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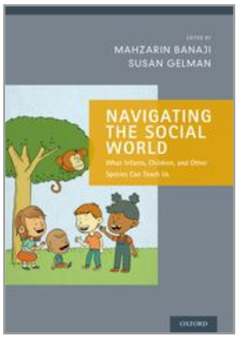

Navigating the Social World: What Infants, Children, and Other Species Can Teach Us
Mahzarin R. Banaji and Susan A. Gelman

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Early Social Deprivation and the Neurobiology of Interpreting Facial Expressions

Nim Tottenham

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Abstract and Keywords

Successful social interaction depends upon the ability to accurately process expressions from the faces of others. By adulthood, our ability to recognize social signals from the faces of others is a well-developed skill. Numerous studies have shown that this skill results from a developmental process. This chapter argues that this process relies on an early species-expected learning environment interacting with neurobiology involving the amygdala. It has been suggested that facial expressions are learned via principles of classical conditioning, and therefore, our understanding of the meaning of facial expressions in adulthood relies on associations that are formed throughout development. The chapter considers the nature of these associations in the context of both species-expected and species-unexpected early social environments (e.g., caregiver deprivation). Early social deprivation results in deviant facial expression processing because of two primary factors: deprived experience with human faces and atypical development of the neurobiology underlying facial expression processing, with particular emphasis on the amygdala. Children reared in deprived social environments are subject to both of these factors and should exhibit face expression processing behaviors that emerge in predictable, albeit atypical, ways.

Keywords: social cognition, facial expression processing, social environment, children, social deprivation, human faces, neurobiology, amygdala

Successful social interaction depends upon on our ability to accurately process expressions from the faces of others, and persons with lower face processing skills have reported lowered social competence than those with higher skill (Nowicki & Mitchell, 1998). By adulthood, our ability to recognize social signals from the faces of others is a well-developed skill. Numerous studies have demonstrated that this skill results from a developmental process, and the current chapter presents an argument that this process relies on an early species-expected learning environment interacting with neurobiology involving the amygdala. It has been suggested that facial expressions are learned via principles of classical conditioning (Davis & Whalen, 2001; Tottenham, Hare, & Casey, 2009), and therefore, our understanding of the meaning of facial expressions in adulthood relies on associations that are formed throughout development. In this chapter, we consider the nature of these associations in the context of both species-expected and species-unexpected early social environments (e.g., caregiver deprivation). We argue that early social deprivation results in deviant facial expression processing because of two primary factors: deprived experience with human faces and atypical development of the neurobiology underlying facial expression processing, with particular emphasis on the amygdala. Children reared in deprived social environments are subject to both of these factors and should exhibit face expression processing behaviors that emerge in predictable, albeit atypical, ways.

The ability to understand facial expressions develops in a robust manner in most individuals, and this development most likely results from an expected early social environment including a parent who provides not only important caregiving functions but also informative facial expressions. The development of face expression processing undergoes a protracted time course that begins with perceptual discrimination in infancy (e.g. Amso, Fitzgerald, Davidow, Gilhooly, & Tottenham, 2010) and extends at least until adolescence to include interpretation of those expressions (e.g., Gao, Maurer, & Nishimura. 2010; Herba, Landau, Russell, Ecker, & Phillips, 2006). This extended time course allows for ample opportunities to learn from a highly regular social environment. This association between typical experience with faces and expression processing ability is supported by the primacy with which happy faces are correctly identified during development and the high frequency with which happy faces are typically perceived (Somerville & Whalen, 2006).

Facial Expression Processing Following Early Deprivation

Highly deviant social environments have been shown to alter perceptual biases for emotional faces. For example, exposure to physically abusive caregivers results in expertise for threatening faces, such as angry faces (Pollak & Sinha, 2002). This behavioral effect is accompanied by differential brain electrical activity as measured by the P3b component in the event-related potential (ERP) measured at the scalp, suggesting an enhanced attentional bias when abused children view angry faces (Pollak, Klorman, Thatcher, & Cicchetti, 2001). This expertise seems rooted in their lowered threshold for identifying a face as angry. It has been argued that the high frequency with which physically abused children are exposed to hostility engenders expertise for angry faces (Pollak & Sinha, 2002). Whereas typical rearing results in expertise for happy faces (Gao & Maurer, 2010), abusive parenting increases expertise for angry faces. Parental neglect represents another deviation from typical (p.156) early environments, and children who experience neglect exhibit extremely poor face expression processing skills in that they do not show expertise for any expressions, presumably because of the profound face deprivation they experience. Thus, for three different populations of children—typical, physically abused, and neglected—face expression processing skills mirror the experiences that children have with face stimuli.

Children raised in institutional care experience extreme neglect, including social, maternal, physical, and sensory (Gunnar, Bruce, & Grotevant, 2000). If face expression perception relies on species-typical experiences, then we should expect that children reared in institutional care, where the caregiver to child ratio is devastatingly low, will exhibit significant difficulties. However, as will be discussed, these impairments seem to be associated, not with an inability to discriminate facial expressions from each other, but rather with a difficulty assigning appropriate emotional meaning to expressions. Based on visual discrimination tests (visual paired comparisons task), looking performance did not differ between infants (13–30 months old) raised in an institutional setting and typically raised controls (Nelson, Parker, & Guthrie, 2006). That is, infants were able to demonstrate visual discriminations for emotions, including happy, sad, fear, and neutral. It is unlikely that group differences in discrimination are “masked” in infancy and emerge at a later age, since when this sample was assessed at a later age (42 months old), the same result was obtained (Jeon, Moulson, Fox, Zeanah, & Nelson, 2010).

While previously institutionalized children do not show evidence of poor discrimination, there is an emerging body of evidence showing atypical interpretation of facial expressions. For example, 4-year-olds who had spent the first 2 years of life in institutional care were significantly impaired in choosing appropriate emotional expressions for puppets in several emotional conditions (Vorria et al., 2006). Similarly, 4-year-olds demonstrated worse performance compared to typically raised children when asked to choose an appropriate facial expression to match emotional vignettes; these deficits could have been caused by difficulties understanding vignettes, but subjects also showed difficulty providing appropriate verbal labels for visually presented expressions (Camras, Perlman, Wismer Fries, & Pollak, 2004; Wismer Fries & Pollak, 2004). It was suggested that these behavioral differences reflected a delay, rather than a deviation, in the development of facial expression processing since the previously institutionalized children had performed in a way characteristic of younger children (Wismer Fries & Pollak, 2004), that is, with highest accuracy for happy expressions and lowest for negatively valenced expressions. While as a group previously institutionalized children showed poor performance, accuracy was lower for children who had spent the longest periods in institutional care and improved the longer children lived with their postadoption families, providing a hint that the development of typical facial expression processing is contingent on amount of exposure to typical social environments. It may also be the case that this dose–response relationship reflects a sensitive period for facial expression learning, as has been the case for face identity processing (LeGrand, Mondloch, Maurer, & Brent, 2001). In a separate sample of previously institutionalized children, difficulty interpreting facial expressions continued to be observed into early adolescence. These group differences have been shown to persist in that 11-year-old, previously institutionalized children also showed lower expression recognition scores relative to same-aged peers (Colvert et al., 2008). When the children in all of these studies are adopted, they begin a life of relative enrichment, in which, by the time of testing, they have spent the majority of their lives. Therefore, the effects of early social deprivation on face expression processing seem long-lasting and resistant to recovery (at least without clinical intervention).

In addition to greater difficulty interpreting facial expressions, children with a history of early institutional care show evidence of a behavioral sensitivity to negatively valenced stimuli. During an emotional go/no-go task, where individuals are instructed to press a button in response to rapid presentations of certain expressions (e.g., neutral) and withhold pressing for other expressions (e.g., fear), group differences emerge in behavioral performance between children with a history of infant institutional care and a comparison group. The accuracy of previously institutionalized children was significantly impaired for negative facial expressions relative to the comparison group, and it was no different from the comparison group of children for positive expressions, such as happy (Tottenham et al., 2010). Additionally, there were effects of duration of institutionalization such that the older children were when they were adopted out of institutional care, the greater number of false alarm errors they made toward negatively (not positively) valenced stimuli. These results suggest that regulatory errors were more likely when children were presented with negatively (p.157) valenced faces. There was also evidence of a negativity bias in that as a group, previously institutionalized children slowed down reaction times when responding to neutral faces, a behavioral hallmark characteristic of threatening faces (Hare, Tottenham, Davidson, Glover, & Casey, 2005). This interpretation is based on inference and thus should be taken with caution, but it might suggest that previously institutionalized children have a tendency to assign negative valence to facial expressions, even when such emotion is absent from the expression. All of the behavioral data taken together are consistent with the hypothesis that a history of early social deprivation is followed by poor facial expression processing ability (in terms of appropriate interpretation of emotional meaning) combined with greater reactivity to negatively valenced expressions. That previously institutionalized children continue to exhibit difficulties with the emotional meaning of faces years after removal from deprived environments suggests that early deprivation exerts a significant influence on the neurobiology that supports interpretation of facial expressions.

The Human Amygdala and Facial Expressions

The amygdala is one of the key neural structures that support learning about the emotional value of perceived stimuli. Much animal work has established the amygdala's role in emotional learning—in particular, fear learning (see Davis & Whalen, 2001 for review). The amygdala acts to determine the species-specific relevance of various stimuli, including faces. In humans, the amygdala responds best for faces that represent danger to the animal. The typical adult amygdala responds robustly to faces expressing highly arousing emotions, like fear, relative to faces with neutral expressions (Davis & Whalen, 2001), and this activity seems to reflect the fact that facial expressions are conditioned stimuli that hold informational value to the perceiver. An increase in amygdala activity while learning about the affective value of faces (Petrovic, Kalisch, Pessiglione, Singer, & Dolan, 2008) and facial expressions (Kim et al., 2004) provides support for the notion that our understanding and interpretations of facial expressions rely on amygdala-based emotional learning.

Development of Amygdala Response to Facial Expressions

Amygdala response to emotional facial expressions undergoes dramatic change during childhood and adolescence. Activity in response to facial expressions increases during the transition from childhood to adolescence, reaching an activity peak during adolescence (Guyer et al., 2008; Hare et al., 2008). Not only is there a change in overall response to facial expressions across development, but the typical child amygdala reacts to facial expressions in sometimes contrasting ways from the adult amygdala. Whereas with the adult, fearful faces result in greater amygdala activity than neutral, children's amygdala response to neutral faces exceeds the response to fear faces (Lobaugh, Gibson, & Taylor, 2006; Thomas et al., 2001; Tottenham et al., 2010). This pattern of responding may reflect learned associations with facial expressions that children have (which may differ from adults), the greater associative ambiguity (Whalen, 1998) of neutral faces for children, or relative immaturity of the amygdala response in general.

Amygdala Development Following Early-Life Adversity

In contrast to the amygdala response of typically reared children, previously institutionalized children show an elevated amygdala response to fearful faces above neutral (Tottenham et al., 2011), much like the adult pattern. This result may be an indication that the amygdala, due to early-life adversity, has become prematurely activated by emotional stimuli (discussed in Tottenham, 2012). Numerous nonhuman animal studies have shown that early-life adversity prematurely activates and develops (e.g., myelination) the typically dormant juvenile amygdala via circulating stress hormones (e.g., glucocorticoids) that can pass the blood–brain barrier and bind to receptors within the amygdala (Moriceau, Roth, Okotoghaide, & Sullivan, 2004; Ono et al., 2008). That is, exposure to an atypically adverse postnatal environment promotes developmentally early engagement of the amygdala. As will be discussed, there is emerging structural and functional neuroimaging evidence to support the hypothesis that early-life adversity in humans is similarly followed by early and amplified amygdala development. Face expression processing in previously institutionalized children, therefore, likely occurs against the backdrop of early social deprivation and elevated amygdala activity.

The amygdala is a neural region involved in stress-regulatory processes that help the individual learn about the relative safety or danger in the environment. It is rich with stress hormone (p.158) receptors (e.g., glucocorticoid and CRH receptors) particularly early in life (Avishai-Eliner, Yi, & Baram, 1996), and thus it is a neural target for early-life adversity. Effects of early adversity have been quantified in two separate samples of children using volumetric magnetic resonance imaging (MRI) techniques. Institutional care that occurred in the early postnatal period was associated with enlarged amygdala volumes relative to total brain size (Mehta et al., 2009; Tottenham et al., 2010), and the degree of enlargement was associated with behavioral indices of anxiety and internalizing difficulties (Tottenham et al., 2010). This pattern of amygdala development may amplify response to stimuli with negative value, and it may in part explain heightened behavioral reactivity to negative expressions observed in previously institutionalized children. Indeed, within this sample, there was a trend for a negative association between amygdala enlargement and accuracy for negative expressions during the emotional go/no-go task.

In addition to amygdala structural growth, a history of early social deprivation increases the risk of atypical amygdala activity. Functional neuroimaging has shown that children with a history of early institutional care exhibit significantly greater amygdala response to fearful faces relative to children who had experienced typical early care (that is, within a family) (Tottenham et al., 2011). However, this group difference was specific to fear (and not neutral expressions), suggesting a degree of specificity in amygdala response to negatively valenced expressions. Moreover, regions of the cortex (e.g., inferior frontal and fusiform gyrus) that receive input from the amygdala tend to exhibit relatively little activity in previously institutionalized children in response to face presentations, possibly suggesting certain downstream effects of atypical amygdala development. In support of this assertion are the findings of reduced white matter integrity between the amygdala and cortex (Govindan, Behen, Helder, Makki, & Chugani, 2010). Low cortical recruitment for faces has been shown using ERP in infants and preschoolers living in Romanian orphanages who exhibit decreased cortical electrical activity in response to facial expressions (Moulson, Fox, Zeanah, & Nelson, 2009; Parker & Nelson 2005) (e.g., smaller N170, midlatency negative central component, and positive slow wave component, P400). Importantly, these studies with Romanian infants were able to address issues of causality; random assignment into more typical caregiving environments (i.e., professional foster care) attenuated group differences in the ERP signal, providing more conclusive evidence that early caregiver deprivation disrupted neural development associated with facial expression processing.

Amygdala hyperactivation to facial emotion has been associated with the social behavior of previously institutionalized children. Those children who exhibited the greatest amygdala signal change to fearful faces were more likely to be rated by parents as having the lowest social competence (Tottenham et al., 2011). Additionally, measures of eye contact were taken using two different procedures—a high-precision eye-tracking procedure and an ecologically valid dyadic social interaction. As a group, the previously institutionalized children displayed decreased eye contact during both of these procedures. Moreover, there was a negative association between amygdala reactivity and eye contact. Several studies have suggested that avoiding eye contact is a means of decreasing some of the overarousal associated with face-to-face contact (Pilkonis, 1977; van Reekum et al., 2007), even though this strategy can interfere with successful interpersonal communication. Children who utilize this strategy may experience additional face deprivation in that they miss future opportunities to learn about facial expressions and their appropriate meaning.

In summary, the behavioral evidence suggests that children with an early history of social deprivation (that is, in the form of institutional care) are at risk for difficulties in facial expression processing. The difficulty seems to lie, not in an inability to discriminate based on perceptual features alone, but in a heightened reactivity to negative expressions and in a difficulty assigning appropriate meaning to expressions. The limited, but growing, data suggest that this behavioral profile results from heightened, and possibly premature, amygdala reactivity to arousing stimuli and from limited exposure to facial stimuli early in life. Appropriate assignment of emotional meaning to facial expression, particularly negative expressions which are slowest to be learned under all developmental circumstances, seems to rely heavily on exposure to those expressions and their emotional contexts. Difficulty interpreting faces may place children with histories of social deprivation at risk for future interpersonal challenges, including attachment relationships with parents and intimate relationships with peers. (p.159)

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