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The Importance of Eyes: How Infants Interpret Adult Looking Behavior

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Two studies assessed the gaze following of 12-, 14-, and 18-month-old infants. The experimental manipulation was whether an adult could see the targets. In Experiment 1, the adult turned to targets with either open or closed eyes. Infants at all ages looked at the adult's target more in the open- versus closed-eyes condition. In Experiment 2, an inanimate occluder, a blindfold, was compared with a headband control. Infants 14- and 18-months-old looked more at the adult's target in the headband condition. Infants were not simply responding to adult head turning, which was controlled, but were sensitive to the status of the adult's eyes. In the 2nd year, infants interpreted adult looking as object-directed—an act connecting the gazer and the object.

Gaze following occurs when a person looks where another person just looked. Among adults, detecting the direction of another's gaze is a crucial component of social interactions (Argyle & Cook, 1976; Kleinke, 1986; Langton, Watt, & Bruce, 2000). Gaze following is important from a developmental perspective (Butterworth, 1991; Scaife & Bruner, 1975); for example, individuals with autism have profound deficits in gaze following (Baron-Cohen, 1995; Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Sigman & Ruskin, 1999). Gaze following has been implicated as a building block for developing a "theory of mind" (Baldwin & Moses, 1994; Lee, Eskritt, Symons, & Muir, 1998; Meltzoff & Brooks, 2001). In particular, it is relevant for understanding the meaning of an emotional display because a person's emotion is often "about" what he or she sees in the external world (e.g., that object is pleasant vs. dangerous). One needs to be able to follow gaze to understand the cause and meaning of a person's emotional behavior (Moses, Baldwin, Rosicky, & Tidball, 2001; Repacholi, 1998). Language acquisition is also facilitated by understanding another's line of regard. In the prototypical case, a verbal label refers to the object being looked at and not the other objects that may be in the room (Baldwin, 1995; Bloom, 2002; Tomasello, 1995).

The act of looking at something may take on a referential meaning even to infants (Scaife & Bruner, 1975). The commonsense view is that infants look at the same object as the adult because they want to see what the adult is seeing. From this perspective, infants implicitly understand that the other person is directing his or her own attention to something (Baron-Cohen, 1995; Carpenter, Nagell, & Tomasello, 1998). This interpretation grants a complex interpersonal understanding to infants because it implies that infants interpret the triadic relationship of seeing or attention between themselves, the adult, and the object (Perner, 1991).

Some researchers have offered a more conservative or "leaner" interpretation of infants' gaze following (Langton et al., 2000; Moore, 1999; Moore & Corkum, 1994; Povinelli, 2001). Researchers have suggested that "looking at an object" can be processed as merely an observable movement—the movement of the gazer's head draws the infant's attention to a section of space. This would not require any understanding about the gazer's attention or a reference to the object. Infants may coincidently look at the same object as the adult because they notice the most salient object in the hemifield to which they have been drawn (Butterworth & Jarrett, 1991).

It should be noted that there are several debates being intertwined here. One is about the psychological *attributions* infants make to the adult. The other concerns the *necessary and sufficient cues* for eliciting gaze following. These are correlated but not identical debates. The natural alliances are for those advocating the lean interpretation about cues to also be conservative about attributions. After all, if infants are merely swept to a hemifield of space by another's head movement, there is little reason to argue that gaze following is bound up with the attribution of mental states.

No single study about cues, no matter how well-designed, is likely to provide definitive conclusions about infants' attributions. As shown repeatedly in the history of psychology and philosophy, in schools of thought such as behaviorism, arguments can be mustered to show that even adults (no less infants) are simply smart readers of others' behavior and need not rely on making attributions of mind to other humans (Ryle, 1949). Nonetheless, empirical work provides grist for the debate. If young infants simply follow global head movements to a hemifield but older infants do more than this and selectively follow only when an adult can see the target, this begins to raise questions about the young

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child's developing understanding of "seeing" as psychological connectedness between observer and object (e.g., Flavell, 1988, 2001).

Researchers have explored whether head movement is sufficient to elicit infant gaze following by manipulating the head-turn angle and the placement of targets. Between 6 and 12 months of age, infants follow another person's gaze, especially if the targets are within their visual field (Butterworth & Jarrett, 1991; Deák, Flom, & Pick, 2000; D'Entremont, 2000; Morissette, Ricard, & Décarie, 1995). However, careful examination of infants' gaze following reveals that in many cases they do not look at the same target as the adult, but rather match the general direction of the adult turn. Specifically, when given a choice between two potential targets in the correct half of the room, infants usually stopped searching for a target when they arrived at the first available target on their own scan path (Butterworth, 1991). Because of this response pattern, some theorists have argued that the adult's head turn pulls infants in the generally indicated direction, providing support for the leaner interpretation of gaze following (Butterworth & Grover, 1990; Moore, 1999).

Researchers have also investigated which features (e.g., head, eyes) are necessary for gaze following. For example, Johnson, Slaughter, and Carey (1998) presented 12-month-old infants with a round, furry toy animal. The animal either had a face or not and either interacted contingently with the infant or not. The results showed that the 12-month-old infants turned in the same direction as the faceless, eyeless animal as long as it had previously interacted with them in a contingent manner. The authors interpreted these findings to mean that adult eye gaze was not necessary for infant turning.

In another study, Corkum and Moore (1995) pitted the direction of head movement against eye movement to assess which one elicited a response from infants. They tested whether 6- to 19-month-old infants follow eye gaze in conditions such as (a) turns of the eyes (with head remaining forward), (b) turns of the head (with eyes forward), and (c) head and eyes turning in opposite directions. The youngest infants to reveal a significant turning pattern were the 12-month-olds, and they matched the direction of head orientation rather than eye orientation. In this study, there was no age at which infants followed the adult's gaze when only eyes were turned in the absence of head movement. On the basis of these results and others (Caron, Butler, & Brooks, 2002), a number of authors have suggested that the adult's head movement often directs where infants look because it is distinct and salient enough to override eye-gaze information (Corkum & Moore, 1995; Farroni, Johnson, Brockbank, & Simion, 2000; Moore & Corkum, 1998).

It is important to realize, however, that when head and eyes point in different directions, this presents young infants with a conflict between cues. For example, showing the eyes turning left while the head moves to the right provides an unnatural and potentially confusing display. If we design a test in which the head and eyes are not in conflict, we may find that infants are more sensitive to the role of eyes than previous studies suggest.

We designed a study comparing infants' reactions to an adult who either had open or closed eyes as she turned toward a target. This controls for the head movement, because the movement is identical whether the eyes are open or closed. Surprisingly, few studies of human infants have assessed gaze following in open-versus closed-eyes conditions (for an exception, see Caron et al., 2002). The closed-eyes stimulus has been used to test older children's understanding (O'Neill, 1996) and has also been used by Povinelli (2000) in work with chimpanzees. Povinelli argued that chimpanzees do not understand the meaning of eye closure inasmuch as they are as likely to direct food-begging gestures to an adult with an unobstructed view of objects as to an adult with an obstructed view (i.e., closed eyes, a blindfold, or a bucket-over-the-head). Systematic tests with human infants seemed worthwhile.

We also reasoned that progress could be made in addressing questions about the meaning of infant gaze following and the attributions legitimately credited to infants if we moved beyond narrow data collection strategies. The focus has traditionally been on whether infants follow the adult's gaze. It became apparent to us in pilot studies, however, that gaze following is only one component of a richer envelope of social behavior. It is this cluster that is so striking in face-to-face adult interaction and so absent in children with autism and in other animals. For example, infants typically use a rich repertoire of behaviors to indicate objects when adults are present, including vocalizing and pointing (Franco & Butterworth, 1996; Moore & D'Entremont, 2001). Humans may be the only species that uses their index finger to draw a conspecific's attention to a location or object in space (Butterworth, 1991). In addition to measuring infants' looking behavior, we investigated whether infants would use pointing and vocalizing more often when the adult turned to look at a distal object with open rather than closed eyes.

Experiment 1

The study investigated whether adult head turns with open versus closed eyes differentially influenced infants' target-directed acts. The primary measure was infant looking at the target, but we also measured infant pointing and vocalizing. The principal experimental question was whether infants rely exclusively on head direction or use the status of the adult's perceptual organs (open vs. closed eyes) to govern their behavior. In the former case, infants would simply look toward the targets regardless of whether the viewer could or could not see the targets. In the latter case, infants would look more often at a target indicated by an adult's open-eyes than closed-eyes head turn. Previous research suggests that there may be a developmental change in gaze following between 12 and 18 months (Corkum & Moore, 1995; Franco & Butterworth, 1996), and therefore that was the developmental window selected for study.

Method

Participants

The participants were 96 infants, with 32 infants at each of the following three ages: 12 months (M = 12.2 months, SD = 3.1 days); 14 months (M = 14.1 months, SD = 3.6 days); and 18 months (M = 18.1 months, SD = 4.0 days). The children were recruited by telephone calls from the University of Washington's infant studies participant pool. All infants were full-term (37–43 weeks) with normal birth weight (2.5–4.5 kg) and had no major complications at birth. Half the infants at each age were randomly assigned to the open-eyes condition, and the other half were assigned to the closed-eyes condition. Equal numbers of girls and boys were assigned to each age and condition. Additional infants were excluded because of sleepiness and fussiness ($n = 12$), repeated infant movement at trial onset ($n = 4$), parental interjections ($n = 4$), and procedural error ($n = 6$). Parents gave informed consent for their infants' participation and received a reimbursement for their parking expenses.

Experimental Setting and Apparatus

The experiment took place in a room with uniform wall coloring and plain window curtains. Two chairs faced each other across a table (75 cm). One chair was set for the infant to sit on a parent's lap, which situated the infant across from the experimenter at approximately eye level. On either side of the infant (at a distance of 135 cm) were two identical, colorful toys (16 cm $\times$ 9 cm) resting on plain pedestals (93 cm tall). The targets were approximately at the eye level of the infants and at a 75° angle from the infants' midline. This placement corresponded to a 70° angle from the experimenter's midline. A black curtain underneath the table hid additional materials that were necessary for the study, including toys for the intertrial interval.

The main camera, which recorded the infant's face and upper body, was synchronized to another camera that recorded the experimenter's behavior. Each camera sent audiovisual feed to separate VHS recorders in an adjacent control room. A character generator added synchronized time codes (accurate to 1/30th of a second) to each recording for scoring purposes.

Procedure

Before their arrival, infants were randomly assigned to either the open-eyes or the closed-eyes condition. Preceding the session, the parent was instructed to refrain from moving his or her own head and body and from talking during the trials. After warm-up play at the table, the experimenter placed the targets on the peripheral pedestals (counterbalanced left vs. right side for first target placement). Then, the experimenter resumed playing with the infant by using a toy at the table.

Before the start of each head-turn trial, the experimenter dropped the tabletop toy out of view. Next, the experimenter made eye contact with the infant to ensure that every infant began the trial in a controlled fashion, namely at midline and looking directly at the experimenter's face. For the closed-eyes condition, after the experimenter made eye contact with the infant, she closed her eyes and then turned her head to the predetermined angle (i.e., aligning with one target). For the open-eyes condition, the adult turned her head with open eyes. In every trial, the experimenter turned silently. Each 6.5-s trial started when the adult began to turn her head to the side. This trial length was selected because a majority of previous studies used trials in the 5- to 7-s range (Butterworth & Jarrett, 1991; Caron et al., 2002; Corkum & Moore, 1995; Moore & Corkum, 1998; Morissette et al., 1995; Scaife & Bruner, 1975), and because in our own pilot work, infants became bored or fussy during significantly longer trials. A timer provided a silent, tactile signal for the experimenter at the end of each trial. After the trial, the experimenter returned to midline, made eye contact with the infant, and resumed the play interaction.

Four trials were conducted with approximately a 2-min intertrial interval. The direction in which the experimenter turned followed either a pattern of ABAB or ABBA, with the direction of the first turn counterbalanced (left vs. right) and with each pattern counterbalanced with condition, age, and gender. Four trials were always presented, but infrequently one trial was excluded because of infant movement (e.g., looking down) during trial onset (2.9% of the trials) or procedural error (1.3% of the trials).

Scoring

For scoring, the coder did not see the adult movement and was kept uninformed about condition (open vs. closed eyes) and direction of experimenter turn. The coder scored the 96 infants in a random order. She was informed as to the two target locations, although the targets were not visible in the display. Infant behaviors were tallied according to the dependent measures described below.

Looking score. Looking was scored when the infants' eyes and head aligned with one target for at least 0.33 s (10 video frames). Within each trial, an infant's first look was designated as either a "correct look" if it matched the target of the experimenter's turn (+1) or an "incorrect look" if it was to the opposite target (−1). If infants did not look at either target (e.g., stared at the experimenter or looked down), they received a score of 0 indicating "nonlooking." As is the standard practice in gaze-following literature, the looking score for each infant was the sum of the correct looks, incorrect looks, and nonlooks (e.g., Butler, Caron, & Brooks, 2000; Corkum & Moore, 1995; Deák et al., 2000; Johnson et al., 1998; Moore & Corkum, 1998). For example, if an infant looked correctly on two trials, incorrectly on one trial, and did not look at all on one trial, then the infant's looking score was +1. The possible range of scores was from −4 to +4.

Average duration of correct looks. For each child, the average duration score was a calculation based on the total duration of correct looks divided by the number of trials with a correct look.

Vocalizing score. Voiced sounds that occurred synchronously with a look at a target were tallied (with vegetative sounds, such as sighs and coughs, excluded). *Occurred synchronously with* was operationally defined as starting within 0.33 s of infant-looking behavior. For each trial, the first such vocalization was scored as correct if it occurred synchronously with a correct target look (+1) or incorrect if it occurred with an incorrect target look (−1). Trials without a target-directed vocalization received a score of 0. The vocalizing score was a sum based on four trials, resulting in a possible range from −4 to +4.

Pointing score. Points were either index-finger or whole-hand points (with all fingers extended; Leavens & Hopkins, 1999).[1] The first point to a target was coded as correct (+1) or incorrect (−1) for each trial, and any trials without a target-directed point received a score of 0. The pointing scores from the four trials were tallied, resulting in a possible range from −4 to +4.

Scoring Agreement

The inter- and intraobserver agreement scores were evaluated by reviewing a random sample of 25% of the infants. The second observer was uninformed of the experimental condition and direction of experimenter turns. Using Cohen's kappa, the interrater agreement was excellent (Bakeman & Gottman, 1997) for all dependent measures: looking score (.89), pointing (.99), look duration (.98), and vocalizing (.95). The intrarater agreement was also high for the looking score (.92) and the pointing, look duration, and vocalizing scores (.99, .99, and .95, respectively).

Results and Discussion

Looking at the Target

A 2 (condition: open vs. closed eyes) $\times$ 3 (age: 12, 14, and 18 months) $\times$ 2 (gender) analysis of variance (ANOVA) for looking scores yielded a significant condition effect, $F(1, 84) = 23.73$, $p <$

[1] Because infants' full hands were not visible on 40% of the trials with "points," the coding on those trials was simplified to an arm extension that aligned with a target location.

.01.[2] The open-eyes condition ($M = 1.75$) had significantly higher looking scores than the closed-eyes condition ($M = 0.46$), as shown in Figure 1. No other effects reached significance. The effect of condition was significant at each age considered individually.

The looking score reported above is the standard measure used in the field (e.g., Butler et al., 2000; Moore & Corkum, 1998). Table 1 provides more elementary data from which the score is derived. Infants showed (a) more looking to the correct target in the open-eyes ($M = 2.06$) than closed-eyes condition ($M = 0.73$), $t(94) = 5.98$, $p < .01$; (b) more nonlooking in the closed-eyes ($M = 2.77$) than open-eyes condition ($M = 1.52$), $t(94) = 5.01$, $p < .01$; and (c) infrequent looking to the incorrect target, which did not significantly vary by condition.

We also analyzed each infant's first trial data. The first trial was categorized as either correct (looked at correct target) or not correct (nonlook or looked at incorrect target). A 2 (open vs. closed eyes) × 3 (age) logistic regression yielded a significant effect of condition, $\chi^2(1, N = 96) = 4.53$, $p < .05$. No other effects were significant. More infants looked at the correct target in the open-eyes condition (22 of 48) than in the closed-eyes condition (12 of 48).

Average Duration of Correct Looks

A Condition × Age × Gender ANOVA for average duration of correct looks revealed a significant effect for condition, $F(1, 53) = 6.30$, $p < .05$. Infants looked longer at the correct target in the open-eyes ($M = 1.88$, $SD = 0.94$, $n = 43$) than in the closed-eyes condition ($M = 1.25$, $SD = 0.68$, $n = 22$). There were no other significant effects.

Vocalizing at the Target

We conducted a Condition × Age × Gender ANOVA for infants' vocalizing scores. Infants' vocalizing scores were higher when the adult turned toward the targets with open eyes ($M = 0.87$, $SD = 1.02$) than with closed eyes ($M = 0.08$, $SD = 0.61$), $F(1, 84) = 20.80$, $p < .01$. No other effects were significant. For consistency, these scores were initially analyzed in the same manner as the looking scores. However, vocalizing is different from looking because only a subset of infants vocalized at the target; therefore, we also conducted further analyses in which infants were simply categorized by whether or not they vocalized at a correct target. A Condition × Age logistic regression revealed a significant condition effect, $\chi^2(1, N = 96) = 17.96$, $p < .01$. Of the 48 infants in the open-eyes condition, 29 produced a correct vocalization in one or more trials, whereas only 7 of 48 did in the closed-eyes condition. No other effects were significant.

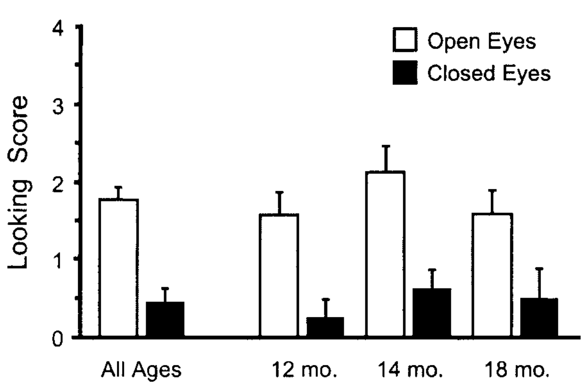

Figure 1. Mean looking score (+*SE*) for open-eyes and closed-eyes conditions, overall ($N = 96$) and at each age ($n = 32$). mo. = months.

Pointing at the Target

The pointing scores were entered into a Condition × Age × Gender ANOVA. The main effect of condition was significant, $F(1, 84) = 13.26$, $p < .01$, with the pointing scores higher in the open-eyes ($M = 0.71$, $SD = 1.05$) than in the closed-eyes condition ($M = 0.12$, $SD = 0.39$). There were no other significant effects. Figure 2 shows an infant pointing to the correct target after the adult looked at it. Again, we conducted a supplementary analysis because the number of infants who pointed was small. As expected, a Condition × Age logistic regression yielded a significant condition effect, $\chi^2(1, N = 96) = 14.90$, $p < .01$, with more infants pointing at the correct target in the open-eyes condition (28 of 48) than in the closed-eyes condition (8 of 48). There was also a significant age effect, $\chi^2(1, N = 96) = 5.87$, $p < .05$, with fewer infants pointing to the correct target at 12 months (6 of 32) than at either 14 months (15 of 32) or 18 months (15 of 32).

In this study, the manipulation was whether an adult had her eyes open or closed during a head turn to the side. In both conditions, the adult moved her head in an identical manner toward a peripheral target. The results showed that infants respond differentially as a function of the adult's eyes. First, infants looked more often at targets indicated by turns with open eyes than with closed eyes, and did so from the very first trial. Second, the target held their interest longer when indicated with open eyes than with closed eyes, even though the targets were identical in appearance. Finally, the infants pointed or vocalized more frequently at the indicated target after the adult turned with open eyes than with closed eyes.

Eye closure is only one way to block a person's view of an object. From an adult perspective, blindfolds have the same function as closed eyes—both prevent visual access. However, young infants may not understand all visual occluders. For example, a recent study suggested that it is only by 18 months of age that children discriminate a wall (i.e., as a visual obstruction) from a window in a gaze-following study (Butler et al., 2000).

Experiment 2

We presented 12-, 14-, and 18-month-old infants with a person who turned toward a target wearing either a headband or a blindfold. In both instances, the person had the same novel feature—an opaque cloth covering part of her face—but in one situation it covered the forehead and in the other it covered the eyes. If infants simply react to the novelty of the cloth, they would refrain from looking at the targets in both conditions. If infants do not recognize blindfolds as a visual obstruction, infants would look at indicated

[2] Nonparametric approaches (Mann–Whitney U tests) also yielded significant effects of open versus closed eyes for each of the principal dependent measures: looking, look duration, pointing, and vocalizing.

Table 1
Mean Frequency (and Standard Deviations) of Infants' Looking Behavior

Behavior	Across ages		12 months		14 months		18 months	
	Experiment 1: Eyes							
	Open	Closed	Open	Closed	Open	Closed	Open	Closed
Correct looks	2.06	0.73	1.69	0.44	2.37	0.81	2.12	0.94
	(1.19)	(0.98)	(1.35)	(0.81)	(1.09)	(1.05)	(1.09)	(1.06)
Nonlooks	1.52	2.77	2.06	3.12	1.37	2.75	1.12	2.44
	(1.30)	(1.13)	(1.53)	(0.96)	(0.89)	(1.24)	(1.31)	(1.15)
Incorrect looks	0.31	0.27	0.12	0.19	0.25	0.19	0.56	0.44
	(0.55)	(0.61)	(0.34)	(0.40)	(0.45)	(0.40)	(0.73)	(0.89)
	Experiment 2: Cloth occluder							
	Headband	Blindfold	Headband	Blindfold	Headband	Blindfold	Headband	Blindfold
Correct looks	2.00	0.96	1.56	1.06	2.19	0.87	2.25	0.94
	(1.38)	(1.03)	(1.50)	(1.00)	(1.38)	(0.89)	(1.24)	(1.24)
Nonlooks	1.48	2.67	1.81	2.69	1.25	2.69	1.37	2.62
	(1.43)	(1.15)	(1.83)	(1.08)	(1.29)	(1.30)	(1.09)	(1.15)
Incorrect looks	0.46	0.27	0.56	0.12	0.50	0.31	0.31	0.37
	(0.68)	(0.49)	(0.73)	(0.34)	(0.73)	(0.48)	(0.60)	(0.62)

Note. Total $N = 192$. The scores have a possible range from 0 to 4 because each participant had four trials.

targets even when the adults' eyes are covered. If infants recognize that a blindfold blocks a person's view but headbands do not, they would look significantly more often at targets indicated by an adult in the latter than in the former condition.

Method

Participants

The participants were 96 infants, with 32 infants at each of the following three ages: 12 months ($M = 12.1$ months, $SD = 3.9$ days); 14 months ($M = 14.1$ months, $SD = 4.3$ days); and 18 months ($M = 18.1$ months, $SD = 3.3$ days). Infants were recruited in the same manner via telephone calls and with the same inclusion criteria as in Experiment 1. Equal numbers of girls and boys were randomly assigned to one of two conditions: headband or blindfold. Additional infants were excluded because of sleepiness and fussiness ($n = 4$), repeated infant movement at trial onset ($n = 9$), parental interjections ($n = 1$), and procedural error ($n = 5$). Parents gave informed consent for their infants to participate. Families also received \$10 and a parking fee reimbursement.

Figure 2. An 18-month-old infant pointing at the correct target.

Experimental Setting and Apparatus

The setting and apparatus were the same as described in Experiment 1, except that a black, opaque, rectangular cloth was included as part of the stimulus condition. This cloth was 6.5 cm × 51.0 cm.

Procedure

The procedure was the same as described in Experiment 1, except for minor changes necessitated by using the cloth occluder. To introduce the cloth to the infants, it was initially wrapped around the first toy and was made available for them to manipulate. During this warm-up phase, the experimenter wrapped the cloth around each of her own wrists (left vs. right counterbalanced) and said, "Sometimes, I like to wear the bandana." The experimenter always referred to the cloth as a "bandana" or "this." Before the experimenter placed the targets, she put the cloth around the top of her head, above her hairline.

The experimenter prepared for each trial by moving the cloth. For the blindfold condition, she pulled the cloth down to cover her eyes and eyebrows, whereas in the headband condition, she pulled it down to cover her forehead above her eyebrows. In both conditions, she maintained eye contact with the infant during the cloth movement. At the end of each trial, the experimenter returned the cloth to the top of her head and then resumed interacting with the infant. Four trials were always presented, but infrequently a single trial was excluded because of infant movement during trial onset (1.8% of the trials) or procedural error (0.3% of the trials).

Scoring

Infants' target looks, points, vocalizations, and look duration were scored in the same manner as in Experiment 1. For a random sample of 25% of the infants, interrater and intrarater agreement was assessed with Cohen's kappa. The interrater agreement was excellent (Bakeman & Gottman, 1997): looking (.99), duration (.98), pointing (.88), and vocalizing (.99). The intrarater agreement was also excellent for these same scores, respectively: .99, .99, .96, and .94.

Results and Discussion

Looking at the Target

Infants' looking scores were submitted to a 2 (condition: headband vs. blindfold) × 3 (age: 12, 14, and 18 months) × 2 (gender) ANOVA. As seen in Figure 3, looking scores were significantly greater in the headband condition ($M = 1.54$) than in the blindfold condition ($M = 0.69$), $F(1, 84) = 8.20$, $p < .01$. There were no other significant effects. We also analyzed each age separately because of previous findings showing that infants younger than 18 months do not readily understand that a physical object, such as a wall, occludes a person's line of sight (Butler et al., 2000). At 12 months, there was no significant difference between headband ($M = 1.00$) and blindfold conditions ($M = 0.94$), $p > .50$, but at 14 and 18 months, infants scored significantly higher in the headband than in the blindfold condition ($ps < .05$).

As noted in Experiment 1, the looking scores are the standard measure used in the field, but Table 1 presents the elementary data from which the scores are derived. As expected, infants produced more correct looks in the headband condition ($M = 2.00$) than in the blindfold condition ($M = 0.96$), $t(94) = 4.18$, $p < .01$, and more nonlooks in the blindfold condition ($M = 2.67$) than in the headband condition ($M = 1.48$), $t(94) = 4.48$, $p < .01$. Incorrect looks were infrequent and did not significantly vary by condition.

The first trial data revealed a significant pattern. A 2 (headband vs. blindfold) × 3 (age) logistic regression for the first trial yielded a significant condition effect, $\chi^2(1, N = 96) = 13.73$, $p < .01$. More infants produced correct looks in the headband condition (24 of 48) than in the blindfold condition (6 of 48). No other effects were significant.

Average Duration of Target Looks

A Condition × Age × Gender ANOVA showed no significant main effects or interactions, but the average duration of correct looks was greater in the headband ($M = 1.66$, $SD = 0.84$, $n = 37$) than in the blindfold condition ($M = 1.41$, $SD = 1.04$, $n = 27$).

Vocalizing at the Target

Infants' vocalizing scores were entered into a Condition × Age × Gender ANOVA. Vocalizing scores were higher in the headband ($M = 0.65$, $SD = 0.98$) than in the blindfold condition ($M = 0.25$, $SD = 0.73$), $F(1, 84) = 4.87$, $p < .05$. There were no other significant effects. An alternative Condition × Age logistic regression revealed the same picture: a significant effect of condition, $\chi^2(1, N = 96) = 5.22$, $p < .05$, with more infants vocalizing at the correct target in the headband condition (22 of 48) than in the blindfold condition (11 of 48).

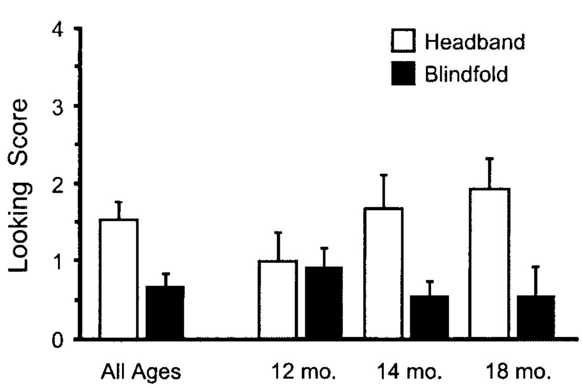

Figure 3. Mean looking score (+*SE*) for headband and blindfold conditions, overall ($N = 96$) and at each age ($n = 32$). mo. = months.

Pointing at the Target

Infants' pointing scores were analyzed with a Condition × Age × Gender ANOVA. The condition effect was significant, $F(1, 84) = 4.85$, $p < .05$. Infants' pointing scores were higher in the headband condition ($M = 0.54$, $SD = 1.01$) than in the blindfold condition ($M = 0.17$, $SD = 0.66$). There was also a significant effect of age, $F(2, 84) = 4.50$, $p < .05$. Post hoc tests (Student Newman–Keuls, $p < .05$) revealed that 18-month-olds ($M = 0.66$, $SD = 1.10$) had higher pointing scores than 12-month-olds ($M = 0.03$, $SD = 0.18$), but 14-month-olds ($M = 0.37$, $SD = 0.94$) did not differ significantly from the other two age groups. There were no other significant effects. As expected, the supplementary logistic regression with age and condition yielded a significant effect for condition, $\chi^2(1, N = 96) = 5.36$, $p < .05$, with more infants (20 of 48) pointing to a correct target in the headband condition than in the blindfold condition (10 of 48). There was also a significant effect of age, $\chi^2(1, N = 96) = 9.23$, $p < .01$. The number of 12-month-old infants who correctly pointed was low (9%) and increased to 34% at 14 months and 50% at 18 months.

The primary goal of the second study was to use a different occluder from the natural biological motion of eye closure. In this study, all adult head turns had an odd or unusual feature (i.e., a cloth over part of the face), but the cloth did not globally disrupt infant gaze following. Infants consistently followed head turns when the adult had the novel feature on her forehead (i.e., a headband) and rarely followed when the novel feature covered her eyes (i.e., a blindfold). They also vocalized and pointed more often at the indicated target when the turning adult wore a headband compared with a blindfold.

General Discussion

A lean interpretation of gaze following is that a visual movement simply drags infants' attention to a hemifield of space where they (happen to) see an interesting object. The adult head movement pulls infants' attention to the indicated side. The current findings indicate that such a mechanism does not provide a full explanation of the behavior of infants in the second year of life, although it remains possible for younger infants (D'Entremont, 2000; Farroni et al., 2000). In the experiments reported here, head movement was controlled. The results show that infants are significantly more likely to look at the indicated target when the adult has an unobstructed view of the target (open eyes or headband) rather than an obstructed view (closed eyes or blindfold).

The effect is evident from the very first trial. Even when facing an atypical adult—one wearing a black cloth on the face—more infants immediately chose to gaze follow when the adult could see (headband) than when she could not see (blindfold). Infants bring the tools into the laboratory to handle this type of novel gaze-following situation.

The current work goes beyond the standard looking measure. We also analyzed how *long* infants look at the adult's target. Even if we select only correct looks at the target, we find that infants examine the target longer when the adult turns toward it with open eyes than with closed eyes. Put another way, even if the adult's head turning brings infants' attention to an object, turning with open eyes prompts them to inspect the object longer than does turning with closed eyes. It is not just a matter of attention getting but also of attention holding. Objects acquire a special valence for infants when adults look at them. This is joint attention, or to use a more conservative term, *joint perceptual exploration*, in action.

The duration measure also allows us to address issues that are left unanswered by the usual looking scores. For example, one alternate explanation to consider is that eye closure (or coverage) creates a global disruption in the interaction (e.g., Tronick, Als, Adamson, Wise, & Brazelton, 1978). The duration measure joins a trio of arguments that counter this possibility as an explanation of the obtained effects. First, although confronting an infant with an *en face* adult who holds her eyes closed for a long time would indeed be disruptive, that was not the procedure. The adult's eyes were shut only slightly longer than the blink of an eye (1 s) before turning toward the object. Second, we systematically reviewed the videotaped records and were not able to detect any difference in the emotional reactions as a function of condition. All infants displayed a calm or positive expression and rarely displayed any distress. Moreover, every infant looked at the adult's face as she began turning (after she closed or covered her eyes), so there was no evidence of aversion. Third, the duration measure becomes relevant because it allows us to measure the length of looking once the infant has turned to the correct target. Having already acted in a systematic way and selected the correct target, why would they look at it *longer* in one case and not in another? A natural explanation is that the infant is exploring the target just exactly because the adult is looking at it.[3]

It is also relevant to theory that infants marshal other target-directed acts, such as pointing and vocalizing, when the adult can see the target. Increased pointing and vocalizing means that infants are not simply mirroring the adult head turn: Infants use actions that the adult did not produce.

The current results match other studies reporting that pointing becomes more consistent by 15 months (Bakeman & Adamson, 1986; Desrochers, Morissette, & Ricard, 1995). We found that 12-month-olds rarely point to targets, but that 14- and 18-month-olds are much more facile pointers. The new piece of information added by this study is that infants point selectively. Infants at 14 and 18 months point more often when an adult can see the target than when she cannot see it. This addresses debates that have been raised in the infant-pointing literature (Bates, 1979; Butterworth & Grover, 1990; Moore & Corkum, 1994; Moore & D'Entremont, 2001). Three issues are addressed. First, the raw presence of a "social other" is controlled in all conditions because the adult is present in all cases. Second, infants cannot be pointing to the object solely because it is salient in and of itself (independent of the person looking at it) because the two identical objects are present in all conditions. Third, the objects were out of reach and infants made no apparent attempt to grasp them. Taken together, the results fit with the idea that infants at this age use pointing to refer to a shared visual object in a "proto-declarative" manner (Bates, 1979; Franco & Butterworth, 1996).[4]

The multiple measures (looking, looking duration, and pointing) provide a pattern of results supporting the hypothesis that eyes are important to infants. Infants interpret the adult's look as an "object-directed" act—as a referential act that connects the person and the external object. However, infants may not understand that looking leads to a mental state in the other person (Flavell, 1988, 2001). There is plenty of room for development. Indeed, we think that infants' processing of eye status is the foundation for developing a more mentalistic concept of seeing and attention. Paying attention to the status of the adult's eyes is the front end to developing concepts of "seeing" and "visual attention," which depend critically on the looker being in perceptual contact with the target object. Thus, gaze following is not an all-or-nothing litmus test for decisions about mentalistic attributions by infants. One could argue that gaze following based on the adult's eyes is a building block for later achievements, just as infants' early analysis of goals from actions is the foundation for later attributing more mentalistic notions of intention and theory of mind (Meltzoff, 1995, 2002; Meltzoff, Gopnik, & Repacholi, 1999).

Our findings also suggest a developmental change in infants' understanding that physical occluders block the adult's view. Older infants (14 and 18 months) treat blindfolds the same as eye closures, whereas younger infants do not. At 12 months, infants are just as likely to look at the indicated target when the adult wore a headband or a blindfold. They apparently do not recognize that a blindfold affects the adult's view.[5] This fits with other work showing that young infants have difficulty understanding that physical objects block other people's views (Butler et al., 2000; Flavell, 2001; Walden, Deák, Yale, & Lewis, 2002).

We speculate that infants' own self-generated experience with eye closing contributes to their understanding of eye closing in others. Infants open and close their eyes and gain experience of seeing or not seeing. According to Meltzoff's (2002) "like me" theory, infants use the self as an analogy for understanding others. Thus, infants may draw on their experience of their own eye closures to recognize the same effect for another person (Meltzoff & Brooks, 2001; see also Woodward & Guajardo, 2002; Woodward, Sommerville, & Guajardo, 2001). Peek-a-boo games between self and others may serve as a tutorial to test the effects of

[3] No single study can rule out every "lean" interpretation. For example, one could argue that infants track the motion of high-contrast units (eyes) and respond to their presence and direction of movement. However, this interpretation does not account for why infants rarely follow eye motion in "conflicted cue" studies, such as when eyes orient in an opposite direction from head orientation (Corkum & Moore, 1995; Moore & Corkum, 1998), or in the context of an inverted face (Farroni, Johnson, Mansfield, Lai, & Simion, 2002). If eyes are simply high-contrast displays to infants, they should look to the correct hemifield in these conditions as well. Moreover, the duration, pointing, and vocalizing data reported here are difficult to accommodate within this interpretation.

[4] Even if one argues that the points are "proto-imperative" (indicating that the infant "wants" one object), this supports the hypothesis that adult gaze carries essential information. In this case, the infant would come to desire one of two identical objects by virtue of the fact that the adult looked at it. Apparently, turning to the object with open eyes (vs. closed eyes), gives the object "desirability."

[5] Infants' following of the blindfold cue also provides evidence against a disruption account because 12-month-olds are not disrupted.

an occluder, and thus may be instrumental for broadening infants' understanding of visual obstructions beyond the eye-closure case.

In sum, infants are sensitive to the status of the perceptual organs. Although younger infants may see a head turn as a directional cue to a hemifield, 12- to 18-month-old infants grant special status to human eyes accompanied by head movement. They respond to this act by identifying the target indicated by the adult. They treat the adult's gaze as object-directed, referring to an external object. Such gaze following is an entrée into a psychological world in which things are important not only because of their physical properties, but because they are referred to by others. At this point, gaze following can be used as a stepping stone for further development, for example, identifying the referent of an adult's emotional reaction or linguistic label (Baldwin, 1995; Moses et al., 2001; Repacholi, 1998; Tomasello, 1995). Seen in this way, gaze following is a crucial developmental bridge. It links observable bodily acts with referential meaning about objects in the external world.

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