The role of early visual attention in social development

Jennifer B. Wagner, Rhiannon J. Luyster, Jung Yeon Yim, Helen Tager-Flusberg and Charles A. Nelson

International Journal of Behavioral Development 2013 37: 118
DOI: 10.1177/0165025412468064

ijbd

International Journal of Behavioral Development
37(2) 118–124

DOI: 10.1177/0165025412468064
ijbd.sagepub.com
SAGE

The role of early visual attention in social development

Jennifer B. Wagner[1], Rhiannon J. Luyster[1,2], Jung Yeon Yim[3], Helen Tager-Flusberg[4], and Charles A. Nelson[1]

Abstract

Faces convey important information about the social environment, and even very young infants are preferentially attentive to face-like over non-face stimuli. Eye-tracking studies have allowed researchers to examine which features of faces infants find most salient across development, and the present study examined scanning of familiar (i.e., mother) and unfamiliar (i.e., stranger) static faces at 6, 9, and 12 months of age. Infants showed a preference for scanning their mother's face as compared to a stranger's face, and displayed increased attention to the eye region as compared to the mouth region. Infants also showed patterns of decreased attention to eyes and increased attention to mouths between 6 and 12 months. Associations between visual attention at 6, 9, and 12 months and the Communication and Symbolic Behavior Scales DP (CSBS-DP) at 18 months were also examined, and a significant positive relation between attention to eyes at 6 months and the social subscale of the CSBS-DP at 18 months was found. This effect was driven by infants' attention to their mother's eyes. No relations between face scanning in 9- and 12-month-olds and social outcome at 18 months were found. The potential for using individual differences in early infant face processing to predict later social outcome is discussed.

Keywords

eye-tracking, face processing, infancy, social development

Introduction

Newborn infants enter the world with attentional biases towards faces, showing a predisposition to identify and focus on one of the most salient and informative stimuli in their new environment. It is widely believed that infants' preference for faces is one of the first indications of the emergence of a 'social brain', solidifying and further building a framework for social communication and language development throughout the lifespan (e.g., Grossman & Johnson, 2007; Leppänen & Nelson, 2009). Though the body of research addressing infant attention to faces is too large to review here, there are three themes that are critical for the current investigation that will be briefly discussed: (1) the role of face familiarity; (2) attention to different facial features; and (3) associations with later social communication development.

From shortly after birth, infants show a preference for faces and face-like patterns (e.g., Simion, Valenza, Umiltà, & Dalla Barba, 1998; Valenza, Simion, Cassia, & Umiltà, 1996). Sensitivity to faces increases over the ensuing weeks, and within the first months of life, infants are able to distinguish their mother's face from a stranger's face in behavioral tasks (Bushnell, Sai, & Mullin, 1989; Field, Cohen, Garcia, & Greenberg, 1984; Pascalis, deSchonen, Morton, Deruelle, & Fabre-Grenet, 1995), showing an emergent ability to discriminate familiar faces from unfamiliar ones. Beyond behavioral measures of discrimination, by 6 months of age, infants show differential patterns of brain activity in response to their mother's face in comparison to a stranger's face (de Haan & Nelson, 1997). With the exception of more recent work using ERPs, many of these studies are based on the paired-comparison paradigm introduced by Fantz (1964) and explore familiarity versus novelty preferences in infants. In general, infants seem to show familiarity preferences, thus looking longer at pictures of familiar faces than images of unfamiliar adults (Brooks-Gunn & Lewis, 1981; Pascalis & de Schonen, 1994; Pascalis et al., 1995). However, it is not clear whether there are developmental effects on performance in paired comparison tasks.

More detailed study of the nuances of early attention to faces has revealed that features—eyes and mouth, in particular, which are known to be important windows into social behavior—may differentially attract the interest of infants. Newborns are able to discriminate faces with open eyes from those with closed eyes, and they prefer to gaze at faces with visible eyes (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Farroni, Csibra, Simion, & Johnson, 2002). Infants' focus on facial features appears to undergo subtle shifts with development: Whereas 1-month-olds attend primarily to external features (e.g., hair or chin), by 2 months, infants direct their attention more towards internal features like eyes and mouth (Maurer & Salapatek, 1976). Three-month-olds are sensitive to cues delivered via eye gaze (Hood, Willen, & Driver, 1998), and neural measures of face processing indicate that 4- and 5-month-olds are sensitive to gaze direction (Farroni et al., 2002; Symons, Hains, & Muir, 1998).

Recent research has suggested that infant attention to faces may shift with their emergent pre-linguistic skills during the second half

[1] Harvard Medical School; Boston Children's Hospital, USA
[2] Emerson College, USA
[3] Biola University, USA
[4] Boston University, USA

Corresponding author:
Jennifer B. Wagner, Boston Children's Hospital/Harvard Medical School, Division of Developmental Medicine, Laboratories of Cognitive Neuroscience, 1 Autumn St., AU641, Boston, MA 02215-5365, USA.
Email: jen.wagner@alum.mit.edu

of the first year of life. Whereas younger infants will persist in attending to eyes even when they hear a face talking (Haith, Bergman, & Moore, 1977), 8–10-month-olds attend preferentially to the mouth region of a speaking face (Lewkowicz & Hansen-Tift, 2012). This process appears to be gradual, with attention to eyes slowly decreasing from approximately 4 months onward, while attention to mouths increases (Hunnius & Geuze, 2004; Lewkowicz & Hansen-Tift, 2012). This increased visual attention to mouths could provide support for understanding linguistic information over the first year of life, as faces convey a wealth of information. For example, work by Weikum and colleagues (Weikum et al., 2007) found that when 4- and 6-month-olds were presented with silent talking faces, the infants could discriminate between faces speaking two different languages using visual inspection alone.

Many theorists have suggested that these core facial features, most notably the eyes, are windows into human communication and social interaction (e.g., Bruce & Young, 1998; Itier & Batty, 2009), and there is considerable evidence for their importance in adult language and face processing (e.g., Bentin, Golland, Flevaris, Robertson, & Moscovitch, 2006; Lansing & McConkie, 1999). Growing evidence has found both concurrent and predictive relations between infant attention to eyes and mouth and later social and communicative abilities. In 9-month-olds, concurrent associations between attention to eyes and social abilities, as well as attention to mouths and receptive language abilities, have been reported, but prior reports have conflicted regarding the directionality of these associations (Key & Stone, 2012; Key, Stone, & Williams, 2009). Studies taking a prospective approach have allowed for more predictive power within the language domain, with findings that attention to mouths at 6 months positively predicted expressive language skills at 24 months (Young, Merin, Rogers, & Ozonoff, 2009), and 6-month-olds' ability to follow eye gaze was positively associated with their vocabulary at 18 months (Morales et al., 2000; Morales, Mundy, & Rojas, 1998). One study has also identified such patterns with later social communication abilities; Schietecatte, Roeyers, and Warreyn (2012) reported that greater attention to eyes in 6-month-olds was associated with better joint attention skills at 8 and 12 months.

While past work over the first year of life has uncovered preferences for familiar faces and shifts in attention to different facial features, no studies have addressed how attention to different features may interact with familiarity to influence infant face scanning during this time period. Further, no work thus far has compared how attention to different facial features might differentially predict later social communication from multiple age points. For instance, is attention to the eyes at 6 months or attention to the mouth at 9 months a greater predictor of social communication at 18 months? Following from earlier research, the present investigation aims to address three questions: 1) Do infant preferences for mother versus stranger change between 6 and 12 months?; 2) Does attention to eyes and mouth change between 6 and 12 months?; and 3) Are any measures of visual attention to faces in the first year associated with later social outcome?

Method

Participants

The final sample consisted of 36 6-month-olds ($M = 195$ days, $SD = 11$; 15 females), 42 9-month-olds ($M = 282$ days, $SD = 11$; 18 females), and 39 12-month-olds ($M = 372$ days, $SD = 13$; 24 females) from the greater Boston area who were enrolled in a longitudinal study of early development. An additional set of infants was excluded because they accumulated insufficient eye-tracking data, looking less than 30% of the time images were on the screen (6-month-olds: 8 infants; 9-month-olds: 16 infants; 12-month-olds: 18 infants). Of the infants who looked to the stimuli more than 30% of the time, an additional four 12-month-olds were excluded for showing a bias to look to one side of the screen more than 85% of the time. Finally, four infants were excluded due to experimental error in data exporting (6-month-olds: 1 infant; 9-month-olds: 2 infants; 12-month-olds: 2 infants). Project approval was obtained from the Institutional Review Boards of Boston Children's Hospital and Boston University and informed consent was obtained from the parents of each infant participant.

Stimuli

Color photographs of emotionally-neutral female faces were employed as stimuli. One of the faces was the infant's mother; the second was a featurally-similar stranger, matched to mother according to racial/ethnic background and other salient aspects (e.g., glasses). Images were cropped and re-sized for uniformity and inserted into stimulus presentation software (i.e., Clearview or Tobii Studio) for display on the eye-tracking monitor.

Apparatus

Images were presented on a 17'' TFT Tobii T60 monitor using Clearview or Tobii Studio software (Tobii Technology AB; www.tobii.com) running off of a PC computer. The eye-tracking monitor recorded gaze position of both eyes at 60 Hz based on the reflection of near-infrared light from the cornea and pupil.

Procedure

Infants were seated on their caregiver's lap in a darkened room approximately 60 cm from the eye-tracking monitor. Before the testing session began, a 5-point calibration procedure was used to confirm that the infant and monitor positions allowed for satisfactory gaze tracking. Following successful calibration, a modified visual paired comparison (VPC) paradigm was administered. Because the mother's face was used as one of the stimuli, a familiarization phase was not incorporated into the session. The presentation included four 10-second trials, each of which showed the mother's face and a stranger's face side-by-side. The positions of the faces were counter-balanced across trials, so that each face was on the right and left side for an equal amount of time.

Social communication measure

The Communication and Symbolic Behavior Scales Developmental Profile (CSBS-DP; Wetherby, Allen, Cleary, Kublin, & Goldstein, 2002) is a norm-referenced measure used to capture the early communicative competence of young children; it is four pages long and includes 45 questions covering seven domains of social communication and symbolic development: emotion and eye gaze, communication, gestures, sounds, words, understanding, and object use. Scoring yields three composite scores: Social (comprised of the Emotion and Eye Gaze, Communication, and Gestures clusters), Speech (comprised of the Sounds and Words clusters), and

Figure 1. Sample stimuli for mother versus stranger visual paired comparison test with areas of interest (AOIs) outlined. For each infant, AOIs included left image, right image, mother's image, stranger's image, mother's face, stranger's face, mother's eyes, stranger's eyes, mother's mouth, and stranger's mouth.

Table 1. Mean eye-tracking responses at 6, 9, and 12 months (standard deviations in parentheses).

	6 months ($n = 36$)		9 months ($n = 42$)		12 months ($n = 39$)	
	Mother	Stranger	Mother	Stranger	Mother	Stranger
Duration (s)						
Overall face	6429 (2832)	5595 (2340)	5797 (2280)	4862 (2047)	5758 (1970)	5289 (1870)
Eye region	4768 (2448)	3924 (2522)	3936 (2323)	3659 (2248)	3323 (2108)	3127 (2035)
Mouth region	242 (699)	209 (438)	181 (424)	98 (254)	594 (1294)	712 (1444)
Proportion						
Eye region	.76 (.04)	.66 (.05)	.67 (.24)	.71 (.24)	.57 (.05)	.61 (.05)
Mouth region	.03 (.01)	.04 (.01)	.03 (.01)	.03 (.01)	.11 (.04)	.11 (.03)

Symbolic (comprised of the Understanding and Object Use clusters). An overall Total score, which captures performance across the three composites, is also obtained. Each raw score is assigned a standard score and percentile rank according to previously established norms (Wetherby et al., 2002).

Data analysis

Infant eye-tracking. Following the completion of the experiment, 10 overlapping areas of interest (AOIs) were defined: left image, right image, mother's image, stranger's image, mother's face, stranger's face, mother's eyes, stranger's eyes, mother's mouth, and stranger's mouth (see Figure 1; left and right AOIs were used for calculation of side bias only). Gaze data were exported using a 100 millisecond fixation filter and a 20 pixel fixation radius. The resulting text file was then run through a custom-made Python script (Python Programming Language; www.python.org) that summed duration of gaze within each of the pre-defined AOIs.

In an effort to capitalize on infants' initial response to the viewing of their mother next to a stranger, while still counterbalancing on which side each image appeared, the present analyses focused on the first two 10-second trials presented to infants. Variables of interest for mother and stranger included: 1) Total time on face; 2) Total time on eyes and mouth; and 3) Proportion of time spent on eyes and mouth (calculated out of total time spent on face).

CSBS-DP at 18 months of age. At 18 months of age, all parents of infants in the present sample were asked to complete the CSBS-DP Caregiver Questionnaire (Wetherby et al., 2002) as a measure of children's social and communicative development. The present analyses focused on the percentile ranks for the Social composite score and the Total score. CSBS-DP scores were unavailable for a subset of children due to either a) failure to return the filled-out questionnaire (6 months: $n = 4$; 9 months: $n = 10$; 12 months: $n = 9$) or b) the inclusion of infants who were still under 18 months old in the VPC analysis (6 months: $n = 13$; 9 months: $n = 10$; 12 months: $n = 6$).

Results

Eye-tracking at 6, 9, and 12 months

Eye-tracking results focused on two sets of analyses using age as a between-subjects variable: 1) duration of time on the face AOI, and 2) attention to the eyes and mouth AOIs, both for total duration in the AOIs and for proportion of time in the AOIs. Although a subset of participants contributed data at multiple time points, the present results focus on cross-sectional analyses. Table 1 shows means for all variables of interest for 6-, 9-, and 12-month-olds. All analyses were conducted using SPSS statistical software. A preliminary repeated-measures ANOVA was run to examine the between-subjects effects of gender and presentation software (Clearview versus Tobii Studio) for each of the three analyses outlined above.

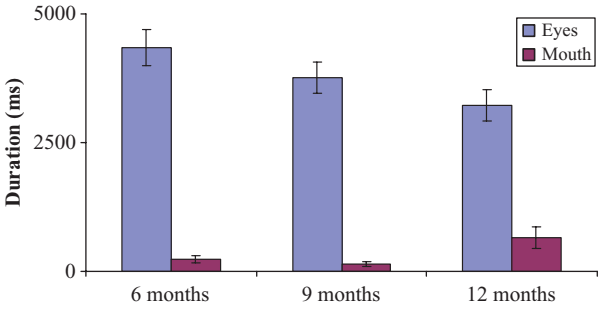

Figure 2. Duration of time on eyes and mouth for 6-, 9-, and 12-month-olds. A significant interaction between age and region showed decreasing attention to eyes and increasing attention to mouths over the second half of the first year of life.

No significant main effects or interactions were found and subsequent analyses collapse across these two variables.

Duration of time on face. A 2 (Identity: mother, stranger) × 3 (Age: 6-month-olds, 9-month-olds, 12-month-olds) repeated-measures ANOVA using identity as the within-subjects factor and age as the between-subjects factor found a main effect of identity on looking to the face, $F(1, 114) = 7.90$, $p = .006$, with infants spending significantly more time on their mother's face ($M = 5978$ ms, $SD = 2371$) than the face of a stranger ($M = 5230$ ms, $SD = 2090$). No other main effects or interactions were significant.

Attention to eyes and mouth. Duration of time on eyes and mouth as well as proportion of time on eyes and mouth were both examined. These analyses used a 2 (Identity: mother, stranger) × 2 (Region: eyes, mouth) × 3 (Age: 6-month-olds, 9-month-olds, 12-month-olds) repeated-measures ANOVA, with identity and region as the within-subjects factors and age as the between-subjects factor, and revealed several significant findings. For both duration of time and proportion of time on eyes and mouth, infants showed a main effect of region, Fs > 230, ps < .001, with significantly more time spent on the eyes (Duration: $M = 3775$ ms, $SD = 2020$; Proportion: $M = .66$, $SD = .25$) than the mouth (Duration: $M = 337$ ms, $SD = 842$; Proportion: $M = .06$, $SD = .14$). Infants also showed an interaction between age and region for both analyses, Fs > 4.1, ps < .02, whereby the 6- and 9-month-olds did not differ in their attention to eyes or mouth, but 12-month-olds showed decreased attention to eyes and increased attention to mouth as compared to the younger ages.

Duration of time on eyes and mouth. The significant interaction between age and region for duration of time on eyes and mouth revealed that for time on eyes, there was a significant decrease between 6 months ($M = 4346$ ms, $SD = 2126$) and 12 months ($M = 3225$ ms, $SD = 1860$; $t(73) = 2.44$, $p = .017$), while looking to eyes at 9 months ($M = 3797$ ms, $SD = 1977$) did not differ significantly from the younger and older age groups (ps > .18). With regards to looking to the mouth, infants showed a significant increase after 9 months. Specifically, there were no differences for looking to the mouth between 6- and 9-month-olds (6-month-olds: $M = 225$ ms, $SD = 438$; 9-month-olds: $M = 139$ ms, $SD = 304$; $t(76) = 1.02$, $p = .31$), but time on the mouth was significantly longer for 12-month-olds ($M = 653$ ms, $SD = 1316$) than 9-month-olds ($t(79) = 2.46$, $p = .016$). A trend towards greater duration of time on the mouth for 12-month-olds was also found in comparison to 6-month-olds ($t(73) = 1.86$, $p = .067$; see Figure 2).

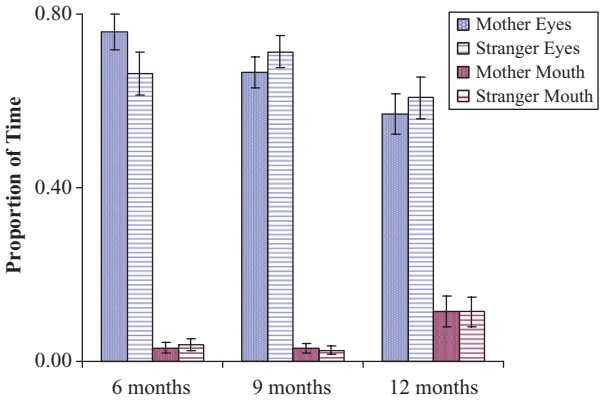

Figure 3. Proportion of time spent on eyes and mouth for mother and stranger at 6, 9, and 12 months. At 6 months, infants spent significantly more time on mother's eyes than stranger's eyes.

Additionally, an interaction between identity and region was found, $F(2, 114) = 4.45$, $p = .037$, such that infants spent significantly more time on the eyes for mother ($M = 3988$, $SD = 2347$) as compared to stranger ($M = 3563$, $SD = 2274$; $t(116) = 2.05$, $p = .043$), but no difference was found between time to mouth for mother ($M = 337$, $SD = 891$) and stranger ($M = 337$, $SD = 915$; $p > .95$). No other main effects or interactions were significant for duration of time on eyes and mouth.

Proportion of time on eyes and mouth. Follow-up analyses from the interaction between age and region for proportion of time on eyes and mouth revealed that 12-month-olds spent a significantly smaller proportion of time on the eye region ($M = .59$, $SD = .27$) as compared with 6-month-olds ($M = .71$, $SD = .25$; $t(73) = 2.03$, $p = .046$) and marginally less than 9-month-olds ($M = .69$, $SD = .22$; 9-month-olds: $t(79) = 1.88$, $p = .063$. Further, 12-month-olds showed a greater proportion of time on the mouth ($M = .11$, $SD = .21$) than 6-month-olds ($M = .03$, $SD = .06$; $t(73) = 2.15$, $p = .035$) and 9-month-olds ($M = .03$, $SD = .06$; $t(79) = 2.49$, $p = .015$).

The analysis of proportion of time on eyes and mouth also revealed an interaction between age and identity, $F(2, 114) = 4.52$, $p = .013$, with 6-month-olds showing a greater proportion of time on the eyes and mouth for mother ($M = .40$, $SD = .10$) than stranger ($M = .35$, $SD = .13$; $t(35) = 2.55$, $p = .015$), and no difference for 9- and 12-month-olds (ps > .20). This finding was qualified by a three-way interaction between age, identity, and region, $F(2, 114) = 4.23$, $p = .017$, showing that the interaction between age and identity was driven by a significantly greater proportion of time scanning the eyes for mother than stranger in 6-month-olds ($t(35) = 2.59$, $p = .014$) and no significant difference between mother and stranger for a) the mouth in 6-month-olds ($p > .65$), b) the eyes and mouth in 9-month-olds (ps > .20), or c) the eyes and mouth in 12-month-olds (ps > .20; see Figure 3). No other main effects or interactions were significant for the analysis of proportion of time on eyes and mouth.

Eye-tracking at 6, 9, and 12 months and CSBS-DP at 18 months

A final set of analyses were run to examine the relations between visual attention to faces as measured by the eye-tracking task in

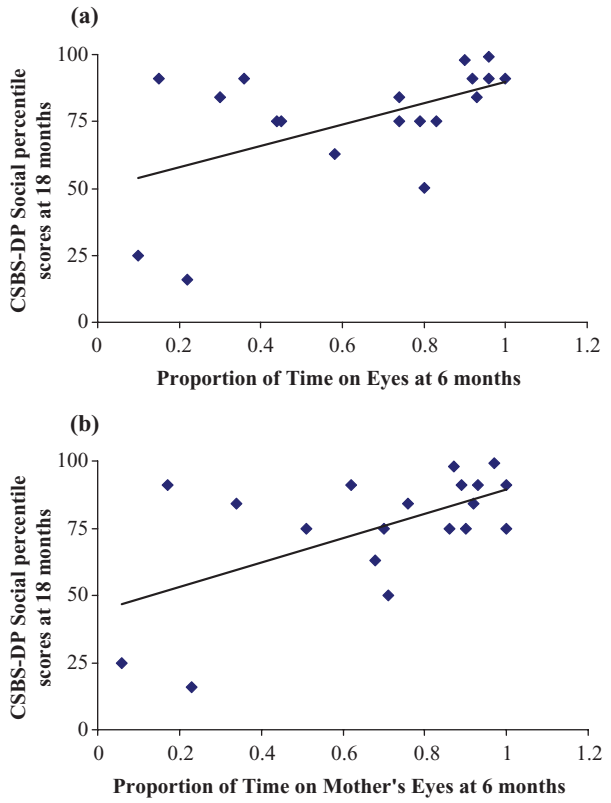

Figure 4. Associations between the proportion of time on eyes at 6 months and CSBS-DP Social percentile scores at 18 months. The significant positive relation with proportion of time on eyes (see a, $r(17) = .53$, $p = .020$) was driven by the proportion of time on the mother's eyes (see b, $r(17) = .59$, $p = .008$).

6-, 9-, and 12-month-olds and social-communicative behavior as assessed through the CSBS-DP at 18 months. The face scanning measures included: 1) total time on faces; 2) total time on eyes; 3) total time on mouths; 4) proportion of time on eyes; and 5) proportion of time on mouths. The CSBS-DP measures included percentile rank for the Social composite score and for the Total score. Each of the eye-tracking measures was compared to the two CSBS-DP measures.

Correlations were run separately for 6-, 9-, and 12-month-olds. For 6-month-olds, a significant positive relation was found between the proportion of time on the eyes and 18 month CSBS-DP social scores, $r(17) = .53$, $p = .020$, with increased attention to the eyes when viewing faces relating to better social functioning (see Figure 4a). This relation showed a similar association for total time on the eyes, $r(17) = .49$, $p = .033$. No significant relations between visual scanning and CSBS-DP total scores were found for 6-month-olds, and no relations with either CSBS-DP social scores or total scores were found for 9- or 12-month-olds. Table 2 presents all correlations found for the three age groups.

Because 6-month-olds showed a significantly greater proportion of time on eyes for mother as compared to stranger, follow-up correlations examined the proportion of time spent on eyes for mother and stranger separately. Findings revealed that the relation between proportion of time on eyes at 6 months and CSBS-DP social scores at 18 months was driven by attention to mother's eyes, $r(17) = .59$, $p = .008$ (see Figure 4b; correlation with stranger's eyes: $r(17) = .37$, $p = .12$).

Table 2. Correlations between eye-tracking at 6, 9, and 12 months, and CSBS scores at 18 months.

	Communication and symbolic behavioral scales at 18 months	
	Social score percentile rank	Total score percentile rank
6-month-olds ($n = 19$)		
Duration on faces	.35 (.15)	.40 (.09)
Duration on eyes	.49 (.03)*	.33 (.16)
Duration on mouths	−.08 (.74)	.14 (.56)
Proportion on eyes	.53 (.02)**	.33 (.16)
Proportion on mouths	−.14 (.56)	.06 (.80)
9-month-olds ($n = 22$)		
Duration on faces	.29 (.19)	.36 (.11)
Duration on eyes	.33 (.13)	.37 (.09)
Duration on mouths	.12 (.61)	.15 (.49)
Proportion on eyes	.21 (.36)	.18 (.43)
Proportion on mouths	−.01 (.98)	.09 (.68)
12-month-olds ($n = 24$)		
Duration on faces	−.03 (.88)	−.15 (.49)
Duration on eyes	.20 (.36)	−.05 (.82)
Duration on mouths	−.19 (.37)	−.17 (.42)
Proportion on eyes	.24 (.27)	.05 (.83)
Proportion on mouths	−.13 (.56)	−.12 (.59)

Note. All eye-tracking variables are collapsed across the two faces. Correlations (r) shown with p-value in parentheses. *$p < .05$; **$p < .025$.

Discussion

The present study examined infants' attention to their mother's face and a stranger's face at 6, 9 and 12 months using eye-tracking, and looked at how attention might relate to social behavior at 18 months. Results of the eye-tracking task revealed that overall, infants prefer to look at the face of their mother as compared to that of a stranger, but this preference did not change significantly between 6 and 12 months of age. These findings are consistent with past behavioral work (e.g., Brooks-Gunn & Lewis, 1981; Pascalis & de Schonen, 1994).

Analyses addressing infant attention to the core features of the face revealed significantly more attention to the eyes than the mouth, as measured by both overall duration and proportion of time on these two regions, and this attention varied as a function of age. While 6- and 9-month-olds showed no differences in attention to eyes and mouths, 12-month-olds differed from younger infants, showing decreased attention to eyes and increased attention to mouths. Lewkowicz and Hansen-Tift (2012) also reported shifts in attention to the mouth over the first year of life, a shift they posit to be related to growing speech perception and production abilities during this time window; these findings show the greatest change occurring between 4 and 10 months of age. The present study found no age where infants preferred the mouth to the eyes, and differences in attention to eyes and mouth occurred between 9 and 12 months (with no differences found between 6- and 9-month-olds). These differential findings across the two studies for attention to eyes and mouth across the first year are likely related to the differential stimuli used, with the present study using static images as opposed to the dynamic audiovisual stimuli used by Lewkowicz and Hansen-Tift (2012).

Our final set of analyses asked whether attention to faces in infancy could be predictive of later social behavior. Only visual attention to eyes in 6-month-old infants showed a significant association with later social abilities, as measured by the CSBS-DP Social composite at 18 months. This relation did not hold with CSBS-DP Total score, suggesting that early attention to eyes has a more specific role in social outcome as compared to more general social-communicative behaviors. Moreover, follow-up correlations revealed that attention to *mother's* eyes drove the significant positive relation between proportion of time on eyes for 6-month-olds and CSBS-DP Social composite score for 18-month-olds, suggesting that the distribution of attention to the core features of a caregiver can have important effects on social development. No significant relations were found between attention to faces in 9- or 12-month-olds and the CSBS-DP scores at 18 months. While past work by Schietecatte and colleagues (2012) found a relation between looking to the eyes in 6-month-olds and social communication at 12 months, the present study extends this finding, showing a link between attention to eyes at 6 months and social abilities at 18 months that is driven by attention to a familiar face. One potential explanation for the significant relation between attention to eyes at 6 months and social behavior at 18 months, alongside the lack of relations with attention at 9 or 12 months, might be the limited behavioral repertoire of a 6-month-old as compared to a 9- or 12-month-old. At 6 months, looking to faces is one of the clearest behaviors to indicate social interest, while 9- and 12-month-olds have an increasingly more complex set of social-communicative behaviors that could extend beyond attention to faces and include vocalizations, gestures, and movements, for example, that all may contribute to predicting later social development. Future work will explore the contributions of additional measures of social communication in the first year in predicting social behavior in the second year of life.

One important limitation of the present study is the lack of heterogeneity in social-communicative outcome, as measured by the CSBS-DP. It is promising that relations between early attention to eyes and later CSBS-DP social score are found despite this, but future work would benefit from expanding these samples to include a larger number of infants with lower CSBS-DP scores later on, such as those infants who might be at risk for later social difficulty. An additional limitation to the present work is that with only a subset of participants contributing both eye-tracking data and CSBS-DP data, the correlations reported were not corrected for multiple comparisons.

The current findings provide an important addition to work examining early infant attention to faces and markers of later social development. With a growing area of research aimed at predicting trajectories of social development in both typically- and atypically-developing populations (e.g., infants with a family history of autism), future work will continue examining these relations to assess the stability of these predictive early markers of face scanning as they relate to later social development.

Acknowledgements

We would like to thank Vanessa Vogel-Farley, Laura Kasparian, Alexandra Libby, and Stephanie Marshall for their help with data processing.

Funding

This research was supported by grants from NIDCD (R21 DC 08637 and R01 DC 10290), Autism Speaks, and the Simons Foundation.

References

Batki, A., Baron-Cohen, S., Wheelwright, S., Connellan, J., & Ahluwalia, J. (2000). Is there an innate gaze module? Evidence from human neonates. *Infant Behavior and Development*, *23*(2), 223–229.

Bentin, S., Golland, Y., Flevaris, A., Robertson, L. C., & Moscovitch, M. (2006). Processing the trees and the forest during initial stages of face perception: Electrophysiological evidence. *Journal of Cognitive Neuroscience*, *18*(8), 1406–1421.

Brooks-Gunn, J., & Lewis, M. (1981). Infant social perception: Responses to pictures of parents and strangers. *Developmental Psychology*, *17*(5), 647–649.

Bruce, V., & Young, A. (1998). *In the eye of the beholder: The science of face perception*. New York, NY: Oxford University Press.

Bushnell, I. W. R., Sai, F., & Mullin, J. T. (1989). Neonatal recognition of the mother's face. *British Journal of Developmental Psychology*, *7*(Part 1), 3–15.

de Haan, M., & Nelson, C. A. (1997). Recognition of the mother's face by six-month-old infants: A neurobehavioral study. *Child Development*, *68*(2), 187–210.

Fantz, R. L. (1964). Visual experience in infants – Decreased attention to familiar patterns relative to novel ones. *Science*, *146*(364), 668–670.

Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proceedings of the National Academy of Sciences of the United States of America*, *99*(14), 9602–9605.

Field, T. M., Cohen, D., Garcia, R., & Greenberg, R. (1984). Mother–stranger face discrimination by the newborn. *Infant Behavior and Development*, *7*(1), 19–25.

Grossmann, T., & Johnson, M. H. (2007). The development of the social brain in human infancy. *The European Journal of Neuroscience*, *25*(4), 909–919.

Haith, M. M., Bergman, T., & Moore, M. J. (1977). Eye contact and face scanning in early infancy. *Science*, *198*(4319), 853–855.

Hood, B. M., Willen, J. D., & Driver, J. (1998). Adults' eyes trigger shifts of visual attention in human infants. *Psychological Science*, *9*(2), 131–134.

Hunnius, S., & Geuze, R. H. (2004). Developmental changes in visual scanning of dynamic faces and abstract stimuli in infants: A longitudinal study. *Infancy*, *6*, 231–255.

Itier, R. J., & Batty, M. (2009). Neural bases of eye and gaze processing: The core of social cognition. *Neuroscience and Biobehavioral Reviews*, *33*, 843–863.

Key, A. P. F., & Stone, W. L. (2012). Same but different: 9-month-old infants at average and high risk for autism look at the same facial features but process them using different brain mechanisms. *Autism Research*, *5*(4), 253–266. doi: 10.1002/aur.1231

Key, A. P. F., Stone, W., & Williams, S. (2009). What do infants see in faces? ERP evidence of different roles of eyes and mouth for face perception in 9-month-old infants. *Infant and Child Development*, *162*, 149–162.

Lansing, C., & McConkie, G. (1999). Attention to facial regions in segmental and prosodic visual speech perception tasks. *Journal of Speech, Language, and Hearing Research*, *42*, 526–539.

Leppänen, J. M., & Nelson, C. A. (2009). Tuning the developing brain to social signals of emotions. *Nature Reviews Neuroscience*, *10*(1), 37–47.

Lewkowicz, D. J., & Hansen-Tift, A. M. (2012). Infants deploy selective attention to the mouth of a talking face when learning speech. *Proceedings of the National Academy of Sciences*, *109*, 1431–1436.

Maurer, D., & Salapatek, P. (1976). Developmental changes in the scanning of faces by young infants. *Child Development*, *47*(2), 523–527.

Morales, M., Mundy, P., Delgado, C. E., Yale, M., Neal, R., & Schwartz, H. K. (2000). Gaze following, temperament, and language development in 6-month-olds: A replication and extension. *Infant Behavior & Development*, *23*(2), 231–236.

Morales, M., Mundy, P., & Rojas, J. (1998). Following the direction of gaze and language development in 6-month-olds. *Infant Behavior and Development*, *21*(2), 373–377.

Pascalis, O., & de Schonen, S. (1994). Recognition memory in 3- to 4-day-old human neonates. *Neuroreport*, *5*(14), 1721–1724.

Pascalis, O., de Schonen, S., Morton, J., Deruelle, C., & Fabre-Grenet, M. (1995). Mother's face recognition by neonates: A replication and an extension. *Infant Behavior & Development*, *18*, 79–85.

Schietecatte, I., Roeyers, H., & Warreyn, P. (2012). Can infants' orientation to social stimuli predict later joint attention skills? *British Journal of Developmental Psychology*, *30*, 267–282.

Simion, F., Valenza, E., Umiltà, C., & Dalla Barba, B. (1998). Preferential orienting to faces in newborns: A temporal–nasal asymmetry. *Journal of Experimental Psychology*, *24*(5), 1399–1405.

Symons, L. A., Hains, S., & Muir, D. W. (1998). Look at me: Five-month-old infants' sensitivity to very small deviations in eye-gaze during social interactions. *Infant Behavior & Development*, 531–536.

Valenza, E., Simion, F., Cassia, V. M., & Umiltà, C. (1996). Face preference at birth. *Journal of Experimental Psychology*, *22*(4), 892–903.

Weikum, W. M., Vouloumanos, A., Navarra, J., Soto-Faraco, S., Sebastian-Galles, N., & Werker, J. F. (2007). Visual language discrimination in infancy. *Science*, *316*, 1159.

Wetherby, A. M., Allen, L., Cleary, J., Kublin, K., & Goldstein, H. (2002). Validity and reliability of the communication and symbolic behavior scales developmental profile with very young children. *Journal of Speech and Hearing Research*, *45*(6), 1202–1218.

Young, G. S., Merin, N., Rogers, S. J., & Ozonoff, S. (2009). Gaze behaviour and affect at 6 months: Predicting clinical outcomes and language development in typically developing infants and infants at risk for autism. *Developmental Science*, *12*, 798–814.