Journal of Cognition and Development
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hjcd20

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Published online: 13 Nov 2009.

JOURNAL OF COGNITION AND DEVELOPMENT, *1*(4), 359–377

Infant Understanding of the Referential Nature of Looking

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To determine whether infants follow the gaze of adults because they understand the referential nature of looking or because they use the adult turn as a predictive cue for the location of interesting events, the gaze-following behavior of 14- and 18-month-olds was examined in the joint visual attention paradigm under varying visual obstruction conditions: (a) when the experimenter's line of sight was obstructed by opaque screens (screen condition), (b) when the experimenter's view was not obstructed (no-screen condition), and (c) when the opaque screens contained a large transparent window (window condition). It was assumed that infants who simply use adult turns as predictive cues would turn equally in all 3 conditions but infants who comprehend the referential nature of looking would turn maximally when the experimenter's vision was not blocked and minimally when her vision was blocked. Eighteen-month-olds responded in accord with the referential position (turning much more in the no-screen and window conditions than in the screen condition). However, 14-month-olds yielded a mixed response pattern (turning less in the screen than the no-screen condition but turning still less in the window condition). The results suggest that, unlike 18-month-olds, 14-month-olds do not understand the intentional nature of looking and are unclear about the requirements for successful looking.

It is now well documented that children beyond the age of 4 years have acquired a "theory of mind," that is, they appeal to a system of unobservable mental states (beliefs, desires, perceptions, and emotions) to explain and predict their own and other people's behavior (Astington, 1993; Mitchell & Lewis, 1994; Perner, 1991; Wellman, 1988). In an effort to locate early precursors of this propensity, recent theory and research have focused on infant understanding of a central property of

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mental states, variously termed *intentionality, referentiality,* or *aboutness* (Astington, 1993; Brentano, 1874/1960; Dennett, 1978; Fodor, 1985; Searle, 1983). What is meant here is the understanding that all mental states are about or directed to some content (perceptible or representational). People do not desire, believe, or perceive in the abstract but desire specific things (e.g., an apple), believe them to be in specific states (on the kitchen table), and perceive what state they are actually in (on the counter).

To determine when and how infants come to understand the intentionality of mental states, a number of investigators have turned their attention to infant comprehension of the referential nature of visual behavior, namely that looking is externally focused and object directed. There is evidence that prior to 6 months of age, infants are sensitive to many attributes that distinguish human agents from inanimate objects (eyes, faces, voices, biological movement, etc.). However, there is no firm indication that they regard visual behavior as intentional at this age or are even aware that the eyes play a role in looking (Caron, Caron, Roberts, & Brooks, 1997). Likewise, although infants as young as 3 months appear able to follow the gaze of an adult to targets within the immediate visual field (D'Entremont, Hains, & Muir, 1997), there is no evidence that they view shifts in gaze direction as a redirection of attention. More reliable evidence of intentional understanding appears at about 10 to 12 months with the emergence of three related phenomena involving triadic interactions among infant, adult, and an external object. At this time infants begin to (a) follow another's gaze direction to targets not in their immediate visual field (Caron, Butler, & Brooks, 2000), (b) direct the attention of others to external objects by pointing or showing (Desrochers, Morissette, & Richard, 1995; Lempers, 1979), and (c) use the emotional reactions of others to fixated objects to guide their own behavior toward these objects (social referencing; Bretherton, 1991).

Because monitoring another's gaze direction appears to be common to all three phenomena, following another's gaze or *joint visual attention* (JVA) has attracted the bulk of the research interest in this area. The tendency to look where someone else is looking has usually been interpreted in commonsense, referential terms as "the infant wanting to see what the other is seeing." Implicit in this proposition is that the infant understands (a) that there is a psychological and attentional relation between adult and target, (b) that the eyes play a key role in this relation, and (c) that it requires an unimpeded line of sight from eyes to target (Baron-Cohen, 1991; Bretherton, 1991; Tomasello, Kruger, & Ratner, 1993). Recently, however, Moore (Corkum & Moore, 1998; Moore, 1999) offered an alternative attentional account of JVA, which specifies that well into the second year of life the adult head turn serves merely as a cue directing infant attention to peripheral locations. Borrowing from the visual attention literature, he speculated that from 3 to 8 months turning to targets in the immediate visual field is a reflexive response to adult gaze orientation, but that beyond 9 months turning to peripheral targets is a voluntary response to the understood directional significance of the adult turn. Presumably, adult turning acquires its predictive value through interactive experience in which it is shown to be discriminative for the location of attractive events. Moore stressed that the adult turn is simply a predictive spatial cue for the infant at this stage, with no comprehension of its psychological relation to targets.

To date, the accumulated research on infant JVA suggests that comprehension of looking as an intentional act does not occur until at least 18 months of age. Not until then are infants able to turn correctly, not only to distant objects fixated by an adult (bypassing intervening objects), but also to those fixated behind them and outside their own visual field (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; Morissette, Ricard, & Gouin-Decarie, 1995). Second, not until 18 months do they emit more JVA turns to adult head plus eye turns than to adult head turns alone (Corkum & Moore, 1995) or can they be conditioned to turn to adult eye turns alone (Moore & Corkum, 1998). Finally, it is not until 18 months that infants try to remove the hands covering their mother's eyes to show her a picture (Lempers, Flavell, & Flavell, 1977). Collectively, these findings suggest that not until 18 months do infants appreciate the role of eyes in visual behavior or understand that looking involves an attentional focus and requires a clear line of sight.

For infants of 14 to 15 months, the situation is more problematic. Although they seem able to fixate a peripherally referenced target beyond an intervening target, they cannot correctly locate targets outside their own visual field (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; Morissette et al., 1995). Butterworth attributed the ability to locate targets within the visual field to a geometric mechanism (projection of head and eye orientation into space), which need not involve intentional understanding. Also problematic for an intentional account is Corkum and Moore's (1995) demonstration that even 15- to 16-month-old infants turned as frequently to head turns alone (eyes frontal) as to head plus eye turns and could not be conditioned to follow adult eye turns unaccompanied by head turns (Moore & Corkum, 1998). Both findings indicate insensitivity to eye status (a minimum condition for comprehension of attentional focus in vision). Moore therefore concluded that prior to 18 months, infants are guided to targets strictly by the direction of the adult head turn, irrespective of eye orientation.

Despite this negative evidence, there are some reasons to believe that infants of 14 to 15 months are not entirely bereft of referential understanding. First, in two recent habituation novelty experiments (Brooks, Caron, & Butler, 1998; Woodward, 1999) both 12- and 14-month-old infants were found to encode the target of an adult's head–eye turn rather than the direction of turn. Moreover, in the Brooks et al. (1998) study, infants did significantly less encoding of targets when the adult's eyes were closed during turning. Although the targets in these experiments were within the infant's immediate visual field, there is no compelling reason why infants should comprehend the referentiality of looking at near targets but not at more distant targets, as is typical of joint attention research.

Second, in Corkum and Moore's (1995) study, referential comprehension might have been obscured because to reduce false positive (elicited) responses, no targets were used. This could have biased against validation of the referential view because if infants turn to see something and there is nothing there, they should refrain from further turning. In subsequent studies, Moore and Corkum did employ targets (Corkum & Moore, 1998; Moore, Angelopoulos, & Bennett, 1997; Moore & Corkum, 1998), but these were training studies involving dynamic targets employed as contingent reinforcers. Because Moore and Corkum never presented their original cues (particularly heads and eyes and head only) in the standard JVA paradigm with static targets, we do not know whether a significant difference might have occurred between their congruent and head-only cues.

In a subsequent study in which static targets were used, Caron et al. (2000) found a significant difference for 14-month-olds between congruent head and eye cues and head-only cues (eyes frontal as well as eyes closed). Moreover, when targets were removed for this same age group, the difference, although still significant, was substantially reduced. Although this might imply that 14-month-olds have some rudimentary understanding that people look at things, these data are not necessarily inconsistent with the attentional account of JVA. For one thing, turning with frontally fixed eyes or closed eyes are probably not familiar predictive cues for infants (people rarely turn in this manner when orienting infants to the environment). Hence, the attenuated turning to these cues could reflect ambiguity as to their directional significance rather than awareness of the role of eyes in visual perception. Additionally, even if 14-month-olds are using eye direction in some limited way to guide their gaze following, they may still not understand the intentional nature of looking as opposed to simply having incorporated eye turns along with head turns as predictors of object location.

Given this interpretive ambiguity regarding the role of eyes, the purpose of this research was to provide a more definitive test of comprehension of the referential aspect of looking in infants of 14 and 18 months. Specifically, participants were tested in three conditions in which the nature of the head turns provided by the experimenter remained identical, but the conditions varied in terms of the visibility of the target to the adult. In Experiment 1, JVA was compared in two visibility conditions: (a) The experimenter could not see the targets due to opaque screens blocking her line of sight, and (b) the experimenter could clearly see the targets (screens folded back). In Experiment 2, another group of infants was exposed to a third condition in which the screen originally blocking the adult's vision contained a large window through which the adult could obviously see the targets.

The use of visual obstructions allowed us to test infant understanding of the referential nature of looking without distorting the adult's naturally occurring turns. If infants understand the intentionality of looking and its line of sight requirements, they should not follow the experimenter's head turn as often when her line of sight is blocked as opposed to when it is not blocked. On the other hand, if infants do not comprehend the referential aspect of looking and turn simply because the adult's turn is a predictive cue, they should follow her turns equally across the screen and no-screen conditions because the nature of the turn remains identical regardless of the presence or absence of obstructions.

Targets were used throughout the study. In addition, each infant was given eight trials involving only two head turn cues (two to each side per cue) to reduce possible confusion due to the presentation of many different cues to each participant. The two cues selected were a congruent head with eye turn and a congruent head with eye turn accompanied by a verbal exclamation (Oh wow!). Adults typically use such markers to direct infant attention to external events (Dunn, 1999), and indeed various studies suggest that verbalization enhances the impression of visual contact during head turning (Morissette et al., 1995; Repacholi & Gopnik, 1997). This possibility provides the opportunity for a further test of referential understanding because infants who understand should be more responsive to the verbal than to the nonverbal cue. On the other hand, infants who do not construe looking as referential should not benefit from the exclamatory accompaniment and should respond no more to the verbal than to the nonverbal cue.

EXPERIMENT 1

Design and Method

Participants. Participants were 100 infants (57 at 14–15 months and 43 at 18–19 months). All were full term (> 37 weeks gestation), of normal birth weight (> 2.5 kg), with 5-min Apgars of at least 7. None had experienced birth complications or major health problems. Thirteen of the 14-month-olds and 3 of the 18-month-olds were excluded due either to fussiness and failure to remain seated on the parent's lap (n = 14), parental interference (n = 1), or experimental error (n = 1). The final sample consisted of forty-four 14-month-olds (28 girls, 16 boys) and forty 18-month-olds (21 girls, 19 boys). The mean age for each group was 14 months, 21 days (range = 14 months, 0 days–15 months, 17 days) and 18 months, 15 days (range = 17 months, 27 days–19 months, 8 days). The infants were from middle-class families with mean maternal education of 17.21 years (SD = 1.86). All participants were recruited through birth records collected from suburban town halls and flyers posted in the Boston area.

Setting. Experimental sessions were conducted in an 8 ft × 6 ft (2.44 m × 1.83 m) cubicle, uniformly lined with light blue curtains on three sides, to a height of 8 ft (2.44 m). The wall behind the mother and infant contained a two-way mirror for observation.

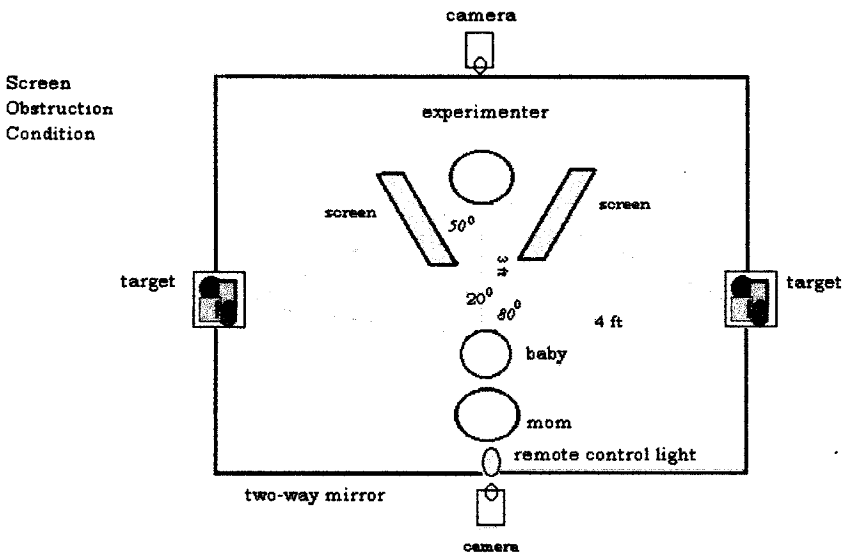
The mother sat in a chair facing the experimenter with the infant on her lap, approximately 3 ft (0.94 m) from the experimenter. The experimenter was seated on a low chair so that infant and experimenter were at eye level. Two identical pictorial targets, 8.5 in. × 11 in. (21.59 cm × 27.94 cm), were hung at the infant's eye level on both sides of the room 80° from the infant's forward line of sight and 50° from the experimenter's forward line of sight. Both targets were visible to the infant at all times (Figure 1).

A small hole in the curtain directly above the experimenter permitted unobserved video recording of the infant's actions. Another camera situated behind the two-way mirror recorded the experimenter's behavior. The output from both cameras was fed into a split screen generator that yielded synchronous videotapes of both the infant and the experimenter. A small remote-controlled light, hung directly above the mother's head, was activated at the beginning of each experimenter turn and terminated after 7 sec. The change in illumination enabled video scoring of the onset and offset of each trial.

Procedure. All infants were tested in an alert state, which was monitored throughout the course of the session. If the infant became fussy, wiggly, or too distracted, the session was terminated. Parents were asked to look down toward their infant and not to move or interact with them to inhibit unintended cuing. At the start of each trial, the experimenter recaptured the attention of the infant to ensure the child's perception of impending turns. Once eye contact was established, the experimenter activated the light behind the infant, simultaneously shifting her head and eye orientation toward one of the targets. Similar to earlier work (Corkum & Moore, 1995; Moore et al., 1997), the experimenter held the new orientation for 7 sec.

Each infant participated in a single experimental condition consisting of eight trials. Four trials involved a simple head and eye turn (silent cue) and four identical turns accompanied by a verbal exclamation of "Oh wow!" (wow cue). Each type of turn was presented twice to the left and twice to the right, in randomized order. The cue that began each session (silent or wow) and its direction (left or right) was counterbalanced across participant, creating four different trial orders.

In Experiment 1, infants were randomly assigned to either of two conditions (Figure 1). Condition 1 (screen condition) included two 24-in. × 48-in. (60.96-cm × 121.92-cm) solid screens on either side of the experimenter and angled 45° with the back wall, which clearly blocked her line of sight to both side targets. The front tips of both screens were 18 in. (0.46 m) away from the infant and 14 in. (0.35 m) from each other, permitting the infant a clear view of the experimenter throughout the session. The Experimenter and the front edges of the screens created a visual angle of 40° to the child. Prior to the onset of Condition 1, when the infant first entered the experimental room, the experimenter stood up behind the screen and waved to the infant. While standing behind the screen, only the top half of the ex-



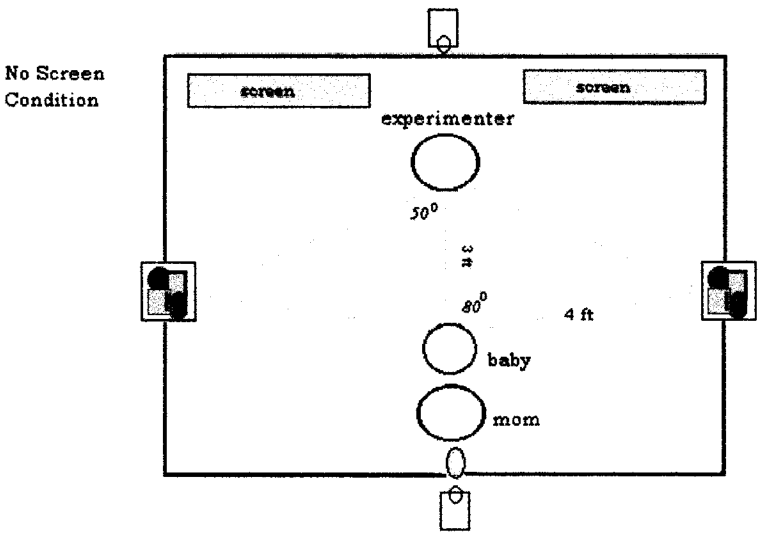


FIGURE 1 Aerial view of Experiment 1: screen obstruction (top) and no-screen condition (bottom).

perimenter was visible to the infant, thus emphasizing that the screen was opaque. Condition 2 (no-screen condition) included eight trials in which the screens were placed flat against the back wall of the experimental room, allowing the experimenter full view of the targets. As in Condition 1, prior to trial onset, the experimenter waved to the infants as they entered the room. All other aspects of the procedure were identical between conditions.

Scoring. Two naive observers, blind to condition, cue, and age, scored the videotapes of infant turns on each trial. A turn consisted of the first infant turn in the horizontal plane to a target. Looks to the inside of the screen (requiring a forward head tilt from the infant to view inside the screen) and looks to the screen itself (turning to the screen without further turning to the target) were also recorded. Only orientation movements making visual contact with the target were counted as turns. Reliability of scoring for all turns (to the referenced target, to the target opposite the referenced target, to inside the barrier, to the barrier, and no turn) was determined by calculating Cohen's kappa coefficient for 100% of the data ($n = 84$). The kappa values were $\kappa = .94$ (14 months) and $\kappa = .92$ (18 months).

Data analysis. A match or correct turn consisted of the infant turning to the target in the same direction as the experimenter and a mismatch or incorrect turn consisted of the infant turning to the target in the opposite direction of the experimenter. A difference score was calculated for each infant by adding the number of correct turns or matches and subtracting the number of incorrect turns or mismatches (Corkum & Moore, 1994, 1995). Thus, scores could range from –4 to +4 in each Condition × Cue subgroup or from –8 to +8 in each condition.

Results

Preliminary analyses. The two left-hand portions of Table 1 (no-screen and screen conditions) provide an overall summary of the mean number of trials per condition in which infants of each age turned in the same direction (match) or in the opposite direction (mismatch) as the experimenter. The amount of mismatched turning to the silent head and eye cue in the no-screen condition (10% of all turns) is comparable to that of Corkum and Moore (1995) to the same cue for a similar age range (14%). There was no overall difference between the 14- and 18-month-olds in the no-screen condition (7% for both age groups) nor in both conditions combined (12% vs. 15%, respectively). However, there tended to be more mismatched turning in the screen than the no-screen condition (22% vs. 7%), particularly for 18-month-olds (32% vs. 7%, respectively).

A preliminary mixed model analysis of variance (ANOVA) of the difference scores was conducted with age, sex, and trial order as between-subjects variables

TABLE 1
Mean Frequency of Matched and Mismatched Turns in Each Age × Cue × Condition Subgroup

	Experiment 1								*Experiment 2*			
	No-Screen Condition				*Screen Condition*				*Window Condition*			
Age	*Wow*	*SD*	*Silent*	*SD*	*Wow*	*SD*	*Silent*	*SD*	*Wow*	*SD*	*Silent*	*SD*
Matched turns												
14 months	2.59	1.37[a]	2.50	0.74[a]	2.18	1.18[a]	1.59	1.22[a]	1.80	1.21[b]	1.13	0.92[b]
18 months	2.75	1.02[c]	1.65	0.75[c]	1.05	1.14[c]	0.45	0.60[c]	2.80	1.21[b]	1.73	0.88[b]
Mismatched turns												
14 months	0.18	0.39[a]	0.23	0.43[a]	0.27	0.55[a]	0.55	0.67[a]	0.33	0.49[b]	0.27	0.59[b]
18 months	0.10	0.31[c]	0.25	0.55[c]	0.20	0.41[c]	0.50	0.61[c]	0.07	0.26[b]	0.13	0.26[b]

Note. Four trials of each cue were presented in each experimental session.
[a]*n* = 22. [b]*n* = 15. [c]*n* = 20.

and direction of the experimenter's head turn (to the right or left) and cue (silent or wow) as within-subjects variables. Because the analysis yielded no significant main or interaction effects involving sex, trial order, or direction of turn, the data were collapsed on these dimensions for all subsequent analyses.

Effects of age, condition, and cue. The difference scores were entered into a mixed two-way ANOVA with age and condition (screen and no-screen) as between-subjects variables and type of cue (wow and silent) as the within-subjects variable. The analysis yielded significant main effects for condition, $F(1, 82) = 47.65$, $p < .0001$; age, $F(1, 82) = 14.93$, $p < .001$; and cue, $F(1, 82) = 17.87$, $p < .0001$, as well as a significant Condition × Age interaction, $F(3, 80) = 4.46$, $p < .05$. None of the remaining interactions were significant. The means for the Condition × Age groups are shown in the upper portion of Figure 2 and for the Condition × Cue × Age groups in the lower portion of Figure 2.

The three main effects indicated: (a) that infant turning was significantly greater in the no-screen ($M = 4.37$, $SD = 1.59$) than the screen condition ($M = 1.88$, $SD = 1.61$), (b) that 14-month-olds ($M = 3.82$, $SD = 1.91$) turned more overall than 18-month-olds ($M = 2.43$, $SD = 1.30$), and (c) there was more turning to the wow cue ($M = 1.94$, $SD = 1.28$) than to the silent cue ($M = 1.18$, $SD = 1.02$) overall.

The Condition × Age interaction indicated that although both age groups responded less in the screen than no-screen condition, the decline was much steeper for the 18-month-olds. They turned significantly less than the 14-month-olds in the screen condition ($p < .05$, Tukey's posttests) but turned as much as the 14-month-olds in the no-screen condition. Additionally, the 14-month-olds re-

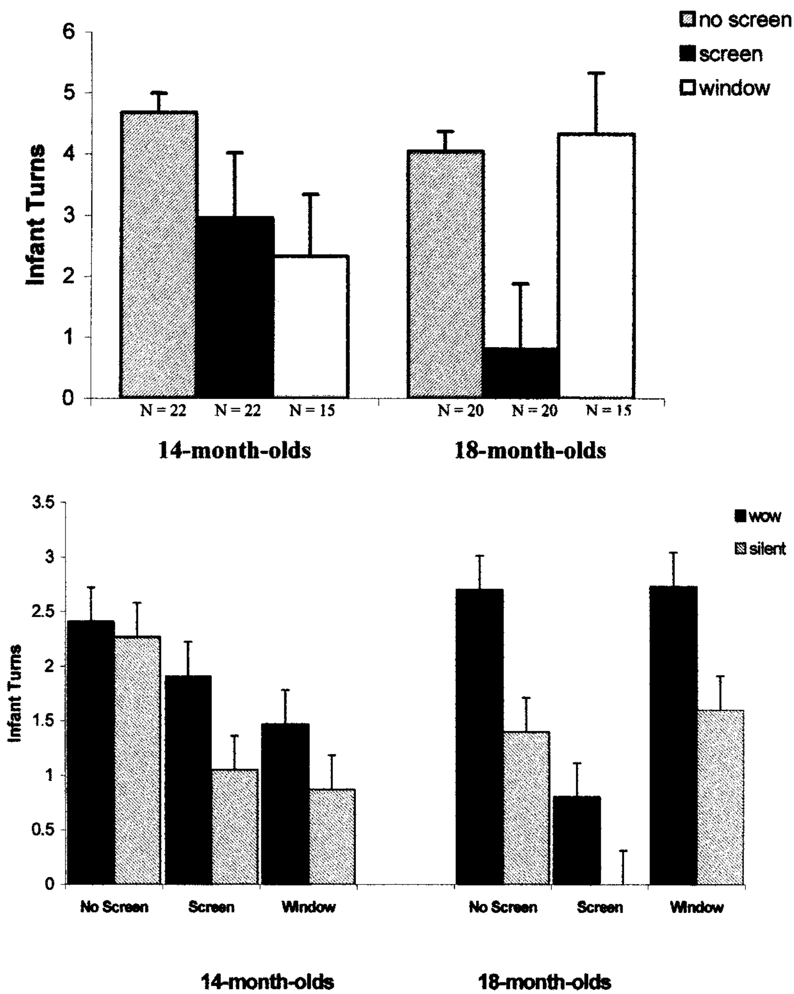


FIGURE 2 Composite figure comparing mean (+ *SE*) difference scores as a function of age (14 and 18 months) and experimental condition (screen, no-screen, and window; top) and mean (+ *SE*) difference scores as a function of age, condition, and cue (wow and silent; bottom).

sponded at well above chance levels in the screen condition, $t(21) = 7.06$, $p < .0001$, whereas the 18-month-olds responded just above chance levels, $t(19) = 3.10$, $p < .01$. Indeed, of 18-month-olds, 8 of 20 responded below chance (difference scores of zero or less), whereas of 14-month-olds, only 1 of 22 did so in the screen condition.

Looking inside the barrier. Infant looking inside the barrier in the screen condition (leaning forward to gaze at the experimenter's side of the barrier rather than turning toward the targets) would suggest that infants regard looking as referential and know that the screens obstructed sight of the peripheral targets. The number of infants looking inside the barrier at least once in the screen condition was therefore compared across ages. A significantly greater proportion of 18-month-olds (7 of 20) looked inside the screens than 14-month-olds (1 of 22), $\chi^2(1, N = 42) = 6.30, p = .01$. This suggests that only the 18-month-olds grasped that the screens constituted a visual obstruction.

Discussion

According to the attentional control interpretation of JVA, infants should have followed adult gazes equally in the screen and no-screen conditions because the adult head turn cues were identical in each. Contrarily, both ages yielded significantly less overall turning in the screen than no-screen condition (although again the decline was much steeper for 18-month-olds). This result is consistent with the conclusion that both age groups comprehend that looking involves focused attention on external targets. However, two alternative explanations for the decline in turning in the screen condition that do not involve intentional understanding warrant consideration.

First, the screens could have served as a competing intervening target in the infant's line of scan so that infants might have arrested their turns at the barriers rather than completing their scans to the further targets on the side walls. Morissette et al. (1995) found that infants of 12 to 14 months tend to look at the first object in the scan path even when it is not the object referenced. Nevertheless, this possibility must be rejected because participants rarely terminated their turning to the barriers; only 12 of 296 turns (4%) for 14-month-olds and 14 of 280 turns (5%) for 18-month-olds were terminated to the screens.

A more plausible artifactual explanation of the response decline in the screen condition is that it was a product of the unnatural, boxed-in appearance of the experimenter in that condition. The strange sight of the adult surrounded by two tall screens could have attracted attention to her at the expense of the side targets. Thus, the drop in turning in the screen condition may have been due to the novelty of the situation confronting the infants, which weakened their tendency to follow the experimenter's gaze direction, rather than to a realization that the adult was unable to see the targets beyond the opaque screens.

To determine whether such a "strangeness artifact" was responsible for reduced turning in the screen condition for either 14- or 18-month-olds and to shed further light on their comprehension of line-of-sight requirements for successful vision, a second experiment was conducted in which the screens now contained a large, cut-out window, which gave the experimenter a clear line of sight to each side target. The rationale for this manipulation was that if infants in Experiment 1 turned less in the screen than the no-screen condition because they regarded the enclosures as intriguingly strange, then this should also apply to screens with transparent windows. Therefore, turning in the window condition should remain as subdued as in the opaque screen condition. On the other hand, if infants turned less in the screen condition because they viewed the screens as barriers to clear sight of the side walls, then this would no longer apply in the window condition, and responding should be as strong in that condition as in the original no-screen condition.

EXPERIMENT 2

Design and Method

Participants. Following the completion of Experiment 1, a new group of 32 infants was recruited (16 at 14–15 months and 16 at 18–19 months of age). As in Experiment 1, all were full term (>37 weeks gestation), of normal birth weight (>2.5 kg), with 5-min Apgars of at least 7. None had experienced birth complications or major health problems. One of the 14-month-olds and 1 of the 18-month-olds were excluded due to fussiness ($n = 1$) and parental interference ($n = 1$). The final sample consisted of fifteen 14-month-olds (8 girls, 7 boys) and fifteen 18-month-olds (9 girls, 6 boys). The mean ages for the groups were 14 months, 25 days (range = 14 months, 0 days–15 months, 3 days) and 18 months, 9 days (range = 18 months, 0 days–19 months, 1 day), quite comparable to the means and ranges in Experiment 1. Analyses of the distribution of boys and girls across condition by age subgroup in Experiments 1 and 2 did not yield any significant differences. Maternal education and family demographics were also comparable to those in Experiment 1, given that the method of recruitment was identical.

Setting and procedure. The general details of the procedure were identical to those in the screen condition of Experiment 1 except for the nature of the enclosures. The same 24-in. × 48-in. (60.96-cm × 121.92-cm) screens were located between the experimenter and the target just as before. However, each screen now contained a large 14-in. × 14-in. (35.56-cm × 35.56-cm) window, cut 2 in. from the top edge and centered within the barrier to allow an obviously clear view of the targets by the experimenter. As infants sat on their mothers' lap, not only was the screen visible to the infants, but it was at an angle that allowed viewing the back wall through each window. When the infant first entered the experimental room and prior to the onset of the session, the experimenter waved to the infant through the window to demonstrate its transparency. Whether the infant received a left or right turn first or a wow or silent cue first was counterbalanced.

Scoring and data analysis. Scoring and data analyses were identical to Experiment 1. Reliability was determined for infant turning by calculating Cohen's kappa coefficient for all 30 infants by two observers. The values for the age groups were $\kappa = .93$ (14 months) and $\kappa = .92$ (18 months).

Results

Preliminary analyses in the window condition. The right-hand portion of Table 1 (window condition) provides an overall summary of the mean number of matched and mismatched turns for each age group in the window condition. Mismatched turns consisted of 10% of total turns in the window condition, a percentage similar to the no-screen condition of Experiment 1 (7%) but less than the screen condition (22%).

A preliminary mixed-model ANOVA with age, sex, and trial order as between-subjects variables and direction of experimenter head turn and cue (silent or wow) as within-subjects variables was conducted. Once again the analysis failed to reveal any significant main effects of sex, trial order, or direction of experimenter turn, so that the data were collapsed on these dimensions for all subsequent analyses.

Effects of age and cue in the window condition. Difference scores in the window condition (right-hand bars in Figure 2) were analyzed in a 2 (age) × 2 (cue) mixed-model ANOVA with age as the between-subjects variable and type of cue (wow or silent) as the within-subjects variable.[1] The analysis yielded a significant main effect for age, $F(1, 28) = 9.69$, $p < .005$, with 18-month-olds turning more than 14-month-olds ($M = 4.33$, $SD = 1.54$ and $M = 2.33$, $SD = 1.95$, respectively). A significant cue effect, $F(1, 28) = 7.76$, $p < .001$, was also found, in which infants demonstrated greater difference scores to the wow cue ($M = 4.20$, $SD = 1.39$) than to the silent cue ($M = 2.47$, $SD = 1.02$). The Cue × Age interaction was not significant.

For both age groups, responding in the window condition was significantly greater than chance: 14-month-olds, $t(14) = 4.63$, $p < .005$; 18-month-olds, $t(14) = 10.88$, $p < .0001$. In contrast with the screen condition, none of the fifteen 18-month-olds in the window condition responded at or below what would be expected by chance, whereas the proportion for 14-month-olds was at about the same low level (2 of 15) as in the screen condition.

Looking inside the window. Unlike the screen condition, there was no age difference in the amount of looking inside the barrier in the window condition, χ^2(1,

[1]ANOVA employing only correct responses as the dependent measure, rather than the difference score, yielded the same pattern of results.

$N = 30) = 1.15$, $p = .28$. At both ages, only a small percentage of infants looked inside the window (3 of 15 for 18-month-olds and 1 of 15 for 14-month-olds).

Effects of condition, age, and cue. These data were compared with those of Experiment 1 in a 3 (condition) × 2 (age) × 2 (cue) mixed-model ANOVA with age and condition (no-screen, screen, and window) as between-subject variables and type of cue (wow or silent) as the within-subjects variable. The analysis yielded significant main effects for condition, $F(2, 111) = 23.18$, $p < .0001$, and cue, $F(1, 112) = 25.29$, $p < .00001$, as well as a significant Condition × Age interaction, $F(4, 109) = 13.43$, $p < .0001$, and a marginal Cue × Age interaction, $F(3, 110) = 3.01$, $p < .08$ (see Figure 2). Neither the age, Cue × Condition, or Cue × Age × Condition interactions were significant.

Post hoc comparisons of the three conditions revealed that overall infant turning was significantly greater in the window condition ($M = 3.33$, $SD = 2.01$) than in the screen condition ($M = 1.88$, $SD = 1.61$). Furthermore, turning in the no-screen condition ($M = 4.37$, $SD = 1.59$) was significantly greater than turning in both other conditions ($p < .05$ in each case, by Tukey's posttests).

The important finding was contained in the Condition × Age interaction (as shown in the top portion of Figure 2). The 18-month-olds turned maximally in the window and no-screen conditions and minimally in the screen condition (Tukey's posttests, $p < .05$). In comparison, the 14-month-olds looked as infrequently in the window condition as in the screen condition, both yielding significantly less turning than the no-screen condition ($p < .05$).

The significant cue effect indicated greater turning overall to the wow cue ($M = 2.00$, $SD = 1.32$) than to the silent cue ($M = 1.19$, $SD = 1.02$). The marginal Cue × Age interaction indicated a greater differential in turning to the wow versus silent cue for 18-month-olds ($M = 2.06$ vs. 1.00, respectively), than 14-month-olds ($M = 1.93$ vs. 1.40, respectively).

Discussion

The aim Experiment 2 was to determine whether the decline in responding in the screen condition of Experiment 1 reflected understanding of the visual obstruction imposed by the barrier as opposed to simply being an artifact of the presence of the barrier. If the infants truly understand the referential nature of visual attention and its visual requirements, they should have responded in the window condition in a manner similar to the no-screen condition because the targets were obviously visible in the window condition. Alternatively, if infants turned less in the screen condition because of the intriguingly strange, boxed-in appearance of the experimenter, they should have responded in the window condition as they did in the screen condition.

These findings suggest that 18-month-olds do indeed comprehend the referential aspect of looking. Their responding in the window condition was just as robust as their responding in the no-screen condition, and in both cases it was significantly greater than in the screen condition. Thus, 18-month-olds turned when the experimenter could see the targets and turned much less when she could not see the targets, a pattern consistent with comprehension that looking has an attentional focus requiring a clear line of sight. Further support for this conclusion follows from the tendency of 18-month-olds to look inside the barrier when the experimenter's vision was blocked, and also their greater turning to the wow than the silent cue. Looking inside the barrier is a sophisticated act requiring an inference about where the experimenter's attention might be focused given the realization that there was no clear line of sight to the side walls. Likewise, enhanced turning to the wow cue may be taken to reflect comprehension of referentiality.

Experiments 1 and 2 indicate that 18-month-olds understand both line of sight and the referential nature of looking, but the results for the 14-month-olds are less straightforward and somewhat harder to interpret. On the one hand, because their level of responding in the window condition was as muted as that in the screen condition and less frequent than that in the no-screen condition, reduced responding in the screen condition may have been due to distraction caused by the enclosed appearance of the experimenter. Given this possibility, one cannot determine whether they have referential understanding or not. On the other hand, other aspects of the data suggest that 14-month-olds have no such understanding. For one, they continued to follow the adult turns at well above chance levels in the screen condition. Also, they never looked inside the screen for alternative targets, suggesting that they did not grasp that the adult was looking at something and that the barriers obstructed her view of the peripheral targets. Third, their failure to benefit from the wow verbalization suggests insensitivity to the referential aspect of visual behavior. Finally, their failure to show even the slightest increase in turning in the window condition is itself revealing. If they had any inkling of line-of-sight requirements for successful viewing, the presence of enclosing structures should have been less inhibiting of gaze following in the window than in the screen condition. On the basis of these observations, it is difficult to make a case for comprehension of the intentionality of looking at 14 to 15 months of age.

GENERAL DISCUSSION

The negative picture presented here of the 14-month-olds relative to the 18-month-olds supports data from some sources and is at odds with other findings. It is consistent with the demonstration by Baldwin (1993) that showed that 14- to 15-month-old infants were unable to establish new word–object links when the experimenter looked at and labeled the toy of an infant's focus. By contrast, at 18 to 19 months they could pinpoint the correct referent even when the experimenter looked at and labeled a toy different from the infant's focus. The results are also consistent with the report by Lempers et al. (1977) that prior to 18 months, infants are unclear about the effects of visual obstructions.

Conversely, the findings reported here appear to be inconsistent with the previously mentioned data of Caron et al. (2000) and those of Woodward (1999) and Brooks et al. (1998), which seem to suggest that infants understand referentiality prior to 18 months of age. Caron et al. found that 14-month-olds followed congruent head and eye turns significantly more than either head turns alone or head turns with eyes closed, which implies that 14-month-olds have some appreciation of the role of eyes in visual behavior. On the face of it, this appears incompatible with their failure in our experiments to grasp the intentionality of looking, but it is possible that by 14 months of age infant attention has come to be controlled not by the head turn alone but by the head turn combined with simultaneous turning of the open eyes. Dual head–eye control of attention could well be an intermediate step prior to full comprehension of looking as target-directed behavior. Indeed, it seems reasonable that the eyes would become a component of directional control before infants ultimately came to construe the referential implications of eyes.

The Woodward (1999) and Brooks et al. (1998) studies appeared to suggest that 12- and 14-month-old infants comprehend the intentionality of looking for objects in the visual field of the adult. Both studies involved a habituation and familiarization phase in which infants saw an adult turn to stare at one of two objects in front and slightly to either side of her, followed by a test phase in which the position of the objects was reversed. Two alternating events were then shown: (a) the adult staring in the same direction but now at the second object, and (b) the adult staring in the opposite direction but at the original object. In both studies, infants looked longer at the change in object than at the change in direction of look, implying that they had encoded the target of the look during habituation.

The studies may be criticized on two grounds. First, it may be that the infants focused on the habituated target as a consequence of directional control by the adult's head turns. Therefore, they would have been particularly sensitive to an object change at that location, and hence may not have been responding to a change in perceived reference but simply to object novelty. Second, we cannot tell from Woodward's (1999) study whether the eyes were even an important part of the head. The infants might simply have been responding to the shift in head orientation as the sole directional cue. The Brooks et al. (1998) study did contain a control group in which the adult's eyes were closed throughout, and the authors found that the 14-month infants no longer preferred to look at the change in target. Although this control indicates that infants may have been responding to the congruent head–eye turn, it still does not tell us whether the control was referential or directional (as argued earlier with respect to the Caron et al., 2000, study).

All things considered, it would appear that between 12 and 18 months the infant's ability to follow an adult's gaze to peripheral targets gradually progresses from use of the head turn alone as a predictive cue (10–13 months) to use of the head plus eye turn as a predictive cue (14–16 months) and finally to giving primary weight to eye orientation and its referential role in looking (18–19 months). If this picture has any validity, one is compelled to speculate about what kind of experience is necessary to move the child from the second stage (14–16 months) to the third stage (18–19 months); that is, from regarding head and eye orientation as directional cues to recognizing them as a visual act with attentional focus. Barresi and Moore (1996) suggested that the key to this achievement is the gradual coordination of the infant's first-person visual experience with the adult's third-person visual experience, and Meltzoff (1999) argued similarly that it is a product of realizing that the other is "like me" and therefore sees as I do. We know that well before 14 months, infants are aware of the conditions that interfere with their own viewing of objects. As early as 9 months, for example, they will remove a cover to reveal an occluded object, and certainly by 12 months they peer around barriers to see things. It is possible then, that intensive training that enhances the reciprocity of "I" and "you" perspectives might propel a 14-month-old to an 18-month level of understanding.

ACKNOWLEDGMENTS

Samantha C. Butler is now at the Department of Psychology at the University of Massachusetts at Amherst. Rechele Brooks is now at the Department of Psychology at the University of Washington.

A portion of this research was reported as a poster presentation at the meeting of the Society for Research in Child Development, Albuquerque, New Mexico in April 1999. We thank Jillian Richards and Rachel Martin for assistance with data collection and scoring of infant videotapes. We also thank the mothers and children who participated in the study.

REFERENCES

Astington, J. W. (1993). *The child's discovery of mind.* Cambridge, MA: Harvard University Press.

Baldwin, D. (1993). Early referential understanding: Infants' ability to recognize referential acts for what they are. *Developmental Psychology, 29,* 832–843.

Baron-Cohen, S. (1991). Precursors to a theory of mind: Understanding attention in others. In A. Whiten (Ed.), *Natural theories of mind: Evolution, development, and simulation of everyday mindreading* (pp. 233–251). Oxford, England: Blackwell.

Barresi, J., & Moore, C. (1996). Intentional relations and social understanding. *Behavioral and Brain Sciences, 19,* 107–122.

Brentano, F. (1960). The distinction between mental and physical phenomena. In R. M. Chisholm (Ed.), *Realism and the background of phenomenology* (pp. 39–61). New York: Free Press. (Original work published 1874)

Bretherton, I. (1991). Intentional communication and the development of mind. In D. Frye & C. Moore (Eds.), *Children's theories of mind: Mental states and social understanding* (pp. 49–76). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Brooks, R., Caron, A. J., & Butler, S. C. (1998, April). *Infant comprehension of looking as an intentional behavior.* Paper presented at the International Conference on Infant Studies, Atlanta, GA.

Butterworth, G., & Cochran, E. (1980). Towards a mechanism of joint attention in human infancy. *International Journal of Behavioral Development, 19,* 253–272.

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

Caron, A., Butler, S., & Brooks, R. (2000). *Infant joint attention: The role of the head and eyes.* Manuscript submitted for publication.

Caron, A., Caron, R., Roberts, J., & Brooks, R. (1997). Infant sensitivity to deviations in dynamic facial-vocal displays: The role of eye regard. *Developmental Psychology, 33,* 802–813.

Corkum, V., & Moore, C. (1994, April). *The origins of joint visual attention in infants.* Paper presented at the International Conference on Infant Studies, New Orleans, LA.

Corkum, V., & Moore, C. (1995). Development of joint visual attention in infants. In C. Moore & P. J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 61–85). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Corkum, V., & Moore, C. (1998). The origins of joint visual attention in infants. *Developmental Psychology, 34,* 28–38.

Dennett, D. C. (1978). Beliefs about beliefs. *Behavioral and Brain Sciences, 4,* 568–570.

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

Desrochers, S., Morissette, P., & Richard, M. (1995). Two perspectives on pointing in infancy. In C. Moore & P. J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 85–101). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Dunn, J. (1999). Making sense of the social world: Mindreading, emotion, and relationships. In P. D. Zelazo, J. Astington, & D. Olson (Eds.), *Developing theories of intention: Social understanding and self-control* (pp. 229–242). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Fodor, J. A. (1985). Fodor's guide to mental representation: The intelligent auntie's vade-mecum. *Mind, 94,* 76–100.

Lempers, J. D. (1979). Young children's production and comprehension of nonverbal deictic behaviors. *Journal of Genetic Psychology, 135,* 93–102.

Lempers, J. D., Flavell, E. R., & Flavell, J. H. (1977). The development in very young children of tacit knowledge concerning visual perception. *Genetic Psychology Monograph, 95,* 3–53.

Meltzoff, A. (1999). Foundations for developing a concept of self: The role of imitation in relating self to other and the role of social mirroring, social modeling, and self practice in infancy. In D. Cicchetti & M. Beegly (Eds.), *The self in transition: Infancy to childhood* (pp. 318–335). Chicago: University of Chicago Press.

Mitchell, P., & Lewis, C. (1994). Critical issues in children's early understanding of mind. In C. Lewis & P. Mitchell (Eds.), *Children's early understanding of mind* (pp. 1–15). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Moore, C. (1999). Intentional relations and triadic interactions. In P. D. Zelazo, J. Astington, & D. Olson (Eds.), *Developing theories of intention: Social understanding and self-control* (pp. 43–62). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Moore, C., Angelopoulos, M., & Bennett, P. (1997). The role of movement in the development of joint visual attention. *Infant Behavior and Development, 20,* 83–92.

Moore, C., & Corkum, V. (1998). Infant gaze following based on eye direction. *British Journal of Developmental Psychology, 16,* 495–503.

Morissette, P., Ricard, M., & Gouin-Decarie, T. (1995). Joint visual attention and pointing in infancy: A longitudinal study of comprehension. *British Journal of Developmental Psychology, 13,* 163–176.

Perner, J. (1991). *Understanding the representational mind.* Cambridge, MA: Bradford Books/MIT Press.

Repacholi, B. M., & Gopnik, A. (1997). Early reasoning about desires: Evidence from 14- and 18-month-olds. *Developmental Psychology, 33,* 12–21.

Searle, J. R. (1983). *Intentionality: An essay in the philosophy of mind.* Cambridge, England: Cambridge University Press.

Tomasello, M., Kruger, A. C., & Ratner, H. H. (1993). Cultural learning. *Behavioral and Brain Sciences, 16,* 495–552.

Wellman, H. M. (1988). First steps in the child's theorizing about the mind. In J. Astington, P. Harris, & D. Olson (Eds.), *Developing theories of mind* (pp. 64–92). New York: Cambridge University Press.

Woodward, A. L. (1999). *Infants' developing understanding of the link between looker and object.* Manuscript submitted for publication.