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Emerging Motivation: Modeling Early Interactive Emotional Development

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Abstract

Early infant emotional development concerns the interactive emergence of emotional states that may motivate approach and withdrawal in epigenetic systems. Different patterns of infant facial expressions, vocalization, and gazing emerge within dyadic interactions in the first 10 months of life. Concretely, the interface of a limited number of interactive parameters create complex real-time patterns which change over developmental time. I describe these phenomena using statistical simulations, continuous ratings, computer vision modeling, and old-fashioned observation, ponder their psychological meaning, and indicate how they are ripe for formal modeling.

1. Introduction

Developers of epigenetic systems confront the problem of motivation or value (Prince, in press). What makes a system inclined to engage in a particular action? Early infant emotional development concerns the interactive emergence of emotional states that may motivate epigenetic systems. A fundamental question to be addressed is: What does the baby want and how does this change with development (Vygotsky, 1978). We begin with an overview of infant emotional expression and then proceed to the question of emotional development in interaction.

2. Infant expressivity

Human infants are altricial in that they cannot locomote or feed themselves. However, their sensory and expressive systems are functional, though not mature, at birth. Before considering development, it is helpful to consider some general features of infant expressivity in social contexts in the first six months of life. These general features involve the centrality of infant facial expressions, and two parallels between negative and positive expressions.

2.1. The centrality of facial expressions

Using statistical simulations of behavior, we analyzed the temporal coordination of infant gazing (at and away from the parent's face) as well as infant facial expressions and vocalizations. The temporal patterning that emerged was substantively and conceptually striking. Substantively, infant facial expressions were central to the coordination of communication (see Figure 1). Gaze at parent's face set the stage for a facial expression that might itself be the context for a vocalization. In these data, there was no direct association of infant gazing and vocalizations (but see (Hsu, Fogel, & Messinger, 2001). Conceptually, then, multi-modal communicative acts were not pre-formed, but emerged through links between individual communicative modalities. This suggests that communicative signals can be modeled as dynamically assembling in real-time.

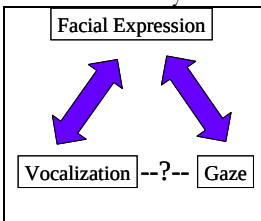

Figure 1.Infant facial expressions "tie" together vocalizations and gazing at the parent (Yale, Messinger, & Cobo-Lewis, 2003).

3. Positive and negative expressions

Facial expressions and vocalizations are two central expressive modalities for infants. The prototypical positive infant facial expression is the smile in which the zygomatic major pulls

the lip corners laterally upward. The prototypical negative expression is a cry-face, a frown or grimace in which the lip corners are pulled laterally, the mouth is typically open to some degree, and the brow is furrowed. (For modelers, it is noteworthy that while cry-faces are common, it is unclear whether discrete expressions of negative emotions such as fear and sadness can be reliably elicited from young infants.)We first consider some unexpected parallels between infant positive and negative emotional expressions, and then go on to consider the full range of affective engagement during interactions.

3.1. Facial expressions and vocalizations

The first parallel between positive and negative expressivity concerns the pairing of facial expressions and vocalizations. Although there is more variability than one might expect (Oller, 2000), neutral and positive vocalizations tend to occur with smiles; fusses and cries tend to occur with negative facial expressions. Our group has shown that the temporal coordination of facial expression and vocalization is relatively invariant (Yale et al., 2003; Yale, Messinger, Cobo-Lewis, Oller, & Eilers, 1999).. We used statistical simulations to analyze the patterning of individual actions in time. Infants tended to embed vocalizations in the course of both frowns and smiles as if to punctuate or call attention to these facial expressions (see Figure 2). The embedding pattern was stronger for frowns than for smiles but did not change with age, suggesting this is a basic feature of the expressive system.

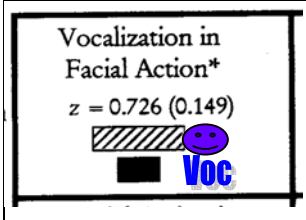

Figure 2. Vocalizations tend to be temporally embedded in smiles and cry-faces at levels greater than expected levels given the temporal features of the constituent vocalizations and facial expressions (Yale et al., 2003; Yale et al., 1999).

3.2. Positive and negative expressions

Infant positive and negative facial expressions have intrinsic parallel features which suggest possible economies in modeling. First, we examine qualitative and continuous affect interpretations of infant smiles, and then note parallels with infant negative expressions.

3.2.1. Qualitatively different smiles

Infants smile in different ways and these smiles may have different social functions (see Figure 3). The Duchenne or cheek raise smile – in which the eyes are constricted by the action of orbicularis oculi, pars lateralis – may be involved in reciprocating the smiles of others. Open mouth smiles tend to be especially associated with social situations producing arousal and excitement. Although these different types of smiles can be modeled as having qualitatively different meanings, there is also evidence that infant positive emotion is a single continuous dimension.

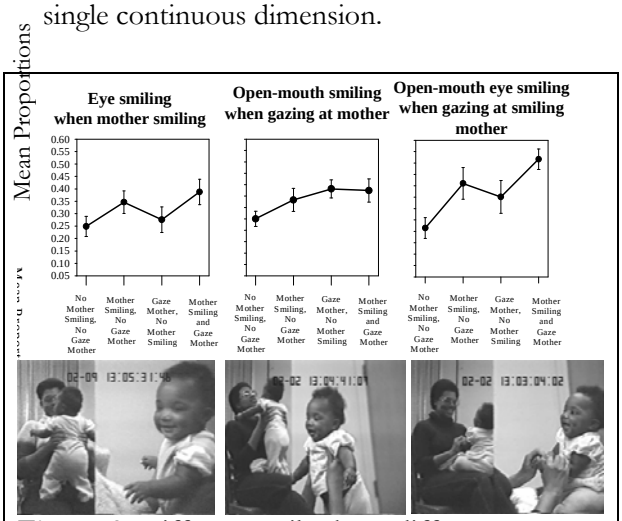

Figure 3. Different smiles have different functions. Smiling with eye constriction (left) occurs in association with parent smiling; smiling with mouth opening (middle) occurs when the infant gazes at the parent; open mouth smiling with eye constriction occurs when the infant is gazing at the smiling parent (DS. Messinger, Fogel, & Dickson, 2001).

3.2.2. Smiles and continuous affect.

Open mouth and eye constriction smiles tend to co-occur and each is associated with a pre-

eminently continuous dimension: the actual strength of the smile indexed by degree of lip movement. Computer vision techniques, in fact, suggest that infant smile strength, eye constriction, and mouth opening may all covary continuously in time. Each parameter is associated with adult perceptions of positive infant emotion, suggesting the utility of modeling infant positive emotion as a single dimension (see Figure 4).

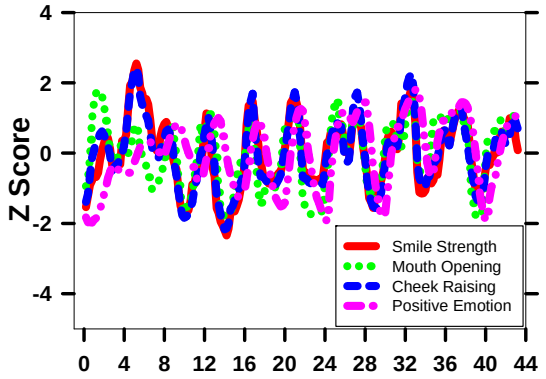

Figure 4. Computer vision measurements of infant smile strength, eye constriction (cheek raising), and mouth opening covary in time; each is associated with continuous ratings of positive emotion.

3.2.3. A positive - negative parallel

The second parallel between negative and positive expressions concerns the structure of the facial configurations (see Figure 5). Stronger eye constriction, mouth opening and lip movement make cry-faces appear more negative, just as they make smiles appear more positive (Bolzani-Dinehart et al., 2005; D. Messinger, 2002). Clearly, not all positive expressions and negative expressions exhibit this parallel structure. Nevertheless, for some classes of infant expressions, epigenetic modelers might construct simple base models of positive and negative expression. Ratcheting up the intensity of these expressions would involve adjusting the same parameters in the negative and positive expressions.

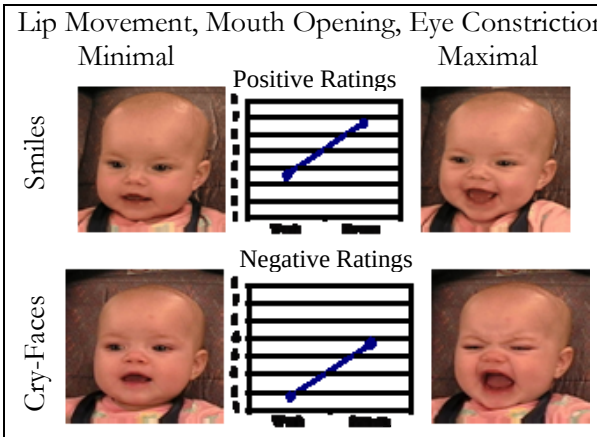

Figure 5. The presence of greater lip movement, mouth opening, and eye constriction is associated with greater ratings of positive emotion for smiles and greater ratings of negative emotion for cry-faces.

3.3. Smiles and arousal

Although smiles are signals of enjoyment, infants also use smiles to manage arousal. Infant heart rate is more rapid during smiling than during neutral expressions (Emde, Campos, Reich, & Gaensbauer, 1978) and infants tend to mouth their hands while smiling, as if dispelling tension. It may be, in fact, that infant smiles are a way to maintain informative but arousing face-to-face eye contact. At times, in fact, infants smile and indices of cry-face expressions can occur in close temporal proximity and even overlap. In these instances, the arousal regulation capacity of infant smiles may be overwhelmed, leading to a negative expression.

3.4. Negative through positive

The occasional proximity of smiling and fussing, and parallels between positive and negative emotion expressions, suggest the utility of continuous measurement and modeling of the affective spectrum (see also (Breazeal & Scassellati, 2000). We have carried out these measurements by asking non-experts to continuously rate negative-to-positive emotional valence using a joystick interface (see Figure 6). Using separate sets of ratings for infants and parents, we have used the technique

to explore mutual infant-parent responsivity during interaction. Another use of this technique is validation of human perceptions of epigenetic systems (e.g. in human-robot interactions). We now turn to the topic of emotional development in interaction.

Figure 6. Screenshot of Continuous Measurement System and joystick used to obtain expert or non-expert ratings of construct of interest (e.g., emotional valence) (available at http://psy.miami.edu/faculty/dmessinger/dv/).

4. Face-to-face interaction as context

We focus here on early face-to-face interaction as a context for modeling the development of infant positive emotion and the desire to engage between one and ten months (see Figure 7). In face-to-face interaction, the interface of a limited number of interactive parameters creates complex real-time patterns. In these interactions, infants can be conceptualized as having two major modalities of action: gaze (at or away from the parent's face) and smiling, which can be modeled dichotomously (smiling or not smiling) or continuously (intensity of smiling).

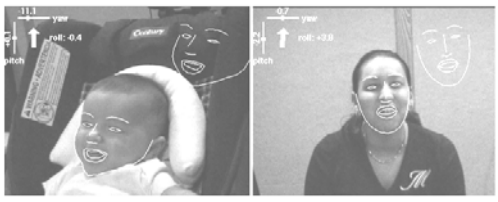

Figure 7. Four-month-old and mother engaged in face-to-face interaction. Using Automated Face Analysis (CMU, RI, complements of J. Cohn), each partner's face is outlined to measure rigid mother and smile-related parameters.

Infant expressive capacities occur in interaction and infant communicative abilities are sharply reduced during experimental perturbations in which parents are asked to not respond to their infants. Generally, parents are highly responsive to their infants while infant responsivity to the parent is more variable. How can the role of the parent – who I occasionally refer to as the mother - be conceptualized and modeled?

4.1. The parent's role

Infant–parent playful interaction is an open system in which the caregiver's expressive energy facilitates the emergence of complex dyadic patterns (Prepin, Simon, Mahé, Revel, & Nadel, 2006). Caregivers use stimulating actions in multiple modalities (e.g., variations in vocal intensity and pitch, variations in visual displays such as proximity and brow raising, and touching and tickling the infant with their hands) to maintain infant engagement. This continuous inflow of physical and emotional energy may be analogous to providing thermal energy to a chemical solution. Like a Benard cell (Prigogine & Stengers, 1984), the inflow of energy produces repeating, but not entirely predictable, dynamic expressive patterns.

From a modeling perspective, however, the parent may be conceptualized more simply as a smile-maximizer. Parents do calm and comfort their fussing infants, which can involve reducing their own level of stimulation. Nevertheless, parents typically smile at their infants whether or not the infant is smiling. They respond to infant smiles (and even infant gazes) with smiles of their own and rarely break off a smile once the infant is smiling. This does not mean parents always effective in eliciting infant smiling.

Parents smile more readily and frequently than infants. Between two and five months, parents' smiles are typically necessary but not sufficient to elicit infant smiling (Symons & Moran, 1994). An infant smile, by contrast, is typically sufficient but by no means necessary to elicit a parent smile as parents often smile in the absence of an infant smile (Cohn & Tronick, 1987; Kaye & Fogel, 1980). Parents typically

smiles in response to infants' smile onsets within a two second time interval (Van Egeren, Barratt, & Roach, 2001). These patterns change with development, however, a topic to which we now turn.

5. Positive emotional development: Gazing and smiling

The patterning of gazing and smiling changes over developmental time - and these changes seem to convey different psychological meanings. Developmentally, infants first come to smile while gazing at their parents' faces, then continue to smile while gazing away from their parents' faces, and, finally, smile and then gaze at their parents' faces in an apparently intentional pattern. We review this development sequentially using overlapping age categories to accommodate individual differences in development.

5.1. Gazing and smiling (1-2 months)

In the first month or two after birth, smiles tend to occur after the presentation of auditory (e.g. high pitched tones) and visual (e.g., static human faces) stimuli. These smiles are preceded by a period of cognitive tension indexed by brow furrowing, which relaxes and disappears as the infant smiles. The same pattern holds for social smiles - smiles while gazing at the parent's face – which develop between 4 and 8 weeks of age. In the second month of interaction, infants gaze at the parent's face, furrow their brows in concentrated attention to her face, and then relax their brows and smile at the parent (Lavelli & Fogel, 2005; Oster, 1978). These may be early mastery smiles - which are thought to index positive emotion following a successful cognitive or physical effort – which have clear implications for motivating epigenetic systems.

5.2. Gazing and smiling (2-3 months)

By two to three months of age, infants spend relatively long periods of time gazing at the parent's face. Infant gaze typically elicits a parent smile, which may then be followed by an infant smile. Three-month-olds tend to begin and end their smiles within the course of a gaze at the parent's face (Yale et al., 2003). Infant smiles, in turn, are likely to elicit parent smiles and parents typically do not cease smiling until the infant has stopped smiling. Early expressions of positive emotion are, then, dependent on ongoing visual contact with the often smiling parent. During this period, through repeated engagements, infants are likely to come to expect that their gazes will be greeted with smiles. But the degree to which these gazes are intentional is not clear; moreover, once infants begin to smile, the smile must run its course before infants gaze away.

5.3. Gazing and smiling (2-6 months)

In the period between two and six months, infant-parent interaction becomes more fast-paced, more contingent, and more affectively intense. The duration of infants' gazes at the parent's face, for example, become briefer. But at the same time infants become more discriminating. Infant time gazing at the parent when he or she is not smiling declines, but overall time gazing at the parent when the parent is smiling remains stable. In sum, time gazing away from the parent's face - at other features of the environment - replaces time gazing at the parent when he or she is being less expressive.

Between two and six months, infants spend increasing amount of time smiling and the duration of individual epochs of smiling increases (Malatesta, Culver, Tesman, & Shepard, 1989). Most types of smiling (see 3.2) rise rather indiscriminately during multiple periods of face-to-face interaction (DS. Messinger et al., 2001). However, more emotionally positive open-mouth smiling involving eye constriction shows a distinct developmental trajectory (see Figure 8). Infants become increasingly likely to engage in open-mouth smiling with eye constriction when they are gazing at their smiling mothers. They become increasingly less likely to engage in this smiling when they are not gazing at mother and mother is not smiling. Infants' increasing tendency to engage their smiling mothers with open-mouth smiling with eye constriction appears to reflect their growing capacity to

dynamically engage in intensely joyful interactions (see Figure 8).

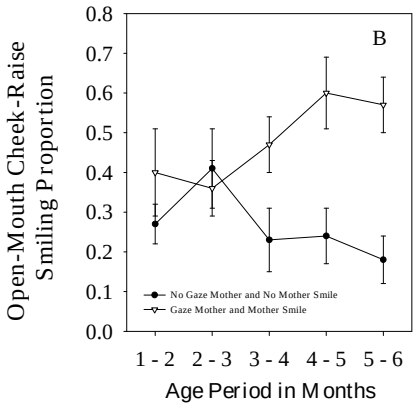

Figure 8. Combined open-mouth smiling with eye increases only in interactive constriction periods likely to elicit positive emotion (DS. Messinger et al., 2001).

Between two and six months of age, infants also become more likely to control their own positive emotion by gazing away from mother during the course of a smile. Such gaze shifts tend to occur during higher intensity smiles (Stifter & Moyer, 1991). That is, infants simultaneously become more actively positive during interactions and become more active at regulating the conditions when they will become positive engaged. This suggests a potential interdependency in the infant's emerging ability to upregulate and downregulate their positive emotional engagement during interaction.

Infants, then, simultaneously become increasingly likely to engage in highly positive emotional engagement with a partner and increasingly likely to temporarily disengage from the partner during highly positive states. Modeling this development raises questions about the underlying processes at work (Mirza, 2006). Perhaps infants' propensity to gaze away from the parent during intense smiles remains constant over development. In this case, increases in smile intensity alone might lead to increased instances of gazing away during smiles. Alternatively, the infant's capacity to disengage – to gaze away - may be a precondition to the development of intense smiling during engaging episodes of interaction.

By disengaging during the peak of smiling, infants may also punctuate their experience with the parent, delimiting peak states which may have a goal-like quality. The infant may seek to re-experience these states, or to intentionally share with others. Some have argued that positive emotion occurs when a goal is attained faster than anticipated (Carver, 2001, 2003). At that point, the individual turns, metaphorically or literally, to attend to other features of the environment including other potential goals. This may be relevant to infant's proclivity to gaze away from the parent's face during a smile. The infant's emerging predilection to gaze away from the parent's face during a smile may index his or her developing comprehension that an emotional climax has been reached: that, in the most primitive sense, a goal has been reached.

Although it may seem that infants have communicative goals during early interaction, there is no evidence that this is the case. One concrete sequence of events – smiling while gazing away from the parent's face and *then* gazing at the parent's face – might suggest that the infant wished to convey a pre-existing feeling to the parent. This sequence occurs *less* than expected by chance at six months of age. It is only at eight and nine months that infants engage in this sequence, initiating smiles even in the absence of a previous maternal smile (Cohn & Tronick, 1987). This greeting of the parent with a smile before being greeted signals the infant's increasingly active, positive participation in the interaction. Additional evidence that such sequences involve some degree of communicative intentionality involves interactions in a different context.

5.4. Gazing and smiling (8-10 months)

One context that elicits a range of smiling behaviors in infants of this age involves an adult who presents amusing wind-up toys. Anticipatory smiles occur when an infant smiles at the interesting toy and then turns to gaze at the tester while continuing to smile (see Figure

9). The smile, in this case, anticipates social contact with the adult. It seems to communicate something like, "that was funny, wasn't it?"

Anticipatory smiles rise between eight and ten months (Venezia, Messinger, Thorp, & Mundy, 2004). An infant's likelihood of engaging in anticipatory smiling is associated with the infant's more general ability to understand means–end relationships (Jones & Hong, 2001). This suggests that anticipatory smiles index infants' developing ability to understand and refer to the relationship of an adult and an object. When engaging in anticipatory smiles, infants appear to be coming to understand that they can communicate to the adult about the toy, which bespeaks some degree of communicative intentionality. Ultimate, the real-time process of smiling and then referencing an object to another suggests how positive emotion may motivate the development of early triadic communications.

Figure 9. Anticipatory smile. The infant gazes at an object (left), smiles at the object (middle), and gazes at the tester while continuing to smile (right) (Venezia et al., 2004).

Anticipatory Smiling may be intentional and appears to be motivated by a desire to share experience. Modeling the development of such behavior appears to be a formidable task. It is nevertheless instructive to consider its ontogeny. In infants, the relatively simple act of gazing away from the parent's face during a smile sets the stage for anticipatory smiling. In gazing away from the parent and toward other features of the environment, the infant for the first time creates a co-occurrence of smiling and looking at an object. This is a logical precondition for sharing positive emotion about an object.

6.0. Conclusion

General features of infant expression – the centrality of facial expressions and their temporal coordination with gazing and vocalizations – appear to be relatively easy candidates for implementation into modeled ontogenetic systems. The rich interplay between infant expression and that of a parent is a more challenging task, even when expressive actions are modeled as dichotomously present or absent. The ultimate test for such modeled systems is their ability to change the patterning of their expressive actions over interactive and development time. Yet it is precisely such modeling challenges that will provide a parsimonious view of infant interactive capabilities, and insight into how development occurs.

Acknowledgments

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