Reading Faces in Infancy: Developing a Multi-Level Analysis of a Social Stimulus

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h1. 1. Introduction

The human face provides a wealth of socially relevant information. Healthy adults readily detect faces and decode all kinds of information from the face such as age, gender, familiarity, race, gaze direction, emotion, etc. The importance of these face-reading capacities for social communication cannot be underestimated; this becomes especially clear when certain face-processing functions are impaired as in certain neuropsychological conditions (e.g., prosopagnosia). Although neuropsychological and neuroimaging work have helped identify a distributed network of specialized brain areas involved in adults' face-processing (Haxby, Hoffman, & Gobbini, 2000), the more basic question remains, how do these adult abilities develop and what are their precursors? It is thus crucial to look at the earliest stage of face-processing: infancy. Therefore, the goal of this chapter is to review the accumulating work on the emergence of the face-processing system during infancy.

Before we turn to developmental work, let us consider a theoretical model of face-processing, based on the neuroanatomical nature of the visual system in which visual information is processed via two routes, a subcortical and a cortical route. With respect to the face as a visual stimulus, it has been proposed that the subcortical route functions in face detection and relies on low spatial frequencies, whereas the cortical pathway is involved in face identification, eye gaze perception, and emotional expression decoding, and relies on high spatial frequencies. Johnson (2005; Johnson & Morton, 1991) proposed that in newborns, the subcortical face-processing route functions to detect and orient neonates towards faces, and to activate relevant cortical areas that later become specialized in processing specific aspects of faces. Following Johnson's logic, we first review work on newborns' face biases, and then review work on infants' developing abilities related to recognition, eye gaze detection, and emotion decoding. Finally, we examine how infants apply these face-reading capacities in social situations. We will not discuss the neural bases

and correlates of face-processing in infancy because these have been reviewed elsewhere (Nelson, 2001).

h1. 2. The newborn's biases: Entering the world prepared for faces

One of the most debated questions in developmental psychology is whether newborns possess face-related preferences. In a series of experiments, Johnson, Dziurawiec, Ellis, and Morton (1991) showed that human newborns preferentially orient towards simple schematic face-like patterns as compared to control stimuli. Several studies have since been published supporting the notion that newborns are biased to attend to stimuli that possess certain characteristics of faces, a bias that is sufficient to elicit a preference for real faces in the natural environment (see Johnson, 2005). What stimulus characteristics are sufficient to elicit this bias? Based on earlier work, it was thought that a stimulus with three high-contrast blobs corresponding to the approximate location of the eyes and mouth might be enough to catch infants' attention. More recently, in some ingenious experiments by Farroni and colleagues (2005), this notion could be refined and extended. In these experiments, newborns were found to show a preference for both schematic and naturalistic upright faces only under positive (eye and mouth region dark, surrounding region lighter) but not under negative polarity (eye and mouth region light, surrounding region black). These findings are of particular interest because they rule out the recent proposal that newborns simply prefer up-down symmetrical patterns with more elements in the upper half (Turati, 2004), since this non-face-specific view would have predicted no effect of contrast polarity.

Another possible objection anticipated by Farroni and colleagues (2005) was that the absence of the effect in the reversed contrast polarity condition might have been due to the low luminance of the negative polarity images, which prevented infants from exploring the details of the stimuli. Based on the hypothesis that one of the functions of newborns' orientation bias is to detect and establish eye contact (see Farroni, Csibra, Simion, & Johnson, 2002), the authors predicted that placing dark "irises" within the white squares in the negative

polarity images would bring back the preference for upright faces. This prediction was supported. Furthermore, newborns were found to prefer human faces under natural lighting conditions (daylight or overhead illumination) as compared to bottom-lit faces. Note that a mechanism which is sensitive to overhead illumination could also explain the sensitivity to darker areas around the eyes and mouth.

There is thus compelling evidence for a face bias in newborns. What function might such a bias serve? Two accounts have been suggested (Farroni et al., 2005). One account stipulates that this bias in newborns allows detection of conspecifics in the environment, and that natural selection has thus sculpted a preference for invariant aspects of faces under natural lighting (top-lit). According to an alternative account, newborns' visual preferences have been selected for the function of detecting communicative partners. The latter is based on newborns' preferences for (1) upright faces and (2) eye-contact and mutual gaze in an upright face. To simply detect another human in the environment, a face in any orientation should be attended to, but only an upright face indicates a communicative partner because human face-to-face communication only takes this form; moreover, mutual gaze in an upright face serves as a further communicative signal. Importantly, these two functional accounts are not mutually exclusive (Farroni et al., 2005). This is because a mechanism that relies on darker elements on a lighter background might help the infant find a top-lit face in the distance or the periphery but could also support eye-contact detection at close proximity; however, this idea remains to be tested. All in all, a face bias provides newborns with rich, socially relevant information, and might help detect conspecifics and/or communicative partners. In the following sections, we focus on infants' developing abilities to extract information about identity, eye gaze, and emotional expression.

h1. 3. Developing face reading capacities

h2. 3.1. Face recognition: Who are you?

Face recognition is the ability to discriminate among different exemplars of the face category and to recognize familiar faces. This ability capitalizes on recognition memory and thus differs from face detection, i.e., the ability to discriminate faces from non-face visual objects. Evidence for early face recognition comes from work showing that just hours after birth, infants exhibit a preference for their mother's face (Bushnell, 1991). Pascalis and de Schonen (1994) demonstrated that after habituating to the photograph of an unfamiliar person and a retention interval of 2 minutes, newborn infants looked longer at a new face than at the face to which they had habituated. This suggests that newborns are capable of learning about individual faces. The question that arises is what information infants use in order to do so.

Pascalis, de Schonen, Morton, Deruelle, and Fabre-Grenet (1995) found that newborns' preference for their mother's face disappeared when the outer contour was masked and only the inner features of the face were visible. Infants thus seem to use outer contour features to identify their mother. This interpretation is consistent with findings on newborns' visual scanning of faces, which tends to be focused on high-contrast areas corresponding to the outer contour of the head or hairline (Maurer, 1983; Salapatek, 1968). Recent work shows that although both inner and outer features are sufficient cues, outer features do have an advantage over inner features in eliciting newborns' face recognition (Turati, Macchi Cassia, Simion, & Leo, 2006). Another interesting finding from this study was that inversion of the face stimuli disrupted recognition only when the inner part of the face was shown, indicating that newborns are not only sensitive to inner and outer features but also to the spatial relations of the local features (face-specific configuration). This finding might be related to the face detection biases for upright faces described in the previous section, and points to a possible interaction of face-detection and face-recognition processes.

An important next question concerns what role experience plays in the developing face-recognition system. Experience plays a critical role for the development of many perceptual and cognitive functions. For example, between 6 and 10 months, infants' ability to

discriminate between native speech sounds improves, whereas the ability to discriminate among foreign speech sounds declines due to a lack of exposure (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). Nelson (2001) suggests that the system underlying face-recognition might be similarly sculpted by experience, and predicts that early in life, infants can discriminate among several different faces and have a broadly defined face prototype. With experience, infants' face-processing becomes more attuned and restricted to faces they are most familiar with (i.e., a more precise face prototype). Indeed, Pascalis and colleagues (2002) showed that although adults and 6- and 9-month-old infants were equally good at discriminating human faces, only the youngest infants could also discriminate monkey faces.

Further evidence for a perceptual narrowing in face-processing comes from the "other-race effect," i.e. the finding that adults find it easier to discriminate faces from their own ethnic group (Sangrioli & de Schonen, 2004). However, this narrowing can be countered with experience. Thus, 6-month-olds exposed regularly to monkey faces for 3 months and then tested at 9 months could discriminate monkey faces (Pascalis et al., 2005). Similarly, Korean adults who had been adopted by French families when they were 3-9 years old performed as well as French natives in a Caucasian faces discrimination task (Sangrioli, Pallier, Argenti, Ventureyra, & de Schonen, 2005), whereas Koreans who had moved to France as adults showed the other-race effect. Together, these findings highlight the importance of experience in the development of face expertise.

h2. 3.2. Eye gaze perception: What are you looking at?

The detection and monitoring of eye gaze direction is essential for effective social learning and communication among humans (Bloom, 2000; Csibra & Gergely, 2006). Eye gaze informs us about the target of others' attention and expression, and conveys information about communicative intentions and future behavior (Baron-Cohen, 1995). Sensitivity to eye contact is evident early in human ontogeny. From birth, infants prefer to look at faces with their eyes open (Batki, Baron-Cohen, Weelwright, Connellan, & Ahluwalia, 2000), and faces

that engage them in mutual as compared to averted gaze (Farroni et al., 2002).

Averted gaze may trigger a reflexive shift of an observer's visual attention (e.g., Driver et al., 1999). Numerous studies have investigated the effects that perceived gaze direction has on adults' spatial attention (e.g., Friesen & Kingstone, 1998; Langton & Bruce, 1999). The robust finding is that observers are faster to detect a target stimulus occurring in the peripheral visual field if it is preceded by a face looking in the direction of the stimulus rather than in the opposite direction. Newborns are also faster in making saccades to peripheral targets cued by the direction of eye movements of a schematic face, suggesting a rudimentary form of gaze-following (Farroni, Pividori, Simion, Massaccesi, & Johnson, 2004), and 3-month-olds are more likely to orient towards a target if it is preceded by a perceived gaze shift towards the target when photographic images of a face are used (Hood, Willen, & Driver, 1998). Although infants, in contrast to adults, need to see eye-movements to show this effect, motion alone is insufficient to shift infants' attention as gaze shifts in an inverted face do not elicit gaze-following (Farroni, Mansfield, Lai, & Johnson, 2003). Moreover, to find this effect in infants, the face has to be removed before the target object is presented, a finding that may be linked to young infants' difficulty in disengaging from attractive stimuli (Johnson, 1990).

The youngest age at which infants follow the gaze of live partners is between 2 and 3 months (D'Entremont, Hains, & Muir, 1997). Again, the gaze-following response requires special triggering conditions, including constant infant-directed speech and target objects that are close to the presenter's face. By about 6 months, infants follow gaze to more distant targets (Butterworth & Itakura, 2000; Butterworth & Jarrett, 1991), and gaze-following to a single target becomes reliable between 7 and 9 months (Flom & Pick, 2005). However, the precision of 9-month-olds' responses is still fragile when several potential targets are available (Flom, Deák, Phill, & Pick, 2004) because infants around this age usually gaze at the first object on the correct side (Morales, Mundy, & Rojas, 1998). Furthermore, 9-month-

olds follow the head turn of someone whose eyes are closed, whereas only a month later they do not (Brooks & Meltzoff, 2005). Only by 12 months do infants encode the psychological relationship between a person and the target of her gaze (Woodward, 2003). However, until 14 months, infants follow blindfolded people's head turns (Brooks & Meltzoff, 2002). At this age, infants start to take into account whether the other has visual access to the target object (Dunphy-Lelii & Wellman, 2004) and correctly integrate information from head and eye direction (Caron, Keil, Dayton, & Butler, 2002).

Gaze-following is a critical social skill. It helps coordinate visual attention and thereby achieve joint attention with conspecifics (Tomasello, 1999). More specifically, it has been hypothesized to serve various functions, including (a) instrumental learning or obtaining rewards by directing sight to something interesting (Moore & Corkum, 1994), (b) identifying others' attentional or perceptual states (Baron-Cohen, 1991), and (c) finding out what the other person is communicating about (Csibra, submitted).

h2. 3.3 Emotion detection: How do you feel?

Discriminating and recognizing facial expressions permits detection of another's emotional state and provides cues about how to respond. *Discrimination* means the ability to perceive the difference between two or more stimuli (de Haan & Nelson, 1998). Expressions can be discriminated solely by detecting feature differences between them, such as the different shape and configuration of the mouth or eyes. *Recognition* implies more than discrimination; it involves understanding the 'meaning' of the emotional expressions (Oster, 1981; Bornstein & Arterberry, 2003). Nonetheless, to assign meaning to expressions, infants need to discriminate them, making discrimination integral to recognition.

There is evidence that even newborns may discriminate between facial expressions (Field, Woodson, Greenberg, & Cohen, 1982). In this study, newborns were tested with happy, sad, or surprised facial expressions presented by a live female model. One expression was posed repeatedly until infants looked at it for less than 2 seconds, after which the other

two expressions were presented. Field and colleagues found that infants' looking time increased when the expression changed, suggesting that newborns could discriminate among the expressions (but see Kaitz, Meschulach-Sarfaty, Auerbach, & Eidelman, 1988). More rigorous studies suggest that certainly by 3 months, infants can discriminate happy from surprised and from angry faces (see Nelson, 2001), and can also discriminate different intensities of a happy expression (Kuckuck, Vibbert, & Bornstein, 1986). By 4 months, infants look longer at happy than angry or neutral expressions (LaBarbera, Izard, Vietze, & Parisi, 1976), and discriminate mild from intense examples of fearful faces (Nelson & Ludemann, 1986). Six-month-olds reliably discriminate varying intensities of happy and angry facial expressions (Striano, Brennan, & Vanman, 2002). Note, however, that order effects have been observed. For example, 7-month-olds in a habituation procedure can discriminate happy from fearful faces if they are habituated to happy but not if they are habituated to fearful faces (Nelson, Morse, & Leavitt, 1979). Overall, infants do discriminate among several facial expressions.

These studies do not indicate, however, whether infants' responses generalize beyond the model tested, nor whether infants discriminate based on local feature information (e.g. raised vs. lowered eyebrows) or respond to the invariant configuration of facial features that constitute an emotional expression. For a facial expression to be useful in communication, infants need to understand that the expression conveys the same 'meaning' across individuals and remains the same despite changes in intensity. Researchers have thus assessed infants' abilities to categorize facial expressions. In one such study, Nelson et al. (1979) familiarized 7-month-old infants to happy expressions posed by two females. In the test phase, infants were shown a third model posing a happy and a fearful expression. Infants looked longer at the fearful expression, indicating that despite the change in identity, they detected that the happy expression belonged to the same category whereas the fearful did not. However, infants did not show categorization abilities when they were first familiarized to the fearful

expression. These findings have since been replicated and extended (Kotsoni, de Haan, & Johnson, 2001; Ludemann & Nelson, 1988). Thus, perhaps infants can categorize a very familiar expression (e.g., happy) and then discriminate it from a novel expression, whereas a novel expression (e.g., fearful) is more difficult to categorize.

Kestenbaum and Nelson (1990) also found that 7-month-olds recognized the similarity of happy faces over changing identities and discriminated this expression from fear and anger when the facial stimuli were presented upright, but not when they were inverted. In a second experiment, Kestenbaum and Nelson showed that, regardless of orientation, 7-month-old infants were able to discriminate between happy, fear, and anger posed by a single model. It was thus suggested that *categorization* of emotional expressions might depend upon infants' ability to attend to affectively relevant information, which relies on configurational processing of the face and is thus disrupted by inversion. *Discrimination*, however, can be performed on feature information irrespective of stimulus orientation.

The results of the reviewed studies suggest that (1) although even newborns might react differentially to facial expressions, it is by 3 to 4 months that infants can reliably discriminate among at least some expressions, and (2) infants can form categories of happy expressions by 5 months, although the ability to form categories of less familiar expressions might not develop until after 7 months.

We have identified three levels of information (identity, gaze, and emotion) that infants become sophisticated at gleaning from the face during the first year. In everyday interactions, these generally occur together and are thus best processed in an integrated fashion. We thus now consider when infants begin to integrate these levels of facial information. To do so, we examine infants' use of others' facial information to guide their own actions and to predict others' actions.

h1. 4. Using others as informants: A case for multi-level integration

Social referencing is a communicative process whereby infants use others' interpretations of ambiguous situations to form their own interpretations of those situations and to thereby learn about their environment (Campos & Stenberg, 1981). Social referencing thus aids our basic survival and permits the successful transmission of culture (Tomasello, 1999). In a typical social referencing study, infants are presented with a novel stimulus about which an adult delivers emotional cues. If infants engage in social referencing, they should modify their behavior according to the cues provided. This phenomenon can occur via multiple modalities, but we focus here on the facial modality.

What minimum abilities are needed to social reference using facial cues? One obvious candidate is emotion reading: infants must discriminate and identify the emotion in order to use it appropriately. Additionally, infants must understand the referential nature of the cues, which, in the context of facial cues, means they must follow the adult's gaze to the stimulus. Critically, infants must integrate these pieces of information. Research suggests that infants display such integration by 12 months; younger infants respond only to the emotional information. Thus, Walden and Baxter (1989) found that although 6-12-month-olds showed differential looking to their parents' positive versus fearful facial expressions, they did not appropriately regulate their behavior towards ambiguous toys, whereas infants older than 12 months did (see also Mumme, DiCorcia, & Wedig, submitted). In Sorce, Emde, Campos, and Klinnert's (1985) study, most 12-month-olds on the shallow side of a visual cliff crossed the cliff if mothers expressed interest or joy, but few crossed if mothers expressed fear or anger (see also Camras & Sachs, 1991; Klinnert, 1984).

Emotional and referential cues can also be integrated to draw inferences and make predictions about the signaler, i.e., about her stance and actions towards the stimulus. In one recent study (Phillips, Wellman, & Spelke, 2002), 12-month-olds were habituated and 14-month-olds familiarized to an experimenter (E) looking at and positively emoting about object A. Infants then saw two kinds of test events: *consistent* events entailed E looking at and

positively emoting about another object (B), and then holding B, whereas *inconsistent* events involved E looking at and positively emoting about A, but then holding B. Fourteen- but not 12-month-olds looked longer at the inconsistent than the consistent test events, which was interpreted as suggesting that by 14 months, infants combine a person's gaze direction and emotional expression to predict her action (see also Sodian & Thoermer, 2004). However, it is unclear whether infants used both gaze and positive emotion cues, since using gaze cues alone would have led to the same prediction as using both cues.

Vaish and Woodward (unpublished manuscript) addressed this problem by using negative emotions, which predict that the emoter will *not* reach for the object she has attended to. They familiarized 14-month-olds to an experimenter (E) looking into a cup and emoting happily or disgustedly while ignoring another cup. Test events involved E reaching into either the cup she had emoted about (Attended) or the other cup (Unattended). If infants understand emotions as action predictors, they should look longer at Unattended events in the happy condition but at Attended events in the disgust condition. However, infants in both emotion conditions looked longer at Unattended events, suggesting that they used attention but not emotion cues to predict E's actions[i]. Thus, by 14 months, infants may not yet integrate gaze and emotional cues to predict others' actions, and might instead use only gaze cues to do so.

Can infants integrate identity with gaze and emotion cues? When social referencing, infants need to identify trustworthy and knowledgeable sources of information (Baldwin & Moses, 1996). Typically, since caregivers are familiar, trusted, and knowledgeable, infants need only identify caregivers (which we have seen they can do early in the first year), and use cues provided by them. What if familiarity and knowledge are found in different individuals? Extant work addressing this issue provides mixed results. Zarbatany and Lamb (1985) placed 12-month-olds in a room with either their mother or a stranger. Infants then saw a novel stimulus about which they received positive or fearful facial cues from the adult. Infants in the 'mother' condition looked as much at mothers as infants in the 'stranger' condition looked at

the stranger, but only infants in the ‘mother’ condition regulated their behavior towards the stimulus. This suggests that infants note the informant’s identity and only modify their behavior in response to cues from the familiar and trusted informant. However, infants in the ‘stranger’ condition might have been so stressed by the mother’s absence that they were unable to use the stranger’s signals (Klinnert, Emde, Butterfield, & Campos, 1986).

To counter this problem, Klinnert et al. (1986) had 12-13-month-olds play with an experimenter (E) while mothers sat some distance behind the infants. When a novel toy appeared, E displayed happy or fearful facial expressions. The results contrasted with Zarbatany and Lamb’s (1985): infants referenced E first and more than the mother, and although most infants looked to their mothers (who were neutral) before acting, infant behavior was nevertheless influenced by E’s cues. Thus, infants do not blindly use signals from a familiar person; rather, when an unfamiliar adult has more information than the familiar one (as in this case because mothers were farther away and thus less aware of the ambiguous situation than was E), infants do effectively use information from the more knowledgeable adult. Of course, in most situations, familiar persons are knowledgeable and are the only informants; only in situations in which familiarity and knowledge are found in two different people do infants need to pick knowledge over familiarity. Given the mixed findings, there is clearly need for more work assessing whether infants can do so.

Recent research (Gergely, Egyed, & Király, 2007) investigated whether infants can integrate identity, gaze, and emotional information to predict others’ actions, but revealed that 14-month-olds cannot. This finding is not surprising given that 14-month-olds may not even predict others’ actions by integrating gaze and emotion cues (Vaish & Woodward). Thus, although 12-month-olds can effectively combine a signaler’s facial cues to modify their *own* behaviors towards target stimuli, even 14-month-olds may not yet integrate these cues to appropriately predict the *signaler’s* behavior.

h1. 5. Conclusions

This chapter was designed to review and integrate the accumulating work on early face-processing skills. We have shown that despite major developments in face-processing abilities during the first year and beyond, there is also immense continuity. Infants come into the world prepared to attend to socially engaging faces and possess rudimentary capacities for face-identification, gaze-following, and emotion-processing. These skills quickly become sophisticated, and by the end of the first year, are ready to be integrated. One capacity that emerges from such integration is social referencing, which, at a minimum, consists of the abilities to use emotional and referential information, but is in fact larger than the sum of these parts as it allows infants to engage in an activity that is crucial for survival and enculturation (Tomasello, 1999). Twelve-month-olds use others' gaze, emotion, and, arguably, identity cues to modify their own behavior, but even 14-month-olds seem unable to construe others' behavior in terms of these cues. Thus, there is a significant difference in the way 12-14-month-olds use their face-processing skills for themselves versus to understand others, and the ability to construe others' actions in terms of these cues seems to still be developing in the second year.

Finally, it should be pointed out that infants live in a multimodal world in which most cues are provided not only by faces but also by voices, touch, and so on. Indeed, the face may not always be the most potent communicative modality. In particular, infants seem to respond to vocal cues from earlier on and more effectively than to the facial modality (e.g., Mastropieri & Turkewitz, 1999; Vaish & Striano, 2004). It is thus important to consider how voice-processing develops in infancy, and more generally, to not only examine how the dimensions of face-processing are integrated but also how processing of the face is integrated with that of other modalities during development.

References

Baldwin, D. A., & Moses, L. M. (1996). The ontogeny of social information gathering. *Child Development, 67,* 1915-1939.

Baron-Cohen, S. (1991). Precursors to a theory of mind: Understanding attention in others. In Whiten, A. (ed.), *Natural theories of mind: Evolution, development and simulation of everyday mindreading*. Oxford, England: Blackwell.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA : MIT Press.

Batki, A., Baron-Cohen, S., Wheelwright, S., Connellan, J., & Ahluwalia, J. (2000). Is there an innate gaze module? Evidence from human neonates. *Infant Behavior & Development, 23,* 223-229.

Bloom, P. (2000). *How children learn the meaning s of words*. Cambridge, MA : MIT Press.

Bornstein, M. H., & Arterberry, M. E. (2003). Recognition, discrimination and categorization of smiling by 5-month-old infants. *Developmental Science, 6,* 585-599.

Brooks, R., & Meltzoff, A. N. (2002). The importance of eyes: How infants interpret adult looking behavior. *Developmental Science, 38,* 958-966.

Brooks, R., & Meltzoff, A. N. (2005). The development of gaze following and its relation to language. *Developmental Science, 8,* 535-543.

Bushnell, I. W. R. (1991). Mother's face recognition in newborn infants: learning and memory. *Infant and Child Development, 10,* 67-74.

Butterworth, G., & Itakura, S. (2000). How the eyes, head and hand serve definite reference. *British Journal of Developmental Psychology, 18,* 25-50.

Butterworth, G., & Jarrett, N. (1991). What minds have in common is space: Spatial mechanisms serving joint visual attention in infancy. *British Journal of Developmental Psychology, 9,* 55-72.

Camras, L. A., & Sachs, V. B. (1991). Social referencing and caretaker expressive behavior in a day care setting. *Infant Behavior and Development, 14*, 27-36.

Caron, A. J., Keil, A. J., Dayton, M., & Butler, S. C. (2002). Comprehension of the referential intent of looking and pointing between 12 and 15 months. *Journal of Cognition and Development, 3*, 445-464.

Csibra, G. (submitted). Why human infants follow gaze: A communicative-referential account.

Csibra, G. & Gergely, G. (2006). Social learning and social cogniton: The case for pedagogy. In Y. Munakata & M. H. Johnson (Eds.), *Processes of Change in Brain and Cognitive Development. Attention and Performance XXI* (pp. 249-274). Oxford: Oxford University Press.

de Haan, M., & Nelson, C. A. (1998). Discrimination and categorization of facial expressions of emotion during infancy. In A. Slator (ed.), *Perceptual Development* (pp. 287-309). Hove: Psychology Press.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition, 6*, 509-540.

Dunphy-Lelii, S., & Wellman, H. M. (2004). Infants' understanding of occlusion of others' line of sight: Implications for an emerging theory of mind. *European Journal of Developmental Psychology, 1*, 49-66.

Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. Proceedings of National Academy of Science (USA), 99, 9602-9605.

Farroni, T., Johnson, M. H., Menon, E., Zulian, L., Faraguna, D., & Csibra, G. (2005). Newborn's preference for face-relevant stimuli: Effects of contrast polarity. *Proceedings of the National Academy of Sciences USA, 102*, 17245-17250.

Farroni, T., Mansfield, E.M., Lai, C. and Johnson, M.H. (2003). Infants perceiving and acting on the eyes: Tests of an evolutionary hypothesis. *Journal of Experimental Child*

Psychology, 85, 199-212.

Farroni, T, Pividori D., Simion F., Massaccesi, S., & Johnson M. H. (2004). Eye gaze cueing of attention in newborns. *Infancy, 5*, 39-60.

Field, T. M., Woodson, R. W., Greenberg, R., & Cohen, C. (1982) Discrimination and imitation of facial expressions by neonates. *Science, 218,* 179-181.

Flom, R. & Pick, A.D. (2005). Experimenter affective expression and gaze following in 7-month-olds. *Infancy, 7,* 207-218.

Flom, R., Deák, G. O., Phill, C. G., & Pick, A. D. (2004). Nine-month-olds' shared visual attention as a function of gesture and object location. *Infant Behavior & Development, 27,* 181-194.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze.*Psychonomic Bulletin & Review, 5*, 490-495.

D'Entremont, B., Hains, S. M. J., & Muir, D. W. (1997). A demonstration of gaze following in 3- to 6-month-olds. *Infant Behavior & Development, 20,* 569-572.

Gergely, G., Egyed, K., & Király, I. (2007). On pedagogy. *Developmental Science, 10,* 139-146.

Haxby, J. V., Hoffman, E., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences, 4,* 223-233.

Hood, B. M., Willen, J. D., & Driver, J. (1998). Adults eyes trigger shifts of visual attention in human infants. *Psychological Science, 9*, 131-134.

Johnson, M. H. (2000). Cortical maturation and the development of visual attention in infancy. *Journal of Cognitive Neuroscience, 2,* 81-95.

Johnson, M. H. (2005). Subcortical face processing. *Nature Reviews Neuroscience, 6,* 766-774.

Johnson, M. H., Dziurawiec, S., Ellis, H. D., & Morton, J. (1991). Newborns' preferential tracking of face-like stimuli and ist subsequent decline. *Cognition, 40,* 1-19.

Johnson, M. H., & Morton, J. (1991). *Biology and cognitive development: The case for face recognition.* Blackwell: Oxford, UK.

Langton, S. R. H., & Bruce, V. (1999). Reflexive social orienting. *Visual Cognition, 6,* 541-567.

Kaitz, M., Meschulach-Sarfaty, O., Auerbach, J., & Eidelman, A. (1988). A reexamination of newborns' ability to imitate facial expressions. *Developmental Psychology, 24,* 3-7.

Kestenbaum, R., & Nelson, C. A. (1990). The recognition and categorization of upright and inverted emotional expressions by 7-month-old infants. *Infant Behavior & Development, 13,* 497-511.

Klinnert, M. D. (1984). The regulation of infant behavior by maternal facial expression. *Infant Behavior & Development, 7,* 447-465.

Klinnert, M. D., Emde, R. N., Butterfield, P., & Campos, J. J. (1986). Social referencing: The infants' use of emotional signals from a friendly adult with mother present. *Developmental Psychology, 22,* 427-432.

Kotsoni, E., de Haan, M., & Johnson, M. H. (2001). Categorical perception of facial expressions by 7-month-old infants. *Perception, 30,* 1115-1125.

Kuckuck, A., Vibbert, M., & Bornstein, M. H. (1986). The perception of smiling and its experiential correlates in 3-month-olds. *Child Development, 57,* 1054-1061.

Kuhl, P. K., Williams, K. A., Lacerda, F., & Stevens, K. N. (1992). Linguistic experience alters phonetic perception in infants by 6 months of age. *Science, 255,* 606-608

LaBarbera, J. D., Izard, C. E., Vietze, P., & Parisi, S. A. (1976). Four- and six-month-old infants' visual responses to joy, anger, and neutral expressions. *Child Development, 47,* 533-538.

Ludemann, P. M., & Nelson, C. A. (1988). The categorical representation of facial expressions by 7-month-old infants. *Developmental Psychology, 24,* 492-501.

Mastropieri, D., & Turkewitz, G. (1999). Prenatal experience and neonatal responsiveness to vocal expressions of emotion. *Developmental Psychobiology, 35,* 204-214.

Maurer, D. (1983). The scanning of compound figures by young infants. *Journal of Experimental Child Psychology, 35,* 437-448.

Moore, C., & Corkum, V. (1994). Social understanding at the end of the first year of life. *Developmental Review, 14,* 349-372.

Morales, M., Mundy, P., & Rojas, J. (1998). Following the direction of gaze and language development in 6-month-olds. *Infant Behavior & Development, 21,* 373-377.

Mumme, D. L., DiCorcia, J. A., & Wedig, M. M. (submitted). Limitations in 10-month-old infants' emotional processing abilities.

Nelson, C. A. (2001). The development and neural bases of face recognition. *Infant and Child Development, 10,* 3-18.

Nelson, C. A., & Ludemann, P. M. (1986). *The discrimination of intensity changes of emotion by 4- and 7-month-old infants*. Paper presented at the Midwest Psychological Association, Chicago.

Nelson, C. A., Morse, P. A., & Leavitt, L. A. (1979). Recognition of facial expressions by 7-month-old infants. *Child Development, 50,* 1239-1242.

Oster, H. (1981). "Recognition" of emotional expression in infancy. In M. E. Lamb & L. R. Sherrod (eds.), *Infant social cognition: Empirical and theoretical considerations* (pp. 85-125). Hillsdale, NJ: Erlbaum.

Pascalis, O., & de Schonen, S. (1994). Recognition memory in 3- to 4-day-old human neonates. *Neuroreport, 8,* 1721-1724.

Pascalis, O., de Haan, M., & Nelson, C. A. (2002). Is face processing species-specific during the first year of life? *Science, 296,* 1321-1323.

Pascalis, O., de Schonen, S., Morton, J., Deruelle, C., Fabre-Grenet, M. (1995). Mother's face recognition by neonates: A replication and extension. *Infant Behavior and Development, 18,* 75-85.

Pascalis, O., Scott, L. S., Kelly, D. J., Shannon, R. W., Nicholson, E., Coleman, M., & Nelson, C. A. (2005). Plasticity of face processing in infancy. *Proceedings of the National Academy of Sciences USA, 102,* 5297-5300.

Phillips, A. T., Wellman, H. M., & Spelke, E. S. (2002). Infants' ability to connect gaze and emotional expression to intentional action. *Cognition, 85,* 53-78.

Salapatek, P. H. (1968). Visual scanning of geometric figures by the human newborn. *Journal of Comparative and Physiological Psychology, 66,* 247-248.

Sangrioli, S., & de Schonen, S. (2004). Recognition of own-race faces by three-month-old infants. *Journal of Child Psychology and Psychiatry, 45,* 1219-1227.

Sangrioli, S., Pallier, C., Argenti, A. M., Ventureyra, V. A. G., & de Schonen, S. (2005). Reversibility of the other-race effect in face recognition during childhood. *Psychological Science, 16,* 440-444.

Sodian, B., & Thoermer, C. (2004). Infants' understanding of looking, pointing, and reaching as cues to goal-directed action. *Journal of Cognition and Development, 5,* 289-316.

Sorce, J. F., Emde, R. N., Campos, J. J., & Klinnert, M. D. (1985). Maternal emotional signaling: Its effects on the visual cliff behavior of 1-year-olds. *Developmental Psychology, 21,* 195-200.

Striano, T., Brennan, P. A., & Vanman, E. (2002). Maternal depressive symptoms and 6-month-old infants' sensitivity to facial expressions. *Infancy, 3,* 115-126.

Tomasello, M. (1999). *The cultural origins of human cognition.* Harvard University Press.

Turati, C., Macchi Cassia, V., Simion, F., & Leo, I. (2006). Newborns' face recognition: Role of inner and outer facial features. *Child Development, 77,* 297-311.

Vaish, A., & Striano, T. (2004). Is visual reference necessary? Contributions of facial versus vocal cues in 12-month-olds' social referencing behaviour. *Developmental Science, 7,* 261-269.

Vaish, A., & Woodward, A. What will you do next? Infants' use of attention versus emotion cues as predictors of behavior. Unpublished manuscript.

Walden, T. A., & Baxter, A. (1989). The effect of context and age on social referencing. *Child Development, 60,* 1511-1518.

Woodward, A. (2003). Infants' developing understanding of the link between looker and object. *Developmental Science, 6,* 297-311.

Zarbatany, L., & Lamb, M. E. (1985). Social referencing as a function of information source: Mothers versus strangers. *Infant Behavior and Development, 8,* 25-33.

[i] Note that analyses revealed an order effect such that those infants who first saw the Unattended test event looked longer at Unattended than at Attended events, whereas those infants who first saw the Attended event did not look longer to either kind of event. Such order effects were also reported by Sodian and Thoermer (2004).