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Eyes Wide Shut: The Importance of Eyes in Infant Gaze-Following and Understanding Other Minds

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Why did they call him “Magic?” The skill that made Magic Johnson a unique basketball player is that he mastered the “no look” pass. He could pass the ball to a teammate without giving away his intentions through his pattern of gaze. Sometimes, in a particularly devious move, he “looked off” an opponent—he looked at a teammate just long enough to suggest that this player was going to receive the pass, but Magic really was attending to someone else, who was flipped the ball for an easy basket. In short, gaze direction and attention are separable. The former is usually a reliable indicator of the latter, but not always. For adults it is so natural to think that a person is attending where he is looking that one can deceive others by exploiting this default assumption. Psychologists have formal terms for capturing the difference: Gaze direction is a behavior; attention is a state of mind.

The Holy Grail for the developmental scientist is to discover the relation between infants’ treatment of gaze as a bodily act versus an index of a state of mind. Key questions are: (a) whether infants grasp anything more than the behavioral level, and if so, (b) at what age they begin to make more sophisticated

interpretations about “seeing” as a psychological connection between subject and object, and (c) how shall we characterize the attributions at different ages and what is the mechanism of change?

These questions, in turn, run into two familiar problems in developmental cognitive science. First, the words we use may be ill suited to describe infants’ developing interpretations. We are trapped between using terms from behaviorism, such as “conditioning” and “cues” (which may be too lean) and philosophical descriptions based on a full-blown theory of mind, such as “making manifest a mutual awareness” and “representational intentional states” (which may be too rich). We lack a technical vocabulary that captures midway stations. Second, we lack critical data points, and without these it is difficult to propose a mechanism of change.

It is as if we are early biologists who had seen baby tadpoles and adult frogs, but had not yet documented the connecting steps. In such a primitive state of science, there will be some who claim that baby tadpoles are clearly different from adult frogs with no possibility of one being the progenitor of the other—who could be so silly as to suggest that legless, gilled swimmers are the baby versions of lunged four-legged creatures that can drown? It was only when biologists began to study the *metamorphs*—tadpoles who sprouted legs—that the underlying process became clear and the old black-white vocabulary was abandoned as insufficient.

Regarding the ontogeny of gaze-following, we think we have captured tadpoles with legs. We have located a 90-day window in which there are important transformations in infants’ understanding of adult gaze. The critical time for the emergence of gaze-following is between about 260 days old to 350 days old, about 9 to 11 months of age. Based on these new findings, and converging work of others, we suggest that infants in the first 9 months of life do *not* understand gaze-following properly so called. They orient to where the adult’s head is turning, but do not specifically take into account the adult’s eyes, so they are not “gaze-following.” By 10 to 11 months of age, infants begin to follow gaze, as shown in their dual tendency to (a) follow a person who turns to look at an object with open eyes, but (b) refrain from following if the person makes the same head turn with closed eyes. However, infants at this age understand certain types of gaze obstructions (eyes closed) but not others (blind-folds). We argue that infants may use their *own experiences* of eye closure as the basis for making psychological attributions about these behavioral acts in others—the “Like Me” hypothesis (Meltzoff, 2005; Meltzoff & Brooks, 2001). Once infants come to understand that eyes are the organs to monitor in assessing others’ visual perceptions, they have made significant progress in acquiring a more adult-like understanding of the intentional states of others. (See Table 10.1.)

TABLE 10.1.
Developmental Changes in Understanding "Seeing"

9-month-olds	10- to 12-month-olds ^a	12- to 18-month-olds
Body following	Gaze-following	Target sharing Joint visual perception
Other as indicator, orienter	Other as looker with eyes differentiated as organ of seeing	Other has shared view which can be directed (e.g., by pointing)

^aInfants at 12 months are at a transitional age, as discussed in the text.

ASSESSING INFANT GAZE-FOLLOWING: EYES OPEN/CLOSED TEST

Rationale

For adults, certain bodily movements are imbued with particular meanings. If a person looks up into the sky, bystanders follow his or her gaze. The adults are trying to see what the other person is looking at. Adults realize that people acquire information from afar and are in *perceptual contact* with external objects, despite the spatial gap between perceiver and object. When do infants ascribe such distal perception to others? Is there a stage when head turns are interpreted as purely physical motions with no notion that they are *directed toward* the external object—no notion of a perceiver, perception, or a psychological relationship between subject and object?

It is well established that young infants turn in the direction that an adult has turned, but there is a debate about the mechanism underlying this behavior (e.g., Butterworth, 2001; Carpenter, Nagell, & Tomasello, 1998; Deák, Flom, & Pick, 2000; Eilan, Hoerl, McCormack, & Roessler, 2005; Moore & Dunham, 1995; Tomasello, 1995). One conservative proposal is that the behavior is based on infants being attracted to the spatial hemi-field toward which the adult's head is moving (Butterworth & Jarrett, 1991; Moore, 1999; Moore & Corkum, 1994). The infant notices the adult's head motion and thereby swings his or her own head to the correct half of space without processing the adult's gaze to an object. On this view, infants do not understand anything about the adult as a perceiver of an external target, but simply process the salient movements in space caused by the head, regardless of what the organs of perception, the eyes, are doing.

We developed a test procedure that zeroed in on whether infants understand the “object directedness” or a primitive referential version of adult gaze (Brooks & Meltzoff, 2002, 2005). Two identical objects were used, and the adult turned to look at one of them with no verbal or emotional cues. The principal manipulation was that the adult turned to the target object with *eyes open* for one group and with *eyes closed* for the other group. If infants relied simply on gross head motions, they should turn in both cases. If they relied solely on an abstract rule to look in the same direction as a “contingent interactant” or “agent” has turned (e.g., Johnson, Slaughter, & Carey, 1998), they should also look whether the adult’s eyes were open or closed, because it was the same person, with the same history of interactive behavior, who turned in both groups. If, however, infants understand that the eyes are relevant for connecting viewer and object, then they should differentiate the two conditions and turn to look at the target object in one situation and not the other.¹

The reason such a manipulation is crucial for theory is that we do, in fact, see with our eyes and not with our head. Our eyes are the organs of (visual) perception. It is an important step toward gaining the adult psychological interpretation of “seeing” for infants to come to understand that the eyes are critical. It is, after all, the eyes that are the window to the soul—the head is not such a portal.

Empirical Findings and Interpretation

Brooks and Meltzoff (2002) used the Gaze-Following: Eyes Open/Closed test to assess 12-, 14-, and 18-month-old infants. Each infant at each age was randomly assigned to a condition in which the adult turned to the target with either open or closed eyes. The targets were silent 3-D toys placed equidis-

¹This procedure has its own developmental roots. In the primate literature Povinelli (2000) measured food-begging responses to a person with open versus closed eyes, and reported no differentiation by chimpanzees. With older human children, Lempers, Flavell, and Flavell (1977) and O'Neill (1996) used verbal and manual measures to determine what older children know about open versus closed eyes. Of course, such techniques are not suitable for infants. The advance in Brooks and Meltzoff (2002) was to use a simple gaze-following measure within the capacity of young infants and to control for head movement by having the adult turn to an external object with open versus closed eyes. Contemporaneously, co-author Brooks also used eyes open/closed as one condition in another study (Caron, Butler, & Brooks, 2002), but this work may have dampened effects because it showed infants conflicting cues (e.g., eyes pointing ahead and head pointing to the side) in a within-subjects design. As argued in the text, indicating different directions to infants for the object location may confuse them across the test session.

tant from the infant, at approximately a 75° angle off midline. There were four trials (two to the left and two to the right in a counterbalanced order), and each trial was 6.5 s in duration. Thus, there were no linguistic or emotional cues as to where to turn, and no sound-localization cues because the targets were silent. The infant's behavior was videotaped and subsequently scored by an observer who remained blind to whether the adult turned with open or closed eyes and the direction of the adult turn. For each trial, an infant's first target look was categorized as a "correct look," when it aligned with the adult's target (+1), or an "incorrect look," when it aligned with the opposite target (−1). If infants looked at neither target, they received a score of 0 for "non-looking." As is standard in gaze-following procedures, the looking score was a total of the correct looks, incorrect looks, and non-looks (e.g., Butler, Caron, & Brooks, 2000; Flom, Deák, Phill, & Pick, 2004; Moore & Corkum, 1998). Thus, if an infant consistently looks at correct targets, she would have a positive score (with a maximum of 4), but if she frequently looks at incorrect targets, her score would be negative (with a minimum of −4).

The main findings are shown in Figure 10–1. Infants at all ages looked significantly more often at the target when the adult turned with open than with closed eyes. We also scored other behaviors beyond the traditional looking measure. We scored infants' average duration of correct looks. This revealed that infants *inspected the target longer* when the adult turned to it with open versus closed eyes. Also, more infants *vocalized* toward the correct target in the open-eyes than closed-eyes condition. Finally, significantly more

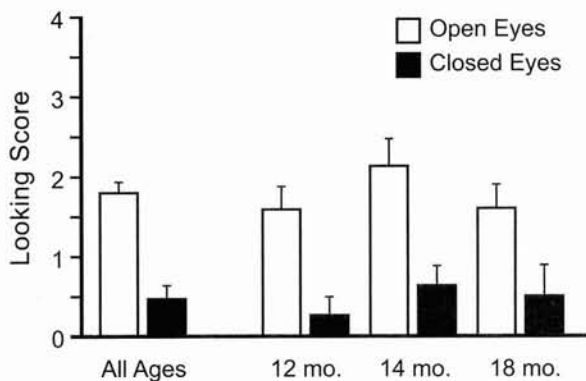


FIGURE 10–1. Infants look at the correct target more often in the open-eyes than the closed-eyes condition. (From Brooks & Meltzoff, 2002. Reprinted with permission of the American Psychological Association.)

infants *pointed to the targets* in the open-eyes condition than in the closed-eyes condition (Figure 10–2). This behavior is particularly striking because it is ostensive—the results show that infants are taking into account the perceptual status of the audience. They point when the social partner can see the objects, but refrain when the partner cannot (eyes closed), which Brooks and Meltzoff (2002) interpreted as evidence of “proto-declarative” pointing (see compatible interpretations about infant pointing by a set of converging studies using varying techniques: Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Camaioni, Perucchini, Bellagamba, & Colonnese, 2004; Franco & Butterworth, 1996; Liszkowski, Carpenter, Henning, Striano, & Tomasello, 2004).

We return now to the rationale for conducting this study. The lean interpretation of gaze-following is that a visible movement simply drags infants’ attention to a hemi-field of space where they (happen to) see an interesting object. It is the adult’s head movement that 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 1-year-olds, although it remains possible for younger infants. In the experiments reported here, head movement was controlled. The results show that infants are significantly more likely to look at the correct target when the adult has an unobstructed view of the target (open eyes) than an obstructed view (closed eyes).

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, these correctly oriented looks are longer when the adult

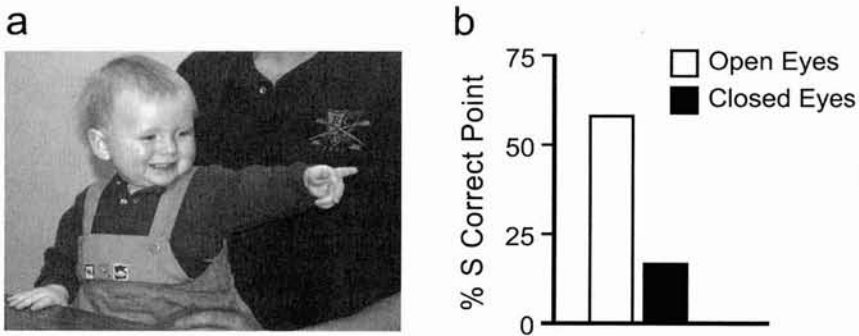


FIGURE 10–2. (a) A 12-month-old boy pointing at the target. (b) Infants selectively point to the target when the social partner has her eyes open versus eyes closed. This suggests that points are used in a “proto-declarative” manner and not produced solipsistically.

turns toward the object with open eyes than with closed eyes. Put another way, even if the adult's head turning brings infants' attention to an object, the adult's open eyes prompt infants to inspect the object longer in one case than the other. This visual inspection is important because the object, in itself, is the same whether the adult turns with open or closed eyes. The object takes on special valence because it is looked at by another person. *It is as if having the adult shine her psychological spotlight on an inanimate object leaves a trace on it, an invisible mark—the mark of having been inspected by someone else.* This shows joint perception or joint visual exploration, not simply directionally appropriate looking.

What These Findings Add

We thus wish to argue that 12-month-old infants should be credited with gaze-following. At first blush, this may not seem new given other reports (Butterworth & Jarrett, 1991; Carpenter et al., 1998; Deák et al., 2000; D'Entremont, 2000; Flom & Pick, 2005; Morales et al., 2000; Mumme & Fernald, 2003; Scaife & Bruner, 1975). However, most of these studies are open to Moore's (1999; Moore & Corkum, 1994) critique that infants could simply be following the direction of head movement.

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 the following conditions in a within-subjects design: (a) turns of the eyes (with the head facing forward), (b) turns of both the head and eyes, (c) turns of the head (with eyes facing forward), and (d) head and eyes turning in opposite directions. There was no age at which infants followed the adult's gaze when only eyes were turned in the absence of head movement. Based on these results and others, a number of authors are hesitant to confirm that 1-year-olds gaze follow, and reserve such capacity for 18 months or older (Corkum & Moore, 1995; 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 a display that indicates two contradictory places in space at the same time. This may dampen the effects. The Gaze-Following: Eyes Open/Closed test provides infants with a situation in which the head and eyes are not in conflict: It pits head direction + neutral eye information (eyes not looking anywhere because they are closed) against consonant head direction + eye direction information. Our finding that 1-year-old infants differentiate between the two conditions and respond appropriately

in the eyes open condition shows that the status of the eyes is responsible for the effects.

Heads vs. Eyes: Can We Escape a Lean View?

We argued herein that 12-month-old infants can be credited with gaze-following given their success in our procedure, but a critic might question one aspect of the procedure. One might wonder whether infants are simply "disrupted" by the sight of a person with eyes closed. If so, they may turn less often in the closed-eyes condition because they were disrupted from turning, due to the novelty of the situation or the break in interaction. This is an interesting point, but there are four arguments weighing against this interpretation.

First, although confronting an infant with an *en face* adult who holds her eyes closed for a lengthy time may be disruptive, that was *not* the procedure. The adult's eyes were shut only slightly longer than the blink of an eye (half a second) before the turning toward the object for a 6.5 s response period. There is nothing in the literature suggesting this would be disruptive (the still-face paradigm does not come into play at these short time intervals, D'Entremont & Muir, 1997; Tronick, 1989; Tronick, Als, Adamson, Wise, & Brazelton, 1978). 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 (see Brooks & Meltzoff, 2002, for a full analysis). Moreover, every infant looked at the adult's face as she began turning (after she closed her eyes).

Third, the duration measure is relevant, because it allows us to measure the length of looking *after* the infant has turned to the correct target. Disruption is not a parsimonious concept in this case, because the infant has chosen to follow the adult to the correct side. If we control for the fact that the infant is looking at the correct target (whether in the open- or closed-eyes condition), why would they inspect it *longer* in one case than another? A natural explanation is that the infant is visually inspecting the target just because the adult is looking at it—trying to see what the adult is looking at.

Fourth, infants marshal other target-directed acts, such as pointing at the target and vocalizing toward it when the adult can see the target. Increased pointing and vocalizing at the target indicates that infants are not simply turning to a hemi-field in space: Infants are generating actions that the adult did not produce. In short, the disruption idea is a logical possibility. However, the painstaking empirical work directed toward exploring this alternative provides both negative evidence (no signs of upset or disruption) and positive evidence (longer infant visual inspection and increased vocalizing and pointing to the target) that weigh against it.

A METAMORPHOSIS IN GAZE-FOLLOWING IN INFANCY

Rationale

The previous study showed that 12-month-olds gaze follow. The question remains as to when does this begin? The Gaze-Following: Eyes Open/Closed test provides a tool for looking at the ontogenesis of gaze-following before the child's first birthday.

Brooks and Meltzoff (2005) recently completed a study of infants during the tadpole era, from 9 months to 11 months of age. We used the same procedure as previously described, but tested infants within a remarkably controlled age window. The infants were recruited to fall at three discrete ages: 9, 10, and 11 months old, with each infant ± 1 week of the target age. This was the equivalent of a cross-sectional microgenetic study—we assessed infants at three moments over a 90-day growth period to see if we could capture a metamorphosis in behavior.

Empirical Findings and Interpretation

As shown in Figure 10–3, 9-month-olds did not discriminate between the open- versus closed-eyes conditions. They turned equally often in both cases. However, there was a clear developmental shift 30 days later. For 10-month-olds, the looking scores in the open-eyes condition were significantly greater than in the closed-eyes condition; and a similar significant effect was also evident among 11-month-olds.

We also analyzed whether infants vocalized while looking at the correct target, categorized as a “correct gaze + simultaneous vocalization.” (Infants

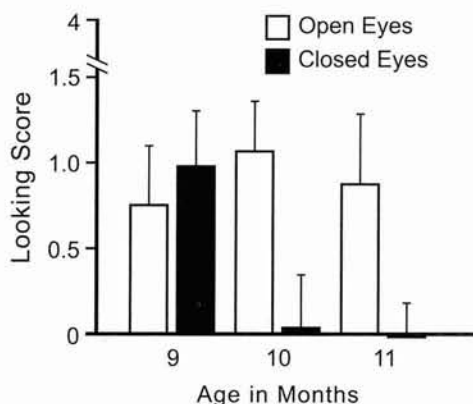


FIGURE 10–3. At 9 months of age infants turn indiscriminately to the target, whether or not the adult can see it. But at 10 and 11 months old, they selectively follow the gaze of the adult in the open-eyes condition. Note the sharp decline in looking when the adult cannot see the target (eyes closed). (From Brooks & Meltzoff, 2005. Reprinted with permission of Blackwell Publishing.)

at these young ages rarely point, but they sometimes vocalize when looking at the target, which may serve a referential function.) The results were significant, with more infants in the open-eyes condition (16 of 48) producing correct gaze + simultaneous vocalizations than in the closed-eyes condition (8 of 48), $p < .05$.

An alternate interpretation is that closed eyes are odd/disruptive to 10- to 11-month-olds. Similar to the earlier study, we scrutinized the records and found that infants in the closed-eyes group gave no signs of being upset, either at the onset of the eye closure or during the brief (6.5 s) response period. As a statistical test, we examined how long infants stared at the experimenter, which could "disrupt" looking to the target. The results showed that infants spent the same amount of time looking at the experimenter in the open-eyes as the closed-eyes condition (average of 60% and 64%, respectively), and with a similar pattern at each of the three ages (see Brooks & Meltzoff, 2005, for full details). In sum, there was no evidence that these young infants were disrupted by the closed-eyes condition. Rather, we believe they did not interpret the adult turn with closed eyes as being "about" or referring to the external object.

What These Findings Add

An important detail about these results is the nature of the developmental change observed. The most significant change between 9 and 10 months of age is the sharp *decline* in turning to the closed-eyes condition (see Figure 10-3). It is not that the 9-month-olds fail to follow the adult's turn. Quite the contrary, in fact, *they follow too much*; they turn even when the adult turns with closed eyes.

This is key for theory because it makes sense of the literature claiming that infants gaze follow starting as early as 3 or 4 months old (e.g., Butterworth & Jarrett, 1991; D'Entremont, Hains, & Muir, 1997; Flom & Pick, 2005; Morales, Mundy, & Rojas, 1998; Scaife & Bruner, 1975; Striano & Stahl, 2005). At first, this might seem in contradiction to our claim about the development of gaze-following at 10 months of age. But there is no contradiction. We believe that infants turn to follow the direction of head movements at 9 months and younger, but that they do not selectively gaze follow properly so called (as shown by their turning to the closed-eyes condition). In fact, a supplementary analysis demonstrates that our findings are very compatible with the other findings in the literature. If we select 9-month-olds in the open-eyes condition, we, too, can show that they consistently turn in the correct direction. The looking scores of the 9-month-olds in the open-eyes condition (Figure 10-2) are significantly greater than 0 (where 0 equals chance, i.e., equal turning to the correct and incorrect side). Thus we replicate the common finding of cor-

rect turning. The problem is not a lack of turning, but that 9-month-olds turn even if the adult cannot possibly see the target.

In sum, our data support the idea that genuine gaze-following develops at about 10 to 11 months of life and emerges from simpler beginnings (more about this later). Although leaner views are possible, our interpretation is that *visual* contact between the looker and the object first becomes important at 10 to 11 months (Brooks & Meltzoff, 2005). Whereas 9-month-olds may understand others as “body orienters,” older infants begin to understand others as “visually connected” to the external world and that the eyes are the critical organ. This is an important step in social cognition.

BIOLOGICAL VERSUS PHYSICAL OCCLUDERS

Rationale

There is a further important development that occurs at about 12 months of age. Eye closure is only one way to block the line of sight to an object. Another way is to use a physical object. From an adult perspective, blindfolds have the same function as closed eyes—both prevent visual access. Our results suggest that infants understand the consequences of eye closure (a biological motion) before they understand blindfolds (an inanimate object). This is fascinating because it opens the possibility that 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—the “Like Me” hypothesis for gaze-following (Meltzoff, 2005; Meltzoff & Brooks, 2001). This hypothesis will be examined in the conclusion of this chapter. For now, it is relevant to summarize the relevant blindfold data.²

Empirical Findings and Interpretation

In our study of inanimate occluders, a person turned toward a target wearing either a headband or a blindfold (Brooks & Meltzoff, 2002; Experiment 2). In both instances, the same cloth covered part of the experimenter’s face, but in one situation the opaque cloth was on the forehead and in the other it was over the eyes. We tested 12-, 14- and 18-month-old infants (all within 1 week

²Blindfolds are only one way of using an inanimate object to block a person’s view. A wall or external barrier is another. We chose a blindfold in part because the occluder was on the face and completely obscured the organs of perception, the eyes, like eye closure does.

of stated age) using the same room set-up as in earlier studies. If infants were flummoxed by the novelty of the opaque cloth, they would stare at the adult and not look at the targets in either condition. If infants are simply following head turns, they would look at the external target but do so indiscriminately in both conditions. If infants recognize that a blindfold blocks visual access but headbands do not, they would look significantly more often at targets indicated by an adult wearing a headband compared to a blindfold.

The results showed that 14- and 18-month-old infants looked at the adult's target significantly more often in the headband than the blindfold condition. The 12-month-old infants did *not* distinguish between the two conditions. They looked at the indicated target just as often when the adult turned wearing the blindfold as the headband. Although they did not distinguish these two conditions, they were not behaving randomly or in a confused manner. The 12-month-olds looked at the correct target significantly more than the opposite target, resulting in their looking scores being greater than 0 (which would have been the chance level of responding). So once again we can say they were systematic in their response and turned to the correct side; their difficulty was that they failed to distinguish the two conditions of blindfold (when the experimenter could not possibly see) and headband (where the experimenter could) and indiscriminately turned in both.

These findings are interesting, especially when compared to the eyes open/closed test. The 14- and 18-month-olds responded just as they had in the earlier study. In both, they followed the adult's gaze when she had visual access to target, but refrained when she did not have visual access (i.e., blindfolded or closed eyes). However, the 12-month-olds, who had succeeded admirably on the eyes closed/open test, responded quite differently. They turned to follow the adult even when the adult wore a blindfold. This is not just a matter of blindfolds causing a general suppression of activity. Rather, infants make the mistake of following the "gaze" of the adult wearing the blindfold. In other words, they acted like the 9-month-olds did in the closed-eyes case. It is as if they had developed an understanding that eye closures block the adult's view, but do not yet understand that blindfolds block perception. Infants develop this latter understanding remarkably early in development, but not as early as they understand eye closure.

What These Findings Add

Not all occluders are equal in the eyes of infants. We have shown that there is a difference between understanding eye closure and blindfolds, with infants' understanding of simple eye closure being in advance. This research adds to other related work using different kinds of visual occluders, such as walls and

detached screens. Taken together, this research suggests that infants come to understand nonbiological occluders to vision sometime around or soon after 1 year of age depending upon the nature of the occluder (Brooks & Meltzoff, 2002; Butler et al., 2000; Caron, Kiel, Dayton, & Butler, 2002; Dunphy-Lelii & Wellman, 2004; Moll & Tomasello, 2004). Future research could profitably be directed at examining the same age children, using the same paradigm, and systematically manipulating different types of barriers: eye closure, blindfolds, distal barriers such as walls/screens. Young infants may not come to understand all of these types of barriers to perception in the same way or at the same age.

AN INTERVENTION EXPERIMENT: THE "LIKE ME" HYPOTHESIS

Rationale

The foregoing research indicates that at least one kind of occluder to vision, eye closure, is understood quite early. One hypothesis is that this is because infants themselves have ample prior experience with the perceptual effects of eye closure. When they do so, the world goes black. The non-biological occluders should become more meaningful to an infant after repeated opportunities to learn that they block vision.

Empirical Findings and Interpretation

Meltzoff and Brooks (2004) gave 12-month-olds experience with blindfolds. Infants were randomly assigned to a baseline condition or two treatment groups, one of which involved blindfolds and the other involved the same black cloth but with an opening cut out of the middle of it. The infants experienced that the blindfold blocked their view. Their view was blocked when the blindfold was held in front of *their* eyes, and was restored again when the blindfold was removed. This experience had nothing to do with the experimenter's viewpoint; it was a first-person experience. In the critical test, the adult put the blindfold over her own eyes. This was the first time the infants were presented with the blindfolded adult. The results showed that infants now interpreted the blindfold correctly. They did not turn when the adult wore the blindfold. In the control groups (baseline and cloth with opening) the infants were allowed to familiarize themselves with the cloth, but without experiencing an obstructed view. This had no effect. As we expected, the control-group infants still mistakenly followed the blindfolded adult's "gaze."

What These Findings Add

This is the first study showing that infants use first-person experience about a mental state such as “seeing” to make interpretations about another person. We believe that first-person experience with blindfolds changes infants’ understanding of the other’s situation. Infants use first-person experience to make third-person attributions about perception. Other explanations may be possible, but we think these training effects are a case of “like me” projection (Meltzoff, 2005), with deep implications for infant development, as will be elaborated in the conclusions.

INDIVIDUAL DIFFERENCES IN EARLY GAZE-FOLLOWING PREDICTS LATER LANGUAGE ACQUISITION

Rationale

On theoretical grounds, there is good reason for thinking that gaze-following may be an important component of language acquisition (e.g., Baldwin, 1995; Baldwin & Moses, 2001; Bruner, 1983; Carpenter et al., 1998; Graham, Nilsen, & Nayer, this volume; Hollich, Hirsh-Pasek, & Golinkoff, 2000; Moore, Angelopoulos, & Bennett, 1999; Tomasello, 1995, 2003). Infants who understand adult gaze as an ostensive act are in a better position to use everyday interactions with adults to learn words as labels for external objects. Not all language refers to tangible entities that can be looked at (Gopnik, 1982, 1988; Gopnik & Meltzoff, 1986), and parents don’t consistently label objects that are in the infants’ current view (Sabbagh & Baldwin, 2005; Tomasello & Todd, 1983). Nonetheless, one basic format in the “initial word learning game” (Bruner, 1983) is for parents to point out salient objects through gaze and then to label them. Infants who are advanced on gaze-following, in particular (and perhaps in understanding referential intent in general), may have a leg up on learning language. In order to pursue this idea within our own data set, we conducted a longitudinal follow-up of the children who came into the lab at 10 to 11 months of age—the tadpoles we caught right at the onset of gaze-following.

Empirical Findings and Interpretation

Brooks and Meltzoff (2005) assessed whether gaze-following behavior at 10 to 11 months predicted later language development. Language development

was assessed with the MacArthur-Bates Communicative Developmental Inventory (CDI; Fenson et al., 1994). The results showed that gaze-following behavior at 10 to 11 months predicted language development over 1 year later. Infants who produced the correct gaze + simultaneous vocalization act at 10 to 11 months had larger receptive vocabularies at 18 months than infants who did not ($p < .001$). The 10- to 11-month-old gaze-following behavior also predicted significantly more complex sentences ($p < .01$) and larger productive vocabulary at 24 months old. Those infants who showed gaze-following + simultaneous vocalization at 10 to 11 months had a 194 word advantage at 24 months over those infants who did not (521 vs. 327 words, $t(23) = 2.96$, $p < .01$).

We also examined the relationship between the average duration of looking to the correct target at 10 to 11 months and subsequent language. This infant gaze-following score at 10 to 11 months predicted by 24 months a significantly larger productive vocabulary size ($r = .63$, $p < .01$). For example, infants who earlier had low gaze-following scores (as measured by average duration at the correct target) produced utterances at 24 months that included structures such as "want more" or "cars vroom." In contrast, infants who had high scores had sentences that included, "Sit right down here mommy, legs out, and play with spinning tops."

What These Findings Add

The current results complement recent empirical reports that infant gaze following predicts language development (Carpenter et al., 1998; Markus, Mundy, Morales, Delgado, & Yale, 2000; Morales et al., 1998, 2000; Mundy, Fox, & Card, 2003; Mundy & Gomes, 1998). The current findings agree with these pioneering reports, but also provide additional data. In the previous studies, the gaze-following procedures included adult vocalizations (and/or communicative points) in conjunction with the adult turning to look at the target. Consequently, it could have been that infants' responsiveness to these linguistic cues provided by the experimenter *during the gaze-following procedure* correlated with later language abilities. In the current study, the adult turned toward the targets silently and displayed no emotional or pointing cues. This control gives us confidence that the significant correlations rest on the predictive nature of infant gaze-following behavior (or more generally, social cognition). The findings strongly suggest that infants who are skilled at early gaze-following enter the language game with an advantage—a boost that persists through 24 months, over a year later.

ASPECTS OF A DEVELOPMENTAL THEORY

Why is gaze-following so fascinating? In adult commonsense psychology, gaze-following entails the ascription of a mental life to the viewer. We follow where another person looks because we want to see what they are seeing. When we see people direct their gaze somewhere, we wonder what object is catching their attention and want to seek out that interesting spectacle ourselves. Thus, a viewer's gaze is intentional in the philosophical sense—it is “about” a distal object. The “aboutness” is demonstrated by the fact that we turn to the same place in space to see, quite literally, *what the look was about*.

To a developmental psychologist, who may or may not care about the philosophy, this immediately raises classic issues: Do infants gaze follow on the same basis as adults? If not, how/when do they develop the adult framework? These empirical questions typically derive from two motivations. First, developmentalists are interested in the origins of adult behavior, and the ontogenesis of gaze-following, like the emergence of the pincer grip, can be charted. Second, we want to use gaze-following as a tool for illuminating the development of children's understanding of other minds or at least others' perceptions. Gaze-following is a window into social cognition.

Now comes the rub—the problem that bedevils all of developmental psychology. We cannot immediately “read off” infants' mental-state attributions based on the fact that they gaze follow. In order for infants to gaze follow, there must first be a stimulus change in the visual world, typically another person turns to look at an object. Although adults ascribe mental experience to the viewer, there may be a simpler basis for gaze-following. Indeed, there are at least two major levels: (a) a *physical* motion in space, and (b) a *psychological* connection between agent and object. Psychologists endlessly debate whether (a) or (b) applies to infants of a given age. Alas, there is no silver bullet for ending the debate. No single experiment will answer whether one or another level provides the best descriptor. As shown repeatedly in the history of psychology/philosophy, with 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.

THE IMPORTANCE OF EYES

In this chapter we discussed an integrated series of findings using the Gaze-Following: Eyes Open/Closed test. This technique provides a test of the leanest interpretation of gaze-following. According to the lean view, infants are attracted to the most salient movement in the stimulus, the head movement.

This movement drags them to the correct hemi-field in space where they happen to encounter an object, by chance. Presto! Infants succeed on the classical gaze-following test, but do not process gaze at all.

The Gaze-Following: Eyes Open/Closed test controls for head movements. Infants are randomly assigned to one of two groups. For one group, the adult turns with eyes open and for another group with eyes closed. Any difference between the groups cannot be due to the head movements, which are controlled. The studies allow us to address whether infants are taking into account the status of the eyes, by the logic of the design. The results show that 9-month-old infants turn regardless of whether eyes are open or closed, but that 10-, 11-, and 12-month-olds selectively turn to follow open rather than closed eyes. We conclude that 9-month-olds do not gaze follow, properly so called.

One response to these findings might be that it is “only a detail” that infants don’t understand gaze. As long as infants follow the head, it matters little that they haven’t isolated the eyes. Our response is that, from a developmental viewpoint, it matters a great deal. It matters for three reasons. First, infants who fail the eyes-closed test cannot be said to be gaze-following *per se*. Second, we humans do, in fact, see through our eyes. Until infants understand that eyes, not heads, are key, they will make many mistakes in real life in decoding the actions of adults. Third, it is a major advance in infants’ understanding of persons and their perceptual-cognitive system for infants to grasp that eyes are the organ of visual information gathering. If one is interested in the development of the notion of perception, seeing, visual attention, and perspective taking, one needs to trace back to the earliest age at which infants begin to focus on eyes as the organ for seeing. Similarly, when infants begin to map their own eyes to the eyes of others, they have made a step forward in understanding self-other similarity.

THE IMPORTANCE OF DEVELOPMENT

The work discussed in this chapter suggests at least three developmental changes:

- Infants at 9 months and younger do not gaze follow. They turn even if the adult cannot possibly be looking at the target because she has her eyes shut.
- At 10 to 12 months infants gaze follow, turning to look at a target selectively according to whether the person has eyes open or not. But they do not yet have a general understanding that occluders block vision. They understand that some occluders (biological motion such as eye closure)

put the person out of perceptual contact, but do not fully understand that other occluders have this consequence.

- By 14 to 18 months of age, infants have a more generalized understanding that opaque occluders interposed between the eyes and the target block the adult's visual contact with this object. Also by this age, there is evidence that the majority of infants share their view with "perceiving others"—they selectively point to objects when the adult has eyes open versus eyes closed (Brooks & Meltzoff, 2002).

Having uncovered these developmental changes, it will be informative to use the eyes open/closed approach to investigate other topics. For studies tracing pointing development, the eye closure manipulation will be useful for clarifying when the infant does and does not deploy pointing as a proto-declarative act (Camaioni, et al., 2004; Franco & Butterworth, 1996; Liszkowski, et al., 2004). Also, it will be interesting for future work to more systematically compare infants' developing understanding of blindfolds to their understanding of free-standing barriers that block the line of sight but not all vision of the external world, such as walls and detached screens (cf., Butler et al., 2000; Dunphy-Lelii & Wellman, 2004; Moll & Tomasello, 2004).

Our current working hypothesis is that the earliest occluder of vision that infants understand is eye closure. Of course, eye closure is a biological motion over which infants have longstanding voluntary control. This raises the interesting possibility that infants have learned about the effects of eye closure by repeatedly opening and closing their eyes themselves.

A MECHANISM OF CHANGE: THE "LIKE ME" HYPOTHESIS

We have noted that there is developmental change in infant gaze-following. Whenever age-related changes are observed, multiple theories can be advanced to fit them. Two extreme options spring readily to mind—innateness and Skinnerian conditioning. Although no one may adhere strictly to either, it is worth considering what they entail. They often "lurk" in the background of discussions of gaze-following, and it is good for the debate to bring them into the open.

On the one hand, it might be suggested that gaze-following is innate. Infants might be born with the proclivity to follow gaze direction and do so on the same basis as older infants. They may not always demonstrate this core ability, but this could be due to "performance constraints" such as poor head control and so forth. An innate Eye Direction Detector (EDD) has been proposed that has this general flavor (Baron-Cohen, 1995). A strong nativist posi-

tion is not especially compatible with the developmental timetable listed previously. Specifically, it would have been more convenient for this theory if young infants had differentiated eyes open versus closed. An EDD ought to lead 9-month-olds to follow in the presence of eyes and not their absence (eyes closed). This did not occur. This view is also stretched thin by the observed difference between eyes closed and blindfolds—1-year-olds follow one but not the other. There are no “eyes” to detect in either case. On the opposite extreme, it might be suggested that gaze-following is nothing more than a conditioned response. Infants learn that the adult head + eye stimulus is a reliable signal (“discriminative cue”) for an interesting sight (“reinforcement”) and infants are operantly conditioned to turn in the direction as the adults turn (“shaped by experience”). The question comes down to “what else” might be going on besides innate perceptual biases plus learning from the success of finding objects indicated by where adults point their heads and eyes?³

We think there is a large “what else.” In order to understand the changing meaning that “turning to look at an object” has for infants, we find it useful to consider the “Like Me” hypothesis (Meltzoff, 1999, 2005; Meltzoff & Brooks, 2001; Meltzoff & Gopnik, 1993). The crux of this view is that infants use their own first-person experience to interpret the acts of others. In particular, we think that infants’ interpretation of the adult’s act of looking-to-target changes as they grow more experienced with their own behavior and map the similarities between self and other.

The intervention study with self-training on blindfolds at 12 months of age tests this idea. The prediction from the “Like Me” hypothesis is that if infants have experience with the consequences of blindfolds for their own perception, they can use this self-experience as background for understanding the situation of others. The conditioning view also emphasizes that infants learn from experience, but the crucial difference is that the experience is of a different kind. On the conditioning view, infants would need to learn that following blindfolded adults leads to finding nothing, whereas following sighted adults leads to a visual object (reinforcement). We did not give them *any* experience with the blindfolded adult at all. There was no opportunity for shaping their response to the cue of an adult-turning-with-blindfold; they were not trained on this. What differed is that infants obtained experience from the opaque cloth held to their *own* eyes. Then, the adult donned the blindfold for the first time. The results showed that infants who were given self-experience with

³We offer the extreme views in the spirit of mapping the conceptual space. There are few who argue that either extreme provides a full explanation of gaze-following in the first 12 to 18 months of life (see the subtleties of the eye-cuing studies by Farroni, Mansfield, Lai, & Johnson, 2003; Farroni, Massaccesi, Pividori, & Johnson, 2004; Hood, Willen, & Driver, 1998; and the learning studies by Corkum & Moore, 1998; and Moore & Corkum, 1998).

blindfolds did not follow where the blindfolded adult turned. This demonstrates the role of experience, but it is not the kind of experience that the behaviorists were talking about. Unlike either conditioning or nativist views, the "Like Me" hypothesis emphasizes the role of infants' own self-experience in interpreting the behavior of others.

Real-life Experience and the Development of Gaze-Following

A "Like Me" mechanism may play a role in everyday life, not just in the experimental setup where infants are specifically given experience. Given that the 9-month-old infants turn indiscriminately to eyes open and eyes closed, we must ask what this means. The current data do not allow firm conclusions, but we can offer three interpretations. First, 9-month-olds may be limited to tracking the adult head movements and run into the object by chance (building on Butterworth's ideas). Second, they may have learned that a head turn is a signal for seeing an object on the periphery, through conditioning or other training from parents (building on Moore's ideas). Third, *they may be body-orientation followers, rather than gaze followers* (building on Meltzoff's "Like Me" hypothesis).

The first two accounts have been described by others and will not be reviewed here. We wish to explore the third possibility. In this view, infants orient where another orients because they interpret bodily postures and familiar gross motor acts as being directed toward an external object. Importantly, however, this does not rely on training from adults. They could understand these behaviors in others based on their own previous experience with *their own acts*. Assuming that infants can at least relate their own gross body acts to those of others, as demonstrated in studies of imitation (Meltzoff, 1988, 1999, 2005), they have grounding for relating the bodily acts that they see to the ones they themselves have performed. Based on this connectedness between self and other, they may use their own experience with intentional body orientation as a template or framework for interpreting similar acts of others. The acts of others are imbued with meaning because they are like the intentional acts that are familiar to the infant in his or her own self-experience. This would allow infants who are 9 months old to turn where an adult is turning (as reported here and in the literature) without yet understanding the importance of eyes per se. Thus 9-month-olds may not understand object-directed gaze, but rather goal-directed bodily orientation.

If infants understand body orientation before gaze, the question naturally arises as to why this is the developmental ordering. One possibility may lie in the type of self-experience these acts entail. The proprioceptive feedback and intentionality involved in making orientation acts toward an object (position-

ing oneself, righting one's posture, orienting hands, head, trunk) would be especially salient for infants, who have to "work at this" to keep their balance. In everyday life, they may do less monitoring of their eyelids.⁴

GAZE-FOLLOWING AND THEORY OF MIND

We have discussed developmental changes in infants' understanding of the gaze of others. We suggested that one contributor to infants' interpretation of adult gaze is their own experience with their own bodies (their directed/intentional head and eye acts). Infants learn from their own bodily experience that eye closure blocks out the visual field, and they use this to interpret the behavior of others. In this way they come to imbue certain adult acts with felt meaning—not just as physical motions in space, but as acts having psychological correlates just like their own acts (see Meltzoff, 2005 for more details).

But as much development as occurs in the first year, there are later changes that build on these early achievements. The Magic Johnson story at the beginning of the chapter illustrates that adults make a differentiation between "seeing" and "attending." We do not think that 9-, 12- or (possibly even) 18-month-olds have a firm grasp on the adult notion of "attention." Attention is much farther "upstream" than seeing—farther from the action as it were. While seeing has an external marker that can be observed in others and felt in the self (for example, effortfully turning to look), attention has no such marker. My eyes can be pointed at a photograph, and my mind somewhere else. I can see things to which I do not attend; conversely, I can attend to that which I do not currently see. We do not think 1-year-olds can make this differentiation, though it is an essential aspect of our adult theory of mind.

We believe that infants' understanding of another's gaze is just one step, albeit a vitally important and early step, on the journey to understanding the richness of others' minds. The job of the developmental scientist is to document the critical transitions and discover the mechanism of change. At the same time, we must be aware that when we find the age when babies gaze follow, we have not moved down the age of the adult-like "theory of mind." What we have caught is a metamorph; there is little gained by arguing whether this is the same as a "real" frog or a frog with "performance constraints" (it can't jump).

⁴Here is a relevant thought experiment: Give infants special training on monitoring their own eye opening/closure through social games or eyelid-sensing technology to controlled external events. Concurrently, they could play imitation games that highlight the self-other mapping between their own and others' eye opening/closing. If the theory is correct, infants given such special training might succeed in our eyes open/closed gaze-following tests in an accelerated fashion.

Netting tadpoles is not trapping frogs. The value, of course, is that if you study the tadpoles, you will finally understand where in the world all those frogs come from. By studying the ontogenesis of gaze-following we are examining an essential foundation for developing the adult understanding of other minds.

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