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The development of gaze following and its relation to language

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Abstract

We examined the ontogeny of gaze following by testing infants at 9, 10 and 11 months of age. Infants (N = 96) watched as an adult turned her head toward a target with either open or closed eyes. The 10- and 11-month-olds followed adult turns significantly more often in the open-eyes than the closed-eyes condition, but the 9-month-olds did not respond differentially. Although 9-month-olds may view others as 'body orienters', older infants begin to register whether others are 'visually connected' to the external world and, hence, understand adult looking in a new way. Results also showed a strong positive correlation between gaze-following behavior at 10–11 months and subsequent language scores at 18 months. Implications for social cognition are discussed in light of the developmental shift in gaze following between 9 and 11 months of age.

Introduction

Adults and preschool-age children pay close attention to the direction of visual gaze of other people (Kleinke, 1986; Langton & Bruce, 1999; Lee, Eskritt, Symons & Muir, 1998). Gaze following is important for developmental theory because it can be seen as a 'front end' ability that contributes to understanding what another is thinking, feeling and intending to do (Baron-Cohen, 1995; Frith & Frith, 2001; Meltzoff & Brooks, 2001; Tomasello, 1995). In this regard, it is intriguing that children with autism do not engage in gaze following in the same way as typically developing children (e.g. Dawson, Meltzoff, Osterling, Rinaldi & Brown, 1998; Mundy, 2003; Mundy, Sigman & Kasari, 2000; Toth, Munson, Meltzoff & Dawson, in press).

To investigate infants' understanding of others' looking, developmental scientists have created a broad set of paradigms. They have used both action measures that rely on infants' actively turning to follow the gaze of others (Brooks & Meltzoff, 2002; Butler, Caron & Brooks, 2000; Butterworth & Cochran, 1980; Butterworth & Itakura, 2000; Carpenter, Nagell & Tomasello, 1998; Corkum & Moore, 1995, 1998; D'Entremont, Hains & Muir, 1997; Moll & Tomasello, 2004; Scaife & Bruner, 1975) and habituation techniques that rely on infants' increased fixation on novel scenes (Sodian & Thoermer, 2004; Woodward, 2003). Although it is clear that infants will turn to look where another person is looking, it is still unsettled whether infants want to see what another person sees (Brooks & Meltzoff, 2002; Deák, Flom & Pick, 2000; D'Entremont, 2000; Moore & Corkum, 1994, 1998). Infants may not interpret another's looking behavior as establishing a psychological connection between the looker and external object or as generating an internal experience of 'seeing' in the looker.

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Some have argued that young infants simply follow the direction of the adult's head movement, and by looking in the same general direction notice an interesting sight (e.g. Butterworth & Cochran's, 1980, ecological mechanism). In support of this position, Butterworth and others found that infants younger than 12 months looked in the same general direction indicated by the adult's turn, but they fixated at the first available object even when that one was not the one the adult was looking at (Butterworth & Jarrett, 1991; Flom, Deák, Phill & Pick, 2004). In a related argument, Moore suggested that infants use the adult's head turn as a cue to anticipate an interesting event (Corkum & Moore, 1998; Moore, 1999).

In everyday adult psychology, it is the eyes, and not the head orientation, that are crucial for seeing. We can turn our head, but if our eyes are closed, we will not experience seeing. A relevant question for developmental science is whether infants know that eyes are the necessary link between looker and external object. Past studies have addressed this issue by testing whether infants follow head *versus* eye movement when the two are oriented in different directions (e.g. a head turn to the right and eyes looking to the left). In a study of 6- to 19-month-old infants, Corkum and Moore (1995) reported that 12-month-old infants generally followed the adult's head orientation (and not the gaze direction), but younger infants rarely followed any of the adult's turns. By 18 months, infants demonstrated some sensitivity to eye gaze by following turns of the head and eyes significantly more often than turns of the head alone (see also Caron, Butler & Brooks, 2002). Overall, the existing literature suggests that infants, who are 12 months and younger, preferentially follow head motion over eye orientation (see related work, Farroni, Johnson, Brockbank & Simion, 2000; Johnson, Slaughter & Carey, 1998). However, one concern is that the existing results may underestimate infants' abilities, because the adult's head and eyes turn in different directions, thereby indicating two contradictory places in space at the same time.

Brooks and Meltzoff (2002) designed an alternative gaze-following procedure, suitable for infants, based on findings that older children distinguish between what a person would see with open eyes versus closed eyes (Flavell, Shipstead & Croft, 1980; Lempers, Flavell & Flavell, 1977; O'Neill, 1996; see also Caron, Butler *et al.*, 2002). Brooks and Meltzoff reasoned that turning with open versus closed eyes provides a crucial infant test, because it controls for head motion. If infants followed head movements alone, they would look at the adult's target in *both* conditions. If infants were sensitive to the perceptual status of the adult's eyes, that is, if they were truly *gaze* following, they would look at the adult's target more often when the adult turned with open than closed eyes. The Brooks and Meltzoff (2002) results showed that 12-, 14- and 18-month-old infants gaze followed more often in the open-eyes condition than the closed-eyes condition.

This eyes open/closed approach provides a method for exploring the origins of gaze following in still younger infants. The period of 9 to 11 months is thought to involve rapid developmental change in social understanding (Bates, Benigni, Bretherton, Camaioni & Volterra, 1979; Carpenter *et al.*, 1998; Flom *et al.*, 2004; Mumme & Fernald, 2003; Striano & Rochat, 2000; Tomasello, 1995; Woodward, 2003). This age range is also of interest because there is reason to think that individual differences in gaze following during this period predict later language development (e.g. Carpenter *et al.*, 1998; Morales, Mundy & Rojas, 1998; Morales, Mundy, Delgado, Yale, Messinger, Neal & Schwartz, 2000). However, the past correlations are difficult to interpret because the procedures included adult vocalizations and/or communicative points during the test interval when the adult turned to look at the target. Consequently, it may be that the obtained correlations simply index infants' responsiveness to language during the gaze-following procedure itself, rather than resting on a predictive correlation between gaze following and later language. In the current study, we present looking behavior without any additional linguistic (or pointing) cues as a strict test of gaze following per se. Although infants heard no adult vocalizations during the trials, the infants sometimes produced their own vocalizations during the test, and we scored such productions.

The main goal is to identify the age at which infants interpret the open- and the closed-eyes conditions differently. Based on past research, we hypothesized that the youngest age group (9-month-olds) would turn to follow the adult's head movement regardless of whether the adult was actually *looking* at the external target. That is, they may follow head movement and understand something about body orientation, but they do not engage in gaze following per se. We also expected to uncover a developmental change within a fairly narrow developmental window because both action measures and habituation techniques suggest that 12-month-olds do more than simply follow head movements (Brooks & Meltzoff, 2002; Woodward, 2003). Moreover, the Woodward findings indicate a developmental change between 9 and 12 months of age. Our pilot studies using the eyes open/closed procedure provided converging evidence of a developmental shift at about this age. This motivated us to trace gaze following in a very fine-grained manner, by sampling infants within this 90-day period at three specific ages: 9, 10 or 11 months of age.

Method

Participants

The participants were 96 infants. There were 32 infants (16 female, 16 male) at each of three ages: 9 months (M = 9 months; 2 days, range = 267 to 281 days), 10 months (M = 9;30, range = 297 to 311 days), and 11 months (M = 11;01, range = 328 to 343 days). Infants were recruited by calling parent volunteers listed in a computerized infant participation pool. All infants were full-term (37–43 weeks), normal birth weight (2.5–4.5 kg), and had no major birth complications or postnatal hospitalizations. Additional infants were excluded because of extreme fussiness or sleepiness (n = 15), procedural problems (n = 4), parent interference (n = 6) or repeated infant movement at trial onset (n = 30). Parents gave informed consent for their infants and received parking reimbursement and a small gift.

Procedure

The experiment took place in a room (3.3 × 3.5 m) with plain curtains and wall coverings to prevent visual and auditory distractions. Two synchronized cameras made separate recordings of the experiment. The main one recorded the frontal view of the infant's face and upper body; the other recorded the experimenter. A character generator added synchronized time codes (accurate to 1/30th of a second) to each recording for subsequent scoring purposes.

Infants sat on their parent's lap across a table from the experimenter (75 cm away). The experimenter sat at approximately the infant's eye level and presented warm-up toys until the infant seemed comfortable playing at the table. Then, the experimenter placed two identical, colorful targets (16-cm high × 9-cm diameter toys) at eye level on either side of the infant (offset 75° and 135 cm diagonally from the infant).

At the start of a trial, the experimenter removed the warm-up toys from the table and made eye contact with the infant to ensure that each infant began the trial in a controlled manner. For the open-eyes condition, she silently turned her head and open eyes toward the target. For the closed-eyes condition, she closed her eyes immediately before (approximately a half second) performing the same head movement. Each 6.5-s trial began with the onset of the adult head movement.

Within each of the three ages, infants were randomly assigned to the open-eyes versus the closed-eyes condition by the following counterbalancing rules: Each condition had an equal number of males and females with counterbalancing for direction of first experimenter turn (left vs. right). Across four trials the experimenter turned toward the left versus right target in either an ABBA or ABAB pattern. Four trials were always presented, but infrequently one trial was excluded from the analysis (7% of the trials) because of infant movement (e.g. looking down) during trial onset.

Language assessment

When the infants were 14 and 18 months old, parents of the infants in the 10- to 11-month-old open-eyes condition (originally $n = 32$) were asked to complete the infant form of the MacArthur-Bates Communicative Development Inventory (CDI; Fenson, Dale, Reznick, Bates, Thal & Pethick, 1994). [1] The mean age of the infants with completed CDI forms was 14.05 months (range = 419 to 443 days, $n = 20$) and 18.16 months (range = 537 to 589 days, $n = 24$).

Scoring and operational definitions

A coder, who was uninformed as to the experimental conditions and the direction of the experimenter's head turn, scored the infants' videotapes in a random order. The coder identified the time when an infant looked at a target, experimenter, parent, and looked away (see operational definitions below). For the latter three behaviors, the accumulated duration was converted to a percent (relative to the total duration of the trials). The infants' vocalizations during the trial were also scored. The scoring was accurate to the video-frame level (30 frames per second).

The operational definition of 'look at target' was that infants had to turn and align their head and eyes with the target location for at least 0.33 seconds (10 video frames). The definition of 'look at experimenter' was that infants had to look at the experimenter's face. 'Look away' was defined as when the infant looked above or below the horizontal plane of the targets. The definition of 'look at parent' included all looks to the parent's face or body. 'Generic vocalizations' were defined as all voiced sounds, thus excluding non-voiced sounds such as coughs or sneezes. (This definition would have allowed words and proto-words to be coded, but few were observed, which is not surprising given the age groups. The overwhelming majority of vocalizations were best characterized as vowel cooing, such as /a/ and /u/, and voiced grunts, such as 'hmm'.) Of particular interest were those instances when infants vocalized while *simultaneously* looking at a correct target (within 0.33 s of target fixation). Because this behavior occurred infrequently (typically less than once per infant), we categorized whether or not individual infants performed this act on any trial, resulting in a dichotomous yes/no score as to whether or not an individual infant performed a 'correct gaze + simultaneous vocalization'.

For each trial, an infant's first target look was designated as either a 'correct look' if it matched the target of the experimenter's turn (+1) or 'incorrect look' if it was to the opposite target (−1). If infants did not look at either target (e.g. looked away), they received a score of 0 indicating 'nonlooking'. As standard in the gaze-following literature, the looking score for each infant was the sum of correct looks, incorrect looks, and nonlooks (e.g. Brooks & Meltzoff, 2002; Corkum & Moore, 1995; Flom *et al.*, 2004; Morales *et al.*, 1998). The possible range for the looking score across 4 trials was from −4 to +4. In

[1] We found that the infant version (8 to 16 months) of the CDI was appropriate for 18 months because the scores for 18-month-olds in a pilot and the current study rarely approached the maximum scores.

addition, we created a dichotomous score (yes vs. no) for whether or not infants looked at the correct target on any trial.

In order to assess inter-rater and intra-rater agreement levels, the main coder and another naïve coder reviewed a random sample of 25% of the infants. Inter-rater agreement was excellent for all scores, with Cohen's kappa (Cohen, 1960) ranging from .79 to .97. The intrarater agreement for all scores was also excellent, with Cohen's kappa ranging from .86 to .99.

Results

Gaze following

A 3 (age: 9, 10, 11 months) × 2 (condition: open vs. closed eyes) analysis of variance (ANOVA) was performed on the looking scores. As expected, there was a significant main effect of condition, $F(1, 90) = 4.57$, $p < .05$. Infants had higher looking scores in the open-eyes condition ($M = 0.90$, SD = 1.42) than the closed-eyes condition ($M = 0.33$, SD = 1.19). There was no main effect for age; the Age × Condition interaction was $F(2, 90) = 2.39$, $p < .10$. Figure 1 displays the looking scores as a function of age and condition. Because of predicted age differences, we examined (with planned contrasts) the difference in response to open versus closed eyes separately at each age. For 9-month-olds, the looking scores in the open-eyes condition were nearly identical to those in the closed-eyes condition ($p > .50$), which is in line with work reported by Woodward (2003) and our own pilot studies using the current paradigm. For 10-month-olds, the looking scores in the open-eyes condition ($M = 1.06$) were significantly greater than in the closed-eyes condition ($M = 0.06$), $p < .05$. A significant condition effect was also evident among 11-month-olds ($M = 0.88$ vs. −0.06), $p < .05$.

For completeness, the looking data were also analyzed in a dichotomous fashion to examine whether more infants looked at the correct target in the open- than closed-eyes condition. A 2 × 2 chi-square analysis yielded a significant effect for the number of infants who looked at the correct target (yes vs. no) as a function of condition (open vs. closed eyes), χ^2 (1, $N = 96$) = 7.09, $p < .005$. Overall, a majority of infants in the open-eyes condition (33 of 48) looked at the correct target; whereas a minority of the infants did so in the closed-eyes condition (19 of 48). The same tests broken down by age revealed the expected pattern. The chi-square test was not significant at 9 months, χ^2 (1, $N = 32$) = 0.58, $p > .20$, but was significant at 10 months, χ^2 (1,$N = 32$) = 3.14, $p < .05$, and 11 months, χ^2 (1, $N = 32$) = 6.35, $p < .01$. Approximately the same number of 9-month-olds looked at the correct target (i.e. the one indicated by the adult's head movement) in the closed-eyes condition (10 of 16) as in the open-eyes condition (12 of 16).

We also analyzed whether more infants produced a correct gaze + simultaneous vocalization in the open-than the closed-eyes condition. The 2 × 2 chi-square was significant, χ^2 (1, $N = 96$) = 2.72, $p < .05$, indicating that more infants in the open-eyes condition (16 of 48) produced correct gaze + simultaneous vocalizations than in the closed-eyes condition (8 of 48).[2] It is important to note that the difference for open versus closed eyes was *not* due to a general propensity to vocalize. We examined the number of infants who vocalized any time during the trials versus the number who remained silent. The 2 (any vocalization: yes vs. no) × 2 (condition: open vs. closed eyes) chi-square test did not yield significant effects overall

[2]Examining the number of infants who produce a correct gaze + simultaneous vocalization at each age, the 9-month-olds did not have a significant condition effect (4 of 16 for the open-eyes and 5 of 16 in the closed-eyes condition), χ^2 (1, $N = 32$) = 0.15, $p > .50$, but 11-month-olds did (7 of 16 vs. 1 of 16, respectively), χ^2 (1, $N = 32$) = 6.00, $p < .05$; the 10-month-olds showed the same direction of effect as 11-month-olds but the effect (5 of 16 vs. 2 of 16) was not significant, χ^2 (1, $N = 32$) = 1.65, $p < .20$.

or at any age taken individually (*p*s > .20). Thirty-four of the 48 infants in the open-eyes condition vocalized versus 29 (of 48) in the closed-eyes condition. This suggests that infants were not generally more talkative in one condition than another, but rather that the infants selectively produced a correct gaze plus *simultaneous* vocalization when the adult looked to a target with open eyes.

An issue that arises from these effects is that head turns with closed eyes may be novel to an infant, and as such they may attract longer looks at the experimenter than head turns with open eyes. In order to assess this possibility, we conducted a fine-grained breakdown of infants' looking behavior (including looking at the experimenter, parent, and away). The results showed that infants spent the same amount of time looking at the experimenter in the open-eyes as the closed-eyes condition ($M = 60.40\%$, SD = 17.87; $M = 64.10\%$, SD = 21.93, respectively). There were no significant main effects or interactions in the Age × Condition ANOVA for looking at the experimenter (*p*s > .30). Likewise, looking at the parent ($M = 1.92\%$, SD = 4.72) or away ($M = 17.92\%$, SD = 15.30) failed to reveal any significant effects for age, condition, or age by condition. This fine-grained scoring yielded results that were in line with our clinical review of the videotapes. We scrutinized the records observing precisely the moment when the adult closed her eyes and turned to the object. The infants in the open-eyes and closed-eyes groups were equally unperturbed, and the latter gave no signs of being upset, either at the onset of the eye closure or during the brief (6.5-s) response period. As will be discussed in more detail below, we believe that the difference between the conditions is not due to disruption but rather to the fact that the adult turn with closed eyes is not interpreted as being 'about' or referring to the external object.

Relation to language

In a longitudinal follow-up, we assessed whether gaze-following behavior at 10–11 months (i.e. following in the open-eyes condition) predicted subsequent language and communication abilities in these same children. We were especially interested in the infants' looking scores and looking with simultaneous vocalization as predictors. As shown in Table 1, the looking score at 10–11 months significantly predicted total gestures at 18 months ($p < .005$), although it did not predict CDI scores at 14 months (*p*s > .15). The correct gaze + simultaneous vocalization score at 10–11 months consistently predicted subsequent language scores at both 14 and 18 months. (All tests were point-biserial correlations.) Interestingly, the correct gaze + simultaneous vocalization score at 10–11 months showed significant positive correlations with three 14-month CDI subscales: phrases understood ($p < .01$), words understood ($p < .05$) and total gestures ($p < .0001$). This same measure at 10–11 months also positively correlated with language 7–8 months later when the infants were 18 months old. Specifically there were significant correlations with phrases understood ($p < .05$), words understood ($p < .001$) and total gestures ($p < .005$). The predictive correlation with comprehension at 18 months of age was particularly striking – infants who had a correct gaze + simultaneous vocalization at 10–11 months understood significantly more words ($M = 337.37$) than did those who did not produce this act ($M = 194.50$). Moreover, these effects were *not* the result of a child's general propensity to vocalize during the test at 10–11 months. Infants' generic vocalization score at 10–11 months did not correlate with any CDI subscale at either 14 or 18 months (all *p*s > .30). As shown in Table 1, infants' language scores at 14 months also predicted language at 18 months, which shows that the scales relate to each other as expected (Fenson *et al.*, 1994; Tsao, Liu & Kuhl, 2004).

Discussion

The results suggest that there is an important change in infants' gaze following during a 90-day window just before 1 year of age. At 9 months, infants do not respond differentially as a function of the perceptual status of the eyes. They follow adult head turns toward a target just as often whether she turns with eyes open or closed. In contrast, 10- and 11-month-olds sharply differentiate these two conditions. The majority of the older infants look at the adult's target specifically when the adult turns with open eyes (and refrain when she turns with closed eyes). The 10- and 11-month-olds are closely monitoring the adult's perceptual organs.

A proponent of a lean interpretation could argue that infants simply find the adult with closed eyes to be odd or novel, but this does not accord with the available data. First, the results showed that infants stared at the experimenter equally in the open- and closed-eyes conditions. Second, a systematic clinical review of the sessions showed no signs of infant distress or avoidance; infants appeared to have positive or neutral affect in both conditions. Third and most importantly, infants at 9 months systematically looked at the correct target even when the adult turned with closed eyes. This suggests that infants (at least at 9 months) were not disrupted. A proponent of the lean interpretation would need to argue that the 9-month-olds did not find the eye closure odd, but that the 10- and 11-month-olds did.

We believe that the data reflect a developmental change in infants' understanding of adult looking. Our suggestion is that 9-month-old infants are not truly *gaze* following. Gaze following develops at about 10–11 months of age. The 9-month-olds cannot be said to be gaze following, because they follow an adult's head movement even when her eyes are shut. They seem to head follow but not gaze follow.[3]

Other findings with 9-month-olds are consistent with this interpretation. Research shows that head turning induces more following than a static presentation at this age (Moore, Angelopoulos & Bennett, 1997). Perhaps the strongest and most relevant piece of converging evidence, however, comes from research using habituation procedures. At 9 months of age, infants fail tasks designed to assess their understanding of the goal of an adult's look. For example, Woodward (2003) reported that 9-month-olds do not encode the link between the adult looker and the target object, even though they encode the relation between a grasping hand and the target object. In contrast, research shows that 12-month-olds register the looker–object link, as measured by a variety of habituation approaches (Phillips, Wellman & Spelke, 2002; Sodian & Thoermer, 2004; Woodward, 2003; Woodward & Guajardo, 2002) as well as by action measures of gaze following (Brooks & Meltzoff, 2002; Moll & Tomasello, 2004). To date, no one has tested infants at 10 to 11 months with the habituation designs, but we predict success at this age. The convergence of findings suggests that we are honing in on a specific change in infants' understanding of looking during a rather narrow time window.

A developmental transition at approximately 9 months of age is noteworthy. It is striking that there are other specific changes in infant behavior reported at this juncture, including deferred imitation (Meltzoff, 1988), object permanence (Meltzoff & Moore, 1998; Moore & Meltzoff, 1999), social cognition (Carpenter *et al.*, 1998; Rochat & Striano, 1999; Tomasello, 1999) and inhibition of prepotent responses (Diamond, 1991). Future studies might examine the potential interrelation among these domains as well as the neurophysiological changes that are implicated in infants' integrating their understanding of people with objects-in-space.

[3]The reader may wonder whether infants followed the adult's gaze to the correct target more often than to the incorrect target. This is essentially an analysis of the open bars in Figure 1, testing whether the obtained looking scores are significantly greater than 0. The results show that infants follow to the correct side at each age, all $ps < .05$ In other words, even 9-month-olds correctly follow the direction of the adult's turn. However, only the 10- and 11-month-olds and not the 9-month-olds differentiate between open and closed eyes (see text).

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The findings concerning vocalization provide additional data concerning the proposed developmental shift. In a sense, the infants themselves could be telling us that they are linking the looker with the object. The significant finding is that by 11 months, but not at 9 months, infants are adding simultaneous ocalizations to their target looks in the open-eyes condition and rarely doing the same in the closed-eyes condition. The vocalizations at this age are simple voiced sounds, such as /a/ or ‘hmm’, and are not proto-words. However, the simultaneous vocalizing and looking (within 0.33 s) is compatible with the interpretation of a proto-declarative effort (Bates *et al.*, 1979; Camaioni, Perucchini, Bellagamba & Colonnesi, 2004; Carpenter *et al.*, 1998; Liszkowski, Carpenter, Henning, Striano & Tomasello, 2004) where the infants refer to the distal object specifically when the person has open eyes and there is some possibility of psychological ‘sharing’.

At a broader level, the current results lend support to the theoretical arguments (Baldwin, 1995; Baldwin & Moses, 2001; Bruner, 1983; Hollich, Hirsh-Pasek & Golinkoff, 2000; Tomasello, 1995, 2003) and empirical findings (Baldwin, 1993; Carpenter *et al.*, 1998; Moore, Angelopoulos & Bennett, 1999; Morales *et al.*, 1998; Mundy, Fox & Card, 2003; Mundy & Gomes, 1998; Tomasello & Farrar, 1986; Tomasello & Todd, 1983), suggesting that gaze following plays a role in language acquisition. In the current study, correct gaze following plus simultaneous vocalization predicted later vocabulary comprehension and gesture production, but general vocalization alone (without looking at the target) did not. Gaze following plus simultaneous vocalization may be a sensitive measure of proto-declarative sharing with another psychological agent. It is also interesting that this measure predicts vocabulary comprehension at 14 and 18 months but not vocabulary production. Language production draws on other factors, including articulatory skills, that go beyond comprehension per se (Bates, 1993; Leonard, Schwartz, Morris & Chapman, 1981; Mills, Coffey-Corina & Neville, 1994; Vihman, 1993). One interpretation of the results is that infants who are advanced in recognizing the connection between looker and objects may have a leg up in word comprehension, perhaps because they use the adult’s gaze to disambiguate the referent of the adult’s linguistic utterances (Baldwin, 1995; Bruner, 1983; Tomasello, 2003).

In sum, our data lend support to the idea that genuine *gaze* following develops at about 10 to 11 months of life and emerges from simpler beginnings. Although lean interpretations are possible, our interpretation, based on converging evidence, is that visual contact between the looker and the object first becomes important for engendering infant gaze-following behavior at 10 to 11 months. Whereas 9-month-olds may view others as ‘body orienters’, older infants begin to regard others as ‘visually connected’ to the external world, which is a potentially important step in social cognition.

It is relevant for developmental theory that this sensitivity to eyes appears to develop months before infants are able to grasp that non-biological occluders, such as blindfolds, block the connection between the looker and the object (Brooks & Meltzoff, 2002; Caron, Kiel, Dayton & Butler, 2002). Infants may use their *own experiences* of eye closure and the result of not being able to see, as the basis for giving meaning to these similar behavioral acts in others (Meltzoff, 2005; Meltzoff & Brooks, 2001). Once infants come to understand that head movements are not crucial, but rather that eyes are the perceptual organs to monitor, they have made a significant step forward in acquiring a more adult-like understanding of the intentional states of others.

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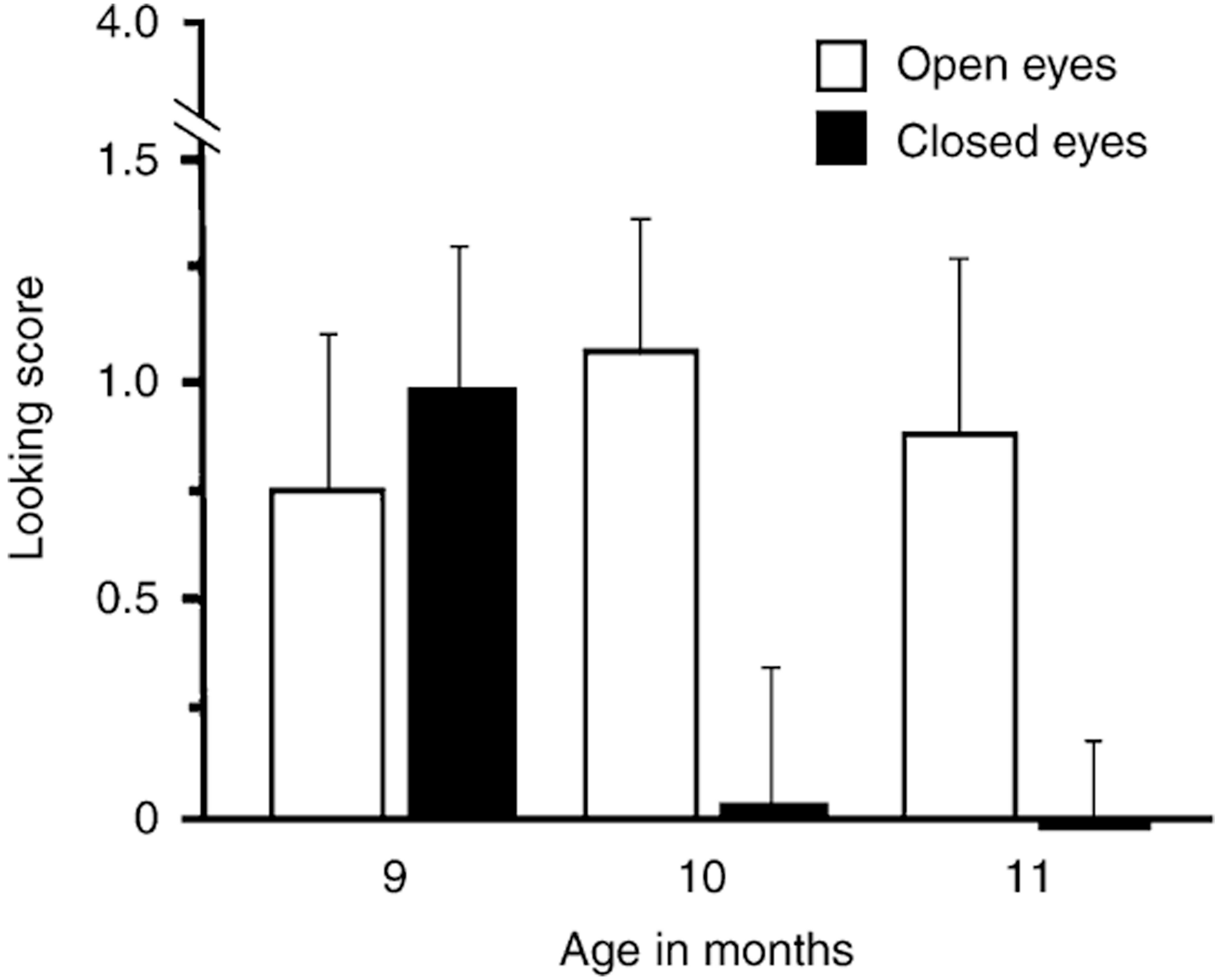

Figure 1.
Mean (SE) looking score as a function of age and condition.

Table 1

Correlations between gaze following and language scores (MacArthur-Bates Communicative Developmental Inventory, CDI)

Age and measure	14-month CDI[a]				18-month CDI[b]			
	Phrases und.	Words und.	Words prod.	Total gest.	Phrases und.	Words und.	Words prod.	Total gest.
10–11 months								
Looking score	.32	.12	−.22	.31	.32	.17	.09	.61**
Correct gaze + voc.	.57**	.49*	.24	.78***	.47*	.64***	.29	.55**
14 months								
Phrases understood	–	.70***	.36	.61**	.63**	.79***	.46	.58*
Words understood		–	.65**	.64**	.56*	.83***	.81***	.52*
Words produced			–	.43	.38	.59*	.79***	.29
Total gestures				–	.45	.71**	.56*	.75***

Note:

[a] $n = 20$,

[b] $n = 24$ with 10–11 months and $n = 16$ with 14 months.

* $p < .05$,

** $p < .01$,

*** $p < .001$.