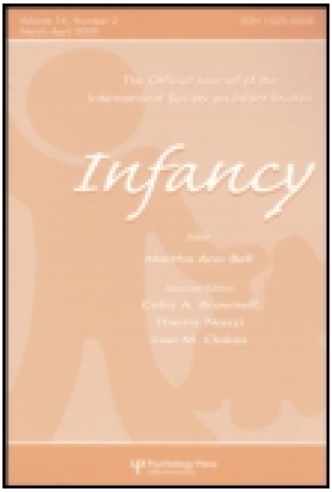

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Differences in How 12- and 24-Month-Olds Interpret the Gaze of Adults

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RESEARCH ARTICLES

Differences in How 12- and 24-Month-Olds Interpret the Gaze of Adults

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This study examined the hypothesis that toddlers interpret an adult's head turn as evidence that the adult was looking at something, whereas younger infants interpret gaze based on an expectancy that an interesting object will be present on the side to which the adult has turned. Infants of 12 months and toddlers of 24 months were first shown that an adult head turn to the side predicted the activation of a remote-controlled toy on that side of the room. After this connection had been demonstrated, participants were assigned to 2 conditions. In the head turn condition the toys were removed but the adult continued to produce head turns to the side. In the toy condition the adult stopped turning but the toys continued to be activated when the participant turned toward them. Results showed that, compared to 12-month-olds, 24-month-olds were more likely to continue to turn to the side when the adult continued to turn even though there was no longer anything of interest to see. In contrast, compared to 24-month-olds, 12-month-olds were, if anything, more likely to continue to turn to the side in the condition in which the adult stopped turning. The latter result was replicated in a condition in which the activation of the toy was not contingent on the child's own head turn. These results imply that the meaning of gaze following may change significantly over the 2nd year of life. For 12-month-olds, gaze is a useful predictor of where interesting sights may occur. In contrast, for 24-month-olds, gaze may be a signal that the adult is looking at something.

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Gaze following—the ability to turn and look in the same direction as someone else—plays a central role in the object-centered or triadic interactions evident toward the end of the first year of life. Once infants can attend to what another person is attending to, they can start to learn about the world through other people. Social referencing, prelinguistic communication, and even language become possible. In the laboratory, gaze following is usually studied by having an infant interact in face-to-face arrangement with an adult—either the mother or an experimenter—and then having the adult periodically break the face-to-face arrangement and turn to the side to fixate some object outside of the infant's visual field. Under these conditions, there is reasonable consensus that infants show gaze following between about 9 and 12 months (e.g., Butterworth & Cochran, 1980; Corkum & Moore, 1998; Scaife & Bruner, 1975).

There is still some debate, however, about what this behavior tells us about 9- to 12-month-olds' understanding of gaze. A commonsense inference would be that infants who show gaze following do so because they understand that the other person is looking at or attending to something. Such an interpretation attributes to infants an understanding of vision or attention (see Moore & Corkum, 1994). The inferential strategy here is essentially the argument by analogy: If infants show behavior that resembles what adults do, then it is reasonable to attribute to the infants the same kind of understanding normally attributed to adults showing the same behavior. The argument by analogy has historically been used to justify anthropomorphic interpretations of nonhuman animal behavior (e.g., Darwin, 1871/1982; Hume, 1739–1740/1978; Romanes, 1882; see Povinelli & Giambrone, 1999, for a discussion of the limitations of this approach). However, the philosophical arguments carry equal force to nonverbal or even verbal members of our own species, so that for some (see, e.g., Russell, 1948) the argument by analogy is what justifies the attribution of mental states in all cases. In the case of human infants, it gains additional force from the obvious fact that infants develop into adults and thus at some point the attribution of adult-like understanding must be warranted.

Some authors have questioned the commonsense view of infant social understanding, arguing that there are a variety of alternative explanations for the behavioral phenomena (e.g., Baldwin & Moses, 1996; Moore & Corkum, 1994; Perner, 1991). In the case of early gaze following in particular, it is possible that infants follow the gaze of an adult because they have in some way acquired an expectation that there will be something worth seeing if they turn in the same direction as the adult (see Corkum & Moore, 1998). If so, then it would be unnecessary to attribute to infants an understanding that people can look at, or attend to, objects in the world. If the same behavior could be accompanied by different kinds of understanding, it should be possible to demonstrate the difference behaviorally. Thus, the general empirical strategy should be to probe the behavior in question in more detail to see whether the analogy between performance at different ages starts to break down under different conditions.

To date, two main approaches have been adopted in the study of gaze following. A number of researchers have examined the development of gaze following to objects in different spatial locations. In the earliest stages of gaze following, from about 3 to 6 months, infants tend to follow gaze only to targets in visible near space (Butterworth & Cochran, 1980; D'Entremont, Hains, & Muir, 1997). During the second half of the first year, infants start to follow gaze to locations that are beyond the immediate visual field (Corkum & Moore, 1998). By 12 to 18 months, infants will follow gaze to targets that are behind them (Deák, Flom, & Pick, 2000), or out of view behind barriers or in containers (Butler, Caron, & Brooks, 2000; Moll & Tomasello, 2004). They also become able to follow gaze to the particular target of the adult's attention even if there is more than one available target (Butterworth & Cochran, 1980; von Hofsten, Dahlström, & Fredriksson, 2005). These studies are all consistent with the idea that as infants' spatial representations become more differentiated, changing from local egocentric frames to include various locations out of immediate view, they become able to use gaze to predict the location of objects within this progressively differentiated three-dimensional world (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991).

The second approach has been to try to consider the differences in the gaze cues that are used by younger and older infants. There is now strong evidence that when infants first start to follow gaze they do so on the basis of head movements (Corkum & Moore, 1995). Use of eye direction develops more gradually. Infants first start to recognize the significance of eyes toward the end of the first year in that they will not follow head turns with eyes closed (Brooks & Meltzoff, 2002). However, infants do not reliably follow adult shifts in eye direction without concurrent head turns to targets outside the visual field until 18 months of age, some 9 months after they follow head turns in the same contexts (Butterworth & Jarrett, 1991; Moore & Corkum, 1998). Research on the use of multiple cues has also demonstrated that infants respond better when there are more cues and more obvious cues, such as larger head turns and gaze–gesture combinations (e.g., Caron, Kiel, Dayton, & Butler, 2002; Deák et al., 2000).

In this work, our approach was to probe further the idea that older toddlers might construe an adult's head turn as meaning that the adult was looking at something, whereas younger infants' behavior in gaze following situations might be governed by an expectancy that an interesting object would be to the side to which an adult turned.

Children were tested in a face-to-face setup with an adult and with two toys, one on each side of the room. These two toys could be activated by remote control. Over four trials, we first showed the children the activation of the toys after the adult turned to fixate them. This familiarization phase served to demonstrate to the children both that interesting toy activations were available to be seen and that adults' gaze shifts were a good cue to when and which toy activation would occur. Our hypothesis was that children on opposite sides of the 18-month transition would have subtly different interpretations of this experience. Infants closer to the onset of gaze following would learn primarily that gaze direction could be used to predict which toy would be activated. In contrast, older children on the other side of the 18-month divide would understand that the adult was turning to look at the interesting events. To examine this hypothesis, we tested children at 12 months (infants) and 24 months (toddlers). We excluded 18-month-olds on the grounds that they might be transitional between the two levels of gaze following.

In Experiment 1 we divided the children into two groups at each age and exposed them to a test phase in which one or other of the components of the familiarization phase was removed. Half the children continued to see the adult turn for a maximum of 20 trials, but in this head turn condition the toys were removed so that there was no longer anything of interest to see on either side. We predicted that because the toddlers would be more likely than infants to interpret the adult's head turn in the test phase as meaning that the adult was looking at something, they would be more likely to continue to follow head turns even after the toys had been removed. We also predicted that the infants would be less likely to continue to follow the adult's head turns in this condition because without the toys there would no longer be a good reason to follow gaze. Given that differences in gaze following in this head turn condition could result from differences in initial interest, continuing interest, or both, in the events independently of the adult's behavior, the other half of the children were assigned to a control condition in which the toys remained in place and were activated if and when the children turned toward them. In this toy condition, however, the adult did not produce any head turns to predict which toy would be activated on any particular trial. If the older children followed gaze more than did the infants in the head turn condition, then this difference should also show up in the toy condition. Experiment 2 introduced an additional control condition similar to the toy condition of Experiment 1 in that there were no adult head turns in the test phase, but different in that the toys were activated on each test phase trial whether or not the infant turned.

EXPERIMENT 1

Method

Participants. Participants were 58 children at two ages—12 months (infants) and 24 months (toddlers). Children were randomly assigned to two conditions at each age with the constraint of equal numbers of participants in each condition. At the younger age, there were 14 infants in the head turn condition (9 boys) with a mean age of 12 months, 18 days (range = 11;12–13;18) and 14 infants in the toy condition (10 boys) with a mean age of 12 months, 25 days (range = 11;08–13;25). At the older age, there were 15 toddlers in the head turn condition (7 boys) with a mean age of 24 months, 6 days (range = 23;23–24;22), and 15 toddlers in the toy condition (7 boys) with a mean age of 24 months, 11 days (range = 23;02–25;04). Five additional children (3 infants, 2 toddlers) did not complete enough trials (a minimum of eight test trials) due to restlessness or fussing. All participants were recruited from birth announcements in local newspapers. Participants were compensated with a certificate of achievement.

Procedure. Sessions were conducted in a small plain room of dimensions 3.19 m × 1.75 m (see Figure 1). On each side of the room was a 45 cm × 45 cm × 45 cm black box that was mounted on the far side of a black plywood wall approximately 77.5 cm from the floor and 1.35 m away from the chair on which the parent and infant sat. Inside each box was a turntable on which was placed an identical black-and-white stuffed dog (approximately 22.5 cm tall). These toys could be seen at all times when in the boxes through a 45 cm × 45 cm Plexiglas window on the front of each box. An experimenter in an adjacent control room watched the session on video and activated either toy as needed. When activated, the turntable rotated and a light mounted above the toy inside the box was illuminated.

During the session, the child was seated on a parent's lap facing a female experimenter about 0.6 m away. The experimenter engaged the child in face-to-face interaction. Parents were asked to close their eyes for the duration of the testing to prevent cuing their child. Both prior to and following each trial, the experimenter used a combination of vocalization and touch to engage the child in a social interaction and reestablish eye contact at midline. Intertrial intervals varied in length depending on how quickly the experimenter was able to reestablish eye contact, but typically were on the order of a few seconds.

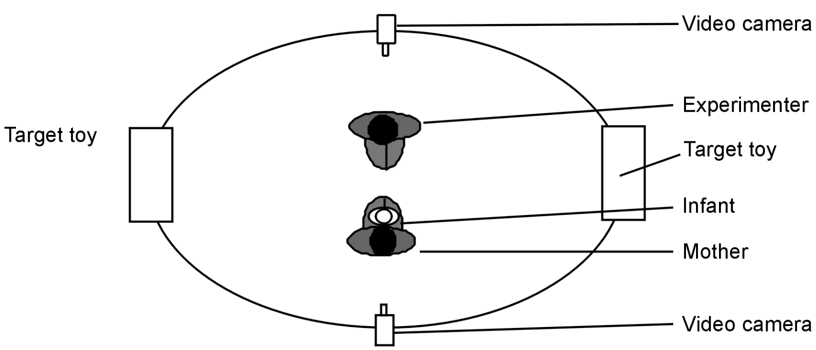

FIGURE 1 Schematic of laboratory layout.

There were two phases in the session. During the first, the familiarization phase, there were four trials (two to each side) of gaze redirection. The change in gaze direction was achieved by the experimenter reorienting her head and eyes to one or other side to fixate on the toy on that side. This reorientation of gaze occurred after the infant was looking at the experimenter and was maintained for a duration of 7 sec. To establish timing, as soon as she initiated the head turn, the experimenter would say "OK" aloud and start a tape that counted down 7 sec into an earpiece that she wore. As soon as the experimenter initiated the change in gaze direction, the toy toward which the experimenter had turned was activated by the second experimenter in the control room. When the countdown reached zero, the interactive experimenter again said "OK" and she turned back to face the child. At this point the activation of the toy was ceased. The familiarization phase demonstrated to the children that the adult's gaze shift was associated with an interesting event. All of the children tested turned to see the activated target on each of the four trials, although on occasion their first head turn was not in the direction of the activated toy (see "Results" section).

After the familiarization phase, the test phase began. For the head turn condition, after the familiarization phase the experimenter got up and removed the two toys from their boxes and hid them out of sight. This action was performed in full view of the child. The experimenter then sat down again opposite the child and continued interacting in the same manner as before. Trials were presented in the same way as in the familiarization phase with the adult turning only after the infant was attending to her, except that there was no toy activation. The experimenter said "OK," turned to one side or the other, and fixated the empty toy box for 7 sec. The side to which the experimenter turned was determined according to two fixed sequences with the constraint that no more than two head turns to the same side occurred consecutively.

For the toy condition, the experimenter continued to interact with the child and, when eye contact had been achieved, she would indicate the start of a trial by saying "OK." This signal marked the beginning of the period during which the toy on one side would be activated by the experimenter in the control room if the infant turned in that direction. At this point, the interactive experimenter would also start a tape that counted down 7 sec into an earpiece that she wore. When the countdown reached zero, the experimenter again said "OK" and the trial ended. The experimenter did not turn to the side for these trials, but continued to look at the infant's face. After the end of the trial, the experimenter then interacted with the child if necessary to reestablish eye contact. The toy that was designated for activation was determined in advance according to the same two fixed sequences as were used for the head turn condition.

There was a maximum of 20 test trials in both conditions. This phase was subdivided into five blocks of four trials each, within each of which there were two trials to each side. Some participants did not complete all 20 trials of the test phase due to restlessness or fussiness. The experimenter who was interacting with the infant and producing the head turns made the decision on termination of the session. Typically the decision hinged on the experimenter's inability to reestablish eye contact after a trial. For scoring purposes, only completed blocks of four trials were included. All participants completed at least two blocks of trials (eight trials). Two participants in each age group completed only two blocks, 6 infants and 10 toddlers completed only three blocks, 9 at each age completed only four blocks, and the rest completed all five blocks (11 infants, 9 toddlers). The numbers of participants who received shortened test phases are considered analytically in the "Results" section.

A full-face view of the experimenter and a full-body view of the infant were recorded with separate video cameras and the two images were combined on a split screen. The session lasted approximately 6 to 8 min.

Scoring. A coder who was naive to the hypotheses of the study scored the videotapes for the direction of all infant head turns in the horizontal plane to occur during each trial. For the familiarization phase and for the head turn condition of the test phase, each head turn was also designated either a match or a mismatch depending on whether the turn was aligned with (match) or in the direction opposite (mismatch) the orientation of the experimenter's gaze. Match–mismatch difference scores were then calculated for the familiarization phase and for the head turn condition of the test phase for each test block by subtracting the frequency of first infant head turns that were mismatches from the frequency of first infant head turns that were matches.

Reliability was carried out by a second coder naive to the hypotheses of the study on 21 participants drawn randomly from each age and condition. Kappa calculated on the direction of first head turn on each trial was .86.

Results

The initial set of analyses was conducted to confirm that the participants assigned to the two test conditions were equivalent in the familiarization phase, during which all participants received the same experience. First, to determine whether there were initially equivalent levels of responding to the directionality of the experimenter's head turn and toy activation, the first head turn following the adult's head turn on each trial was scored and a match–mismatch difference score of head turns to fixate the toy in the same direction as the adult minus head turns to fixate the toy in the opposite direction was calculated. These data were analyzed by a two-way analysis of variance (ANOVA) with age and condition as the between-subject variables. This analysis showed a significant main effect for age, $F(1, 54) = 4.53$, $p < .05$ (ηp^2 partial eta-squared = .077), and no other effects. The means shown in Table 1 confirm that infants were more likely than toddlers to respond to

TABLE 1
Means (and Standard Deviations) for Match–Mismatch Difference Score and Total Number of Head Turns During the Familiarization Phases of Three Conditions

	Experiment 1				*Experiment 2*	
	Head Turn		*Toy*			
	M	*SD*	*M*	*SD*	*M*	*SD*
Difference score (maximum = 4.00)						
12-month-olds	4.00	0.00	3.71	0.73	2.33	1.29
24-month-olds	3.07	1.49	3.60	0.83	3.53	.83
All head turns						
12-month-olds	8.07	2.34	8.21	2.93	6.93	2.84
24-month-olds	8.93	3.99	6.80	2.37	6.87	2.56

Note. $N = 15$ for all cells except 12-month-old head turn and toy conditions where $N = 14$. Condition labels of Experiment 1 (head turn, toy) refer to conditions that participants go on to experience in the test phase of Experiment 1.

the familiarization events by turning in the same direction as the adult to fixate the activated toy. There was no difference in performance between those participants assigned to the head turn condition and those assigned to the toy condition. Performance in all groups was significantly ($p < .001$) above chance, where chance is a difference score of 0. Second, to determine whether there were initially equivalent levels of overall interest in the events, all head turns to the side on trials in the familiarization phase were counted and analyzed according to age and test condition. A two-way ANOVA showed no significant effects, with means shown in Table 1. Therefore initial overall level of interest in the events did not differ according to age or condition.

Next we turned to the analysis of head turns in the test phase (see Table 2a). First, we compared the total number of test phase trials on which participants produced at least one head turn. A two-way ANOVA with age and condition as between-subject variables showed no significant main effects but a significant and strong interaction, $F(1, 54) = 19.76$, $p < .0001$ ($\eta p^2 = .268$). Follow-up one-way ANOVAs of age for each condition showed that in the head turn condition, toddlers turned on significantly more trials than did the infants, $F(1, 27) = 13.57$, $p < .001$ ($\eta p^2 = .334$). In contrast, in the toy condition, infants turned on significantly more trials than did the toddlers, $F(1, 27) = 7.28$, $p < .05$ ($\eta p^2 = .212$).

Because the numbers of trials completed varied across participants, it was important to take this variation into account. In one sense different numbers of trials represent a potential confound compromising interpretation of the effects just reported. However, in another sense, session length may also be taken as a measure of performance because children may become fussy or disinterested depending on

TABLE 2
Performance Measures During the Test Phases of Three Conditions: Mean Number of Trials and Standard Deviations on Which at Least One Head Turn Was Produced; Mean Number of Trials and Standard Deviations Completed; and (c) Proportion of Completed Trials on Which at Least One Head Turn Was Produced

	Experiment 1				*Experiment 2*	
	Head Turn		*Toy*			
	M	*SD*	*M*	*SD*	*M*	*SD*
a) Trials with head turns						
12-month-olds	8.14	3.42	13.71	3.32	18.93	2.37
24-month-olds	12.33	2.69	10.13	3.80	15.53	3.93
b) Trials completed (maximum = 20)						
12-month-olds	15.57	3.96	17.79	2.46	19.27	1.87
24-month-olds	16.67	3.12	15.80	3.41	16.93	3.52
c) Proportion of completed trials with head turns						
12-month-olds	.53	.16	.77	.16	.98	.04
24-month-olds	.74	.10	.64	.18	.91	.08

Note. $N = 15$ for all cells except 12-month-old head turn and toy conditions where $N = 14$.

the significance for them of the events. We therefore analyzed the number of trials completed until termination of the session. A two-way ANOVA with age and condition as between-subject variables was conducted (see Table 2b). This analysis showed no main effects but a marginally significant interaction, $F(1, 54) = 3.17$, $p = .081$ ($\eta p^2 = .055$). There was no age difference in number of trials completed in the head turn condition, but infants completed marginally more trials than toddlers in the toy condition, $F(1, 27) = 3.20$, $p = .085$ ($\eta p^2 = .106$).

These results show that the pattern of performance revealed in the analysis of number of trials completed, although weaker, follows the pattern revealed in the analyses of the number of trials on which a head turn was produced. Because of the potential confound, we carried out two further analyses on the number of trials with a head turn taking number of trials completed into account. First, we repeated the original two-factor ANOVA on the proportion of trials completed on which infants produced at least one head turn (see Table 2c for the descriptive statistics). This analysis yielded no significant main effects but a significant Age Group × Condition interaction, $F(1, 53) = 18.81$, $p < .001$ ($\eta p^2 = .258$). Follow-up one-way ANOVAs for each condition showed that toddlers turned on a significantly greater proportion of completed trials than infants in the head turn condition, $F(1, 27) = 20.25$, $p < .001$ ($hp_2 = .429$), but infants turned on marginally more trials than toddlers in the toy condition, $F(1, 27) = 4.11$,$p = .053$ ($\eta p^2 = .132$).

Second, as a more conservative approach, we also carried out an analysis on a subset of the data: the first two test blocks that all participants completed. Performance in the first and second test blocks of the test phase was compared in three-way mixed ANOVAs with age and condition as between-subject variables and block as a within-subjects variable. This ANOVA again examined the number of trials on which at least one head turn occurred (see Table 3 for the descriptive statistics). This analysis showed a significant effect of block, $F(1, 54) = 11.41$, $p < .01$ ($\eta p^2 = .174$), with more trials in the first block resulting in head turns than in the second block. There was also a significant Age × Condition interaction, $F(1, 54) = 5.38$, $p < .05$ ($\eta p^2 = .091$). Block did not interact significantly with the between-subject variables, so follow-up ANOVAs on age for each condition were done pooling across the two test blocks. Toddlers were more likely to turn in the head turn condition than were the infants, $F(1, 27) = 6.61$, $p < .05$ ($\eta p^2 = .197$), but in the toy condition, there was no significant effect, $F(1, 27) = .80$, *ns* ($\eta p^2 = .029$).

We also analyzed gaze following accuracy in the test phase of the head turn condition by counting the initial head turn to the side on each trial and then calculating a match–mismatch difference score of head turns in the same direction as the adult minus head turns in the opposite direction. In this way, a match–mismatch difference score was generated for each completed four-trial block. Because participants completed different numbers of blocks of trials, we analyzed performance only for the first and second test blocks. A two-way mixed ANOVA with age as the between-subject variable and block as the within-subjects variable showed a significant effect of age, $F(1, 27) = 4.80$, $p < .05$ ($\eta p^2 = .151$), but no effect of block and no interaction between age and block. Comparison of means (Table 4) shows that, in general, older children were more accurate than younger children. Nevertheless,

TABLE 3
Mean Number of Trials and Standard Deviations on Which at Least One Head Turn Was Produced Across the First and Second Test Blocks of Three Conditions

	First Block		*Second Block*	
	M	*SD*	*M*	*SD*
Experiment 1: Head turn condition				
12-month-olds	3.29	0.73	1.79	0.98
24-month-olds	3.60	0.74	2.60	1.18
Experiment 1: Toy condition				
12-month-olds	3.36	1.01	2.86	1.17
24-month-olds	2.87	1.25	2.73	1.10
Experiment 2				
12-month-olds	4.00	0.00	4.00	0.00
24-month-olds	3.97	0.26	3.87	0.35

Note. $N = 15$ for all cells except 12-month-old head turn and toy conditions where $N = 14$.

TABLE 4
Match–Mismatch Difference Scores for the First and Second Test Blocks in the Head Turn Condition of Experiment 1

	First Block		*Second Block*	
	M	*SD*	*M*	*SD*
12-month-olds	1.29	2.36	1.43	1.74
24-month-olds	2.53	1.73	2.60	1.18

Note. $N = 14$ for 12-month-old groups and $N = 15$ for 24-month-old groups.

over the two test blocks, children in both age groups were significantly more likely than chance to turn in the same direction as the adult: infants, $t(13) = 2.91$, $p < .05$; toddlers, $t(14) = 8.33$, $p < .001$.

The preceding analyses all reflect performance based on the first head turn that children produced in a trial. However, children frequently did not produce only one head turn per trial. Often children would look to one side, turn back to the experimenter, and then turn again. In the head turn condition, as noted, the first head turn was more often in the direction of the experimenter's head turn. In the toy condition, the first head turn was essentially random because there was no available cue for the children to predict on which side the activation would occur. Table 5a shows the number of trials in the first two blocks of the test phase with more than one child head turn as a function of age group and condition. Analysis of these data showed no significant effects. Next we examined the direction of the second head turn. Sometimes children's second head turn was in the same direction as their first and sometimes it was in the opposite direction. The proportion of second head

TABLE 5
Comparison of Head Turn and Toy conditions of Experiment 1 Over the First Two Test Phase Blocks for (a) Mean Number of Trials and Standard Deviations on Which More Than One Head Turn Was Produced; and (b) Mean Proportions and Standard Deviations of Second Head Turns in the Same Direction as the First Head Turn

	Head Turn		*Toy*	
	M	*SD*	*M*	*SD*
a) Trials with more than one head turn				
12-month-olds	3.21	1.97	3.29	1.86
24-month-olds	2.93	1.58	2.07	1.98
b) Proportion of second head turns in the same direction as the first				
12-month-olds	.27	.28	.35	.22
24-month-olds	.43	.44	.15	.24

Note. $N = 14$ for 12-month-old groups and $N = 15$ for 24-month-old groups.

turns that were in the same direction as the first head turns was calculated for the first two test blocks and analyzed according to age and condition (see Table 5b). This analysis showed no main effects but a significant Age Group × Condition interaction, $F(1, 54) = 4.75$, $p < .05$ ($\eta p^2 = .081$). Follow-up ANOVAs for each age group on condition showed that toddlers were more likely to repeat the direction of their first head turn in the head turn condition than in the toy condition, $F(1, 27) = 4.41$, $p < .05$ ($\eta p^2 = .136$). In contrast, infants were about as likely in each condition to make as many second head turns in the same direction as their first, $F(1, 27) = .75$, *ns* ($\eta p^2 = .028$).

Discussion

This experiment revealed several differences in patterns of head turning between toddlers of 24 months and infants of 12 months. First, during the familiarization phase, infants turned more in the same direction as the experimenter than toddlers. Because the targets were automatically activated during the familiarization phase, the initial difference does not reflect a difference in gaze following accuracy. Instead it may reflect a greater initial interest in actual target activation for the infants than for the toddlers. However, because there was no age group difference in the overall amount of head turning during familiarization, infants and toddlers seemed to be equally interested in the events as a whole. The test phase of the head turn condition does reflect gaze following because here the targets were not present to attract the children's attention. In this condition both the 12- and 24-month-olds followed the adult's head turn more often than chance, which is consistent with earlier research on gaze following without targets (e.g., Corkum & Moore, 1995; Deák et al., 2000). However, the toddlers were more accurate at gaze following than the infants.

Second, infants and toddlers showed different patterns of head turning in the test phase. When the adult continued to turn in the absence of the toys in the head turn condition, toddlers were more likely than infants to continue following the adult's gaze shift. This difference in performance could not reflect a greater interest in the toy activations in the toddlers or a general lessening of interest over time in the infants because when the toys were still available to be seen and activated in the toy condition, infants maintained their head turning as much or to an even greater extent than did the toddlers even though the adult was no longer turning. This pattern of performance was seen most strongly when the whole data set was analyzed for number of trials on which at least one head turn occurred. A similar trend was observed in terms of the number of test trials completed. Infants were more likely to get restless when the toys were no longer available, whereas toddlers were more likely to get restless when the adult was no longer turning. The interaction between age and condition was maintained even when the analysis was carried out on trials on which at least one head turn occurred as a proportion of number of trials completed. Nevertheless, because of the confound between number of trials completed and overall number of trials on which head turns were produced, the data from the first two test blocks present a more conservative picture of the difference between infants and toddlers. Here, the difference between infants and toddlers still showed up significantly for the head turn condition, with toddlers being more likely to turn than infants through the first two test blocks. In the toy condition, there was no significant difference between the two age groups.

These results are generally consistent with the predictions motivating the study. There was strong evidence that toddlers were more likely than the infants to continue turning to the side when the adult was doing so, even though the original toys had been removed and there was nothing obvious to see. In contrast, there was evidence that infants were as, or even more, likely than toddlers to continue looking toward one or other toy location in the condition where the toys were present and potentially active even though the adult was no longer turning. These results show clearly that infants and toddlers are not behaving the same way in this gaze following situation.

The analysis of second head turns provides additional information on infants' and toddlers' responding to the two experimental conditions. When second head turns in the same direction as the first were analyzed as a proportion of all second head turns, there was again an Age × Condition interaction. Toddlers were most likely to turn in the same direction on both their first and second head turns in the head turn condition and least likely to do so in the toy condition. This result may be interpreted as toddlers checking back to the adult once their initial head turn revealed nothing of interest. When they saw that the adult was still exhibiting the same head turn, they turned back in the same direction. In the toy condition, toddlers tended not to show this pattern: If they produced a second head turn it was very likely to be in the opposite direction. Infants showed the reverse pattern, being less likely to turn in the same direction in the head turn condition than in the toy condition.

This experiment was originally designed to expose children during familiarization to the two elements of the gaze following situation—adult head turns and interesting sights—and then remove one element in each condition during the test phase. However, it could be argued that the toy condition changed two aspects of the situation from the familiarization to the test phases. First, the adult no longer produced head turns. However, in addition to this change, the interesting sight was made contingent on the child's appropriate head turn, whereas in the familiarization phase activation of the toy had occurred whether or not the child turned. It is possible that this change in contingency had an important effect on the infants' performance. In effect, the infants' responses in this condition may have been more driven by a motivation to work out the new contingency between their own movement and the appearance of the toy than the toddlers. Therefore as a control for the head turn condition it may not have been appropriate in introducing a novel feature of the situation. To clarify this issue, we ran an additional control condition in which the same familiarization phase was followed by a test phase in which the adult no longer turned but the toys were activated on every trial, as they had been during familiarization. We predicted that this condition would still lead to equivalent or higher rates of responding in the infants compared to the toddlers.

EXPERIMENT 2

Method

Participants. Fifteen 12-month-olds and 15 24-month-olds made up the final sample. The infants (12 boys) ranged in age from 11;10 to 13;2 (*M* = 12;0), whereas the toddlers (8 boys) ranged from 23;0 to 24;22 (*M* = 23;24). One other infant was too anxious to participate and 1 other toddler became too restless to continue after five test phase trials. Participants were recruited and compensated in the same way as for Experiment 1.

Procedure. The experiment was carried out in the same laboratory environment and the familiarization procedure was in all respects the same as for Experiment 1. All participants turned in the same direction as the experimenter to see the activated toy on at least one trial of familiarization. Three infants and 1 toddler missed one trial on one side.

The test phase was carried out in exactly the same way as the toy condition of Experiment 1 except that during the trials, the activation of the toy on the predetermined side occurred for the duration of the period between the two "OK" signals of the interactive experimenter. Therefore the activated toy was available to be seen for the duration of each trial during the test phase.

Coding of child head turns was carried out as for Experiment 1 by one primary coder and reliability coding was carried out on 15 participants drawn randomly from both ages. Both coders were naive to the experimental hypotheses. Reliability on direction of first head turn was excellent ($\kappa = .94$).

Results and Discussion

As for Experiment 1, the first head turn following the adult's head turn on each familiarization trial was scored and a match–mismatch difference score of head turns to fixate the toy in the same direction as the adult minus head turns to fixate the toy in the opposite direction was calculated. In this experiment, toddlers performed better than infants, $F(1, 28) = 9.15$, $p < .005$ ($\eta p^2 = .246$). When compared to Experiment 1, it can be seen that toddlers' performance was equivalent across experiments, whereas the infants performed rather worse in this experiment (see Table

1). Nevertheless gaze following performance for both age groups was above chance ($p < .001$). Examination of the overall amount of infant head turning during the familiarization phase showed reduced levels in general compared to Experiment 1. The reasons for these differences across experiments are unclear. The participants were drawn from the same population and the experiment was carried out under the same protocol and in exactly the same laboratory context. The average age of the infants was slightly younger in this experiment than in Experiment 1, so it is possible that age differences are involved. In addition, the experimenter was different so interpersonal factors may have had an influence. Nevertheless, it is important to note that there was no difference between age groups within this experiment in the overall amount of head turning during the familiarization phase, suggesting that interest in the events did not vary with age.

Not surprisingly, children's head turning in the test phase of this experiment was rather higher overall than in Experiment 1. Most of the children completed all 20 trials of the test phase. Despite the overall high level of responding, there were still age differences (see Table 2). The infants turned to see the toys on more trials, $F(1, 28) = 8.24$, $p < .01$ ($\eta p^2 = .227$), and completed more trials than did the toddlers, $F(1, 28) = 5.15$, $p < .05$ ($\eta p^2 = .155$). A one-way ANOVA of the proportion of completed trials on which infants produced at least one head turn showed that infants turned on a higher proportion of completed trials than toddlers, $F(1, 28) = 9.11$, $p < .005$ ($\eta p^2 = .246$). Because of a ceiling effect, there was no age difference in terms of performance on the first two blocks of test phase trials (Table 3).

This difference in pattern of head turning across the two age groups is consistent with that found in the toy condition of Experiment 1: Infants showed more interest in locating the toys than did the toddlers. It implies that the results observed in that condition are not a result of the change in contingency between familiarization and test periods. As with the toy condition of Experiment 1, performance in this new condition contrasts with that observed in the head turn condition of Experiment 1, in which toddlers followed gaze to a greater extent than the infants even when there were no toys to be seen. The latter result is therefore consistent with the idea that toddlers are more concerned than infants with determining the locus of the experimenter's gaze, and that this difference is not due to a greater interest in the toy activation events.

GENERAL DISCUSSION

With these new findings, there are now three lines of evidence demonstrating that gaze following differs across age under various experimental conditions. Previous research has shown that the way infants search space in gaze following situations differs across age as the specificity of gaze following to particular locations and targets increases (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991;

Deák et al., 2000; Moll & Tomasello, 2004). It is also known that the gaze cues used by infants at different ages differ, with younger infants tending to follow head turns, whereas older infants recognize the importance of eye direction (Brooks & Meltzoff, 2002; Moore & Corkum, 1998).

Although these previous lines of research point to differences in the way responding to gaze changes with age in late infancy, the results reported here go further in perhaps revealing something about the differing motivations in following gaze that infants and toddlers have. Our results are consistent with the idea that toddlers appear to be more concerned with trying to determine what the interactive partner is looking at as they maintain their gaze following to a greater extent than the infants, even when there is no obvious target. This finding is not a result of toddlers' greater interest in the objects of attention or of 12-month-old infants being generally less interested in the interactive situation as a whole. In these studies, infants found the target sights as interesting as or even more interesting than the toddlers and they used gaze cues when there was something worth looking at. However, when there was no longer something worth looking at, gaze cues were less likely to be used by the infants.

Although our findings add to the evidence of behavioral differences in the gaze following of infants and toddlers, we do not claim that we have shown anything definitive about the difference in understanding of gaze between 12- and 24-month-olds. For example, it could be the case that the interaction we observed is the result of older children being more interested in people's gaze behavior and younger children being more interested in the targets, although such differences in interest beg the question of what makes these events relatively more or less interesting. However, our results do clearly demonstrate that the analogy between infants' and older children's gaze following behavior is at the very least limited in scope. In similar work with chimpanzees, such subtle behavioral differences have been linked to underlying differences in gaze understanding (e.g., Povinelli, 1999). Thus, we present these data in an effort to clarify that gaze following of younger infants may reflect a different understanding of joint attention situations than that of toddlers.

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REFERENCES

Baldwin, D. A., & Moses, L. J. (1996). The ontogeny of social information gathering. *Child Development, 67,* 1915–1939.

Brooks, R., & Meltzoff, A. N. (2002). The importance of eyes: How infants interpret adult looking behavior. *Developmental Psychology, 38,* 958–966.

Butler, S., Caron, A., & Brooks, R. (2000). Infant understanding of the referential nature of looking. *Journal of Cognition and Development, 1,* 359–377.

Butterworth, G., & Cochran, E. (1980). Towards a mechanism of joint visual attention in human infancy. *International Journal of Behavioral Development, 3,* 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., Kiel, E., Dayton, M., & Butler, S. (2002). Comprehension of the referential intent of looking and pointing between 12 and 15 months. *Journal of Cognition and Development, 3,* 445–464.

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. 61–83). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

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

Darwin, C. (1982). *The descent of man.* New York: Modern Library. (Original work published 1871)

Deák, G., Flom, R., & Pick, A. (2000). Effects of gesture and target on 12- and 18-month-olds' joint visual attention to objects in front of or behind them. *Developmental Psychology, 36,* 511–523.

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

Hume, D. (1978). *A treatise of human nature* (2 vols.). Oxford, England: Clarendon. (Original work published 1739–1740)

Moll, H., & Tomasello, M. (2004). 12- and 18-month-old infants follow gaze to spaces behind barriers. *Developmental Science, 7,* F1–F9.

Moore, C., & Corkum, V. (1994). Social understanding at the end of the first year of life. *Developmental Review, 14,* 349–372.

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

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

Povinelli, D. J. (1999). Social understanding in chimpanzees: New evidence from a longitudinal approach. In P. Zelazo, J. Astington, & D. Olson (Eds.), *Developing theories of intention: Social understanding and self-control* (pp. 195–225). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Povinelli, D. J., & Giambrone, S. (1999). Inferring other minds: Failure of the argument by analogy. *Philosophical Topics, 27,* 167–201.

Romanes, G. J. (1882). *Animal intelligence.* London: Kegan Paul.

Russell, B. (1948). *Human knowledge: Its scope and limits.* London: Unwin Hyman.

Scaife, M., & Bruner, J. S. (1975). The capacity for joint visual attention in the infant. *Nature, 253,* 265–266.

von Hofsten, C., Dahlström, E., & Fredriksson, Y. (2005). 12-month-old infants' perception of attention direction in static video images. *Infancy, 8,* 217–231.