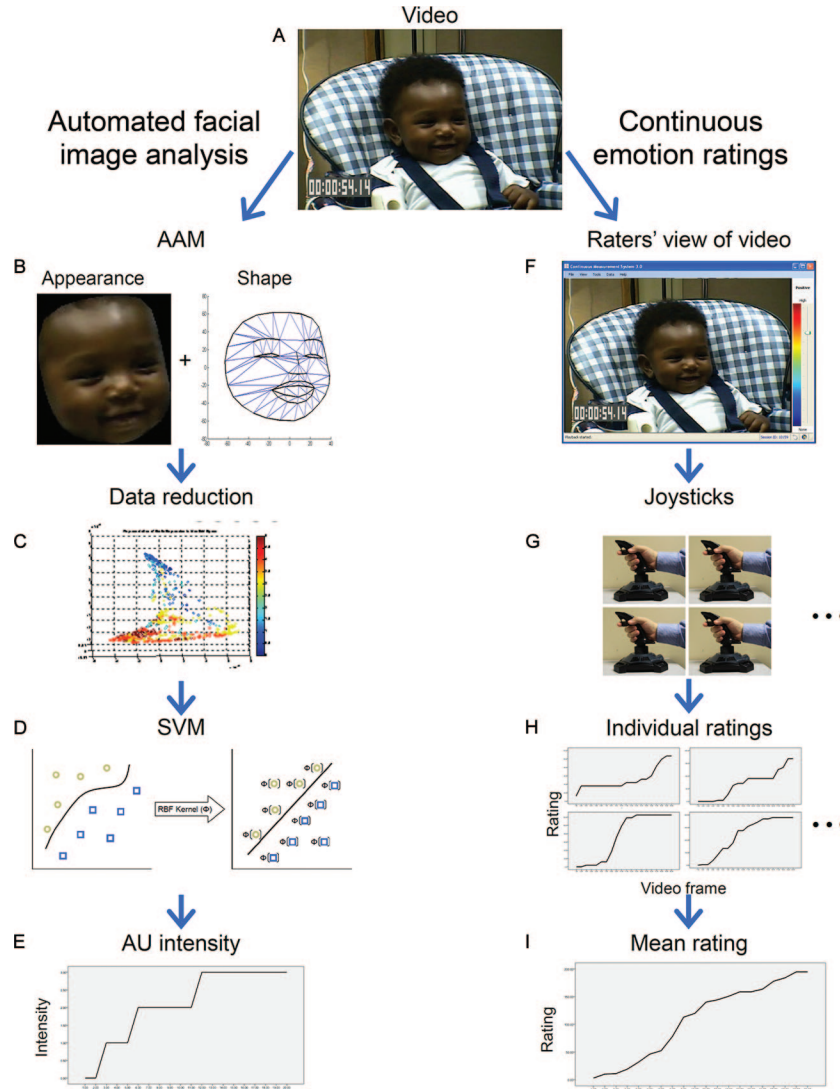
Figure 2. Varying intensities of smiles and cry-faces with co-occurring eye constriction and mouth opening.

Automated Face Modeling

Automated measurement begins with active appearance and shape modeling (Figure 1). Active appearance and shape models (AAMs) track the face over contiguous video frames and were trained on 2.75% of these frames. AAMs separately model shape and appearance features of the face (Baker, Matthews, & Schneider, 2004). Shape features of the face were represented as 66 (x, y) coordinates joined in a triangulated mesh. This constitutes a shape model which is normalized to control for rigid head motion. Appearance was represented as the grayscale values (from white to black) of each pixel in the normalized shape model. The large number of shape and appearance features was subject to nonlinear data reduction to produce a set of 29 variables per video frame that were used in facial action measurement (Belkin & Niyogi, 2003).

Automated Facial Action Overview

Separate support vector machine classifiers (SVMs) were used to measure smiles (AU12), cry-faces (AU20), and eye constriction

(AU6; Mahoor, Messinger, Cadavid, & Cohn, 2009). For each video frame, the designated SVM classifier indicated whether the AU in question was present and, if present, its intensity level. To make this assignment, a one-against-one classification strategy was used (each intensity level was pitted against each of the others) (Chang & Lin, 2001; Mahoor et al., 2009). We constrained the SVM classifiers to utilize only features from those areas of the face anatomically relevant to the AU being measured (Ekman et al., 2002; Oster, 2003).[1]

Automated Facial Action Measurement

The SVM classifiers were trained on manual FACS coding using a leave-one-out cross-validation procedure. Models were trained on data from 11 of the infants in the sample; measurements

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[1] SVM classifiers map the input (face) data into a multidimensional space, which is optimally separable into output categories (AU intensity classes; Cortes & Vapnik, 1995).

were then produced and reliability ascertained on the remaining infant. This was done sequentially for all infants in the sample. Mouth opening was measured directly as the mean vertical distance between three pairs of points on the upper and lower lips using the shape features of the AAM (Messinger et al., 2009). Intraclass correlations indicated high intersystem concordance (reliability) between automated measurements and manual coding of smiles (.83), cry-faces (.87), eye constriction (.82), and mouth opening (.83). The automated measurements of facial actions were used in all data analyses.

Student Raters and Perceived Emotional Valence

The continuous ratings of naive observers were used to measure the intensity of perceived emotional valence (Ruef & Levenson, 2007). Separate samples of 42 and 36 undergraduates rated positive ("joy, happiness, and pleasure") and negative emotional intensity ("anger, sadness, and distress"), respectively. The raters had a mean age of 19.6 years and were 52.6% female; they were African American (6.4%), Asian (2.6%), Hispanic (32.1%), White (51.3%), and biracial/other (7.7%). Using a joystick, they continuously rated emotional intensity on a color scale while viewing video of each infant in real time (Messinger et al., 2009). The positive and negative emotion rating scales ranged from none (-500) to high ($+500$). Mean positive emotion ratings and mean negative emotion ratings were calculated over raters for each frame of video. Mean ratings of positive and negative emotion were highly associated (mean $r = -.87$), motivating the creation of a combined measure of perceived emotional valence (the absolute value of the mean of the positive ratings and sign-reversed negative ratings). Cross-correlations of the valence ratings and automated measurements indicated an average rating lag of about 1 s (see Messinger et al., 2009), which we corrected for in statistical analyses.

Results

Overview

We used correlations to examine the association of eye constriction and mouth opening with smiles and with cry-faces. There were instances in which neither smiles nor cry-faces occurred (both AUs had zero values). These instances were randomly divided between the smile and cry-face data sets to maintain the independence of correlations involving smiles and correlations involving cry-faces. Next we used regression analyses to determine the role of eye constriction and mouth opening in predicting ratings of emotional valence. To ascertain the predictive role of eye constriction and mouth opening—beyond that of smiles and cry-faces—we calculated a variable that combined the intensity measurements of smiles and cry-faces. This combined cry-face/smile variable—the absolute value of the difference between the intensity of smiles and cry-faces—ranged from 0 (*neutral*) to 5 (*most intense smile or cry-face*). In all analyses, we computed correlations, partial correlations, and regression coefficients within infants and used t tests of the mean parameters to determine significance (Figure 3).

Smiles

Eye constriction intensity and degree of mouth opening were independently associated with smile intensity. Associations between these facial actions were strong. Mean correlations of smile intensity with eye constriction and mouth opening were .55 and .43, respectively (Figure 3A).

Cry-Faces

In separate analyses, eye constriction and mouth opening were independently associated with cry-face intensity. Associations between these facial actions were moderate to strong. Mean correlations of cry-face intensity with eye constriction and mouth opening were .48 and .29, respectively (Figure 3A).

Smiles and Cry-Faces

The previous analyses indicated that eye constriction and mouth opening exhibited unique associations with smiles and with cry-faces. Smiles and cry-faces are facial indices of positive and negative emotion, respectively. We next used all these facial actions to predict emotional valence.

Predicting Emotional Valence

The combined cry-face/smile variable, eye constriction, and mouth opening each uniquely predicted continuous ratings of emotional valence. The combined cry-face/smile variable indexed which of these two expressions was prevalent on the face. Eye constriction and mouth opening, then, predicted emotional valence irrespective of whether they were complementing a smile or cry-face expression (Figure 3B). Effects were moderate to very strong with a mean adjusted R^2 of .41.

Discussion

Since Darwin, researchers have attempted to understand how individual facial actions are combined to communicate emotional meaning (Camras, 2011; Darwin, 1877). The dearth of precise measurements of facial expressions in naturalistic conditions has made this task difficult. We addressed this problem by combining objective measurements of infant facial actions with continuous ratings of their emotional valence. We found that eye constriction and mouth opening index the positive emotional intensity of smiles and the negative emotional intensity of cry-faces.

One strand of research categorically distinguishes smiles between smiles that do and do not involve eye constriction in adults (Ekman et al., 1990) and infants (Fox & Davidson, 1988). Smiles involving eye constriction (Duchenne smiles) are thought to uniquely index joy (Duchenne, 1990/1862; Ekman, 1994; Ekman et al., 1990). The current results do not suggest this categorical distinction. Instead, objective measurements of intensity suggest that eye constriction—and mouth opening—rise and fall with the strength of smiling. Together these actions predicted the intensity of positive emotion in dynamically occurring expressions. These results extend previous work using more limited samples and measurement approaches (Fogel et al., 2006; Messinger & Fogel, 2007; Messinger et al., 2009; Oster, 2003). They suggest that the
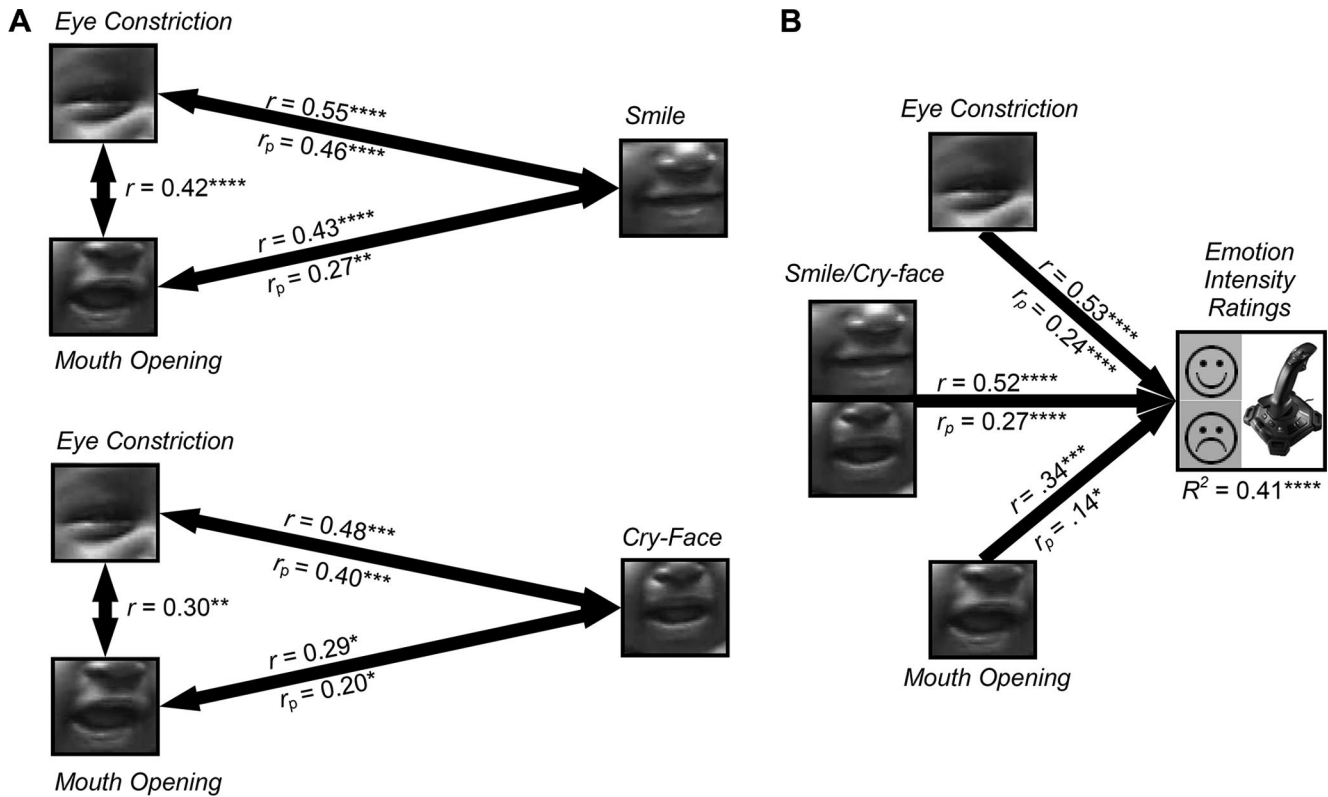
Figure 3. (A) Overall (*r*) and partial correlations (*r*_p) between the intensity of smiles, eye constriction, and mouth opening; and between the intensity of cry-faces, eye constriction, and mouth opening. Frames of video in which neither smiles nor cry-faces occurred (zero values) were randomly divided between the smile and cry-face correlation sets to maintain independence. (B) R^2, *r*, and *r*_p from regressing affective valence ratings on the intensity of smile/cry-faces, eye constriction, and mouth opening. All statistics represent mean values across infants. *p* values reflect two-tailed, one-sample *t* tests of those values: * $p < .05$. ** $p < .01$. *** $p < .001$. **** $p < .0001$.

intensity of multiple actions involved in early smiling index continuous changes in positive emotion.

Paralleling the smile results, degree of eye constriction and mouth opening were covarying indices of the intensity of negative emotion during infant cry-faces. These results stem from objective measurement and continuous ratings of naturalistic facial expressions. They extend previous findings involving ratings of static expressions (Bolzani-Dinehart et al., 2005; Messinger, 2002; Oster, 2003). The results indicate that the intensity of lateral lip stretching, eye constriction, and mouth opening are linked indices of negative affect.

Eye constriction and mouth opening were predictors of continuous ratings of infant positive and negative emotion. Moreover, the intensity of eye constriction and mouth opening were associated with the intensity of both smiles and cry-faces. This suggests the primary function of eye constriction and mouth opening was accentuating the emotional intensity of these expressions. We discuss the implications of this finding for discrete emotion theory and componential emotion theory below.

Discrete emotion theorists emphasize the role of eye constriction—the Duchenne marker—in indexing the positive intensity of smiles (Ekman et al., 1990). In coding manuals and guides, theorists (Ekman et al., 2002; Izard, 1982) have noted the presence of

variants of eye constriction in negative as well as in positive expressions. Nevertheless, to the degree that one emphasizes the *discrete* character of positive and negative emotion expressions, the current pattern of results is not easily explained (Ekman, 1992; Izard, 1997). In a rigidly discrete account, affect programs responsible for producing smiles and cry-faces are distinct and separate. Similarities between the expressions—including the common role of eye constriction and mouth opening—would be coincidental.

Componential emotion theories do suggest potential commonalities between facial expressions (Ortony & Turner, 1990; Scherer & Ellgring, 2007; Smith, 1989). The current results may reflect links between facial actions and specific appraisals. Mouth opening, for example, could conceivably index a surprise component in both smiles and cry-faces. Eye constriction might indicate protective wincing, potentially indicating a reaction to the intensity of the interactive conditions involved in both smiles and cry-faces (Fridlund, 1994; Scherer & Ellgring, 2007). Eye constriction provides a clear signal that one is reducing one's field of view during reactions to intense stimuli, but eye constriction alone does not actually close the eyes. Consequently, we speculate that eye constriction communicates a focus on internal state in both positive and negative emotional contexts. Mouth opening, by contrast, enables efficient respiration and affective vocalizing; in older children and

chimpanzees, it can enable playful or aggressive biting (Parr, Waller, Vick, & Bard, 2007). Mouth opening, we believe, communicates an aroused, excited state, be it positive or negative. It should be acknowledged, however, that the results do not support one of these interpretations over another. They simply indicate that certain facial actions have a general function of indexing and communicating both positive and negative affective intensity. This possibility is consonant with and appears to extend current formulations of componential emotion theory.

Infant smiles and cry-faces differ in many respects. Each, in fact, appears to be perceived as part of an emotional gestalt that dictates the perceived meaning of associated eye constriction and mouth opening (Figure 2). In both smiles and cry-faces, however, eye constriction and mouth opening can index emotional intensity in a continuous, but valence-independent fashion. Overall, then, human infants appear to utilize a parsimonious display system in which specific facial actions index the emotional intensity of both positive and negative facial expressions. Ekman has proposed the existence of families of related emotions (e.g., a family of joyful emotions) whose differences in intensity are expressed by related facial expressions (Ekman, 1993). In this integrative account, the infant smiles observed here may reflect a family of positive emotions related to joy, happiness, and pleasure; the cry-faces may reflect a family of infant negative emotion related to anger, sadness, and distress (Camras, 1992).

The current findings reflect associations between continuous ratings of emotional valence and automated measurements of facial action using the full FACS intensity metric in the well-characterized FFSF protocol. This focus on the production of infant facial expressions addresses the need for observational data on the occurrence of relatively unconstrained facial expressions in emotionally meaningful situations. There is evidence in the literature that smiling with eye constriction (Duchenne smiling)—and open-mouth smiling—index intense positive emotion among older children and adults, although less information is available on negative emotion expression (Cheyne, 1976; Ekman et al., 1990; Fogel et al., 2006; Fox & Davidson, 1988; Gervais & Wilson, 2005; Hess, Blairy, & Kleck, 1997; Johnson, Waugh, & Fredrickson, 2010; Keltner & Bonanno, 1997; Matsumoto, 1989; Oveis, Gruber, Keltner, Stamper, & Boyce, 2009; Schneider & Uzner, 1992). Intriguingly, adult actors—like the infants observed here—use eye constriction and mouth opening in portrayals of both strong positive (joy/happiness) and strong negative (despair) emotion (Scherer & Ellgring, 2007). We do not claim, however, that either eye constriction or mouth opening indexes the intensity of all emotion expressions throughout the life span; counterexamples abound. Instead, findings from infancy suggest early regularities in the expression of both negative and positive expressions whose relevance to adult expression awaits further investigation.

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