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The Role of Movement in the Development of Joint Visual Attention

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Two experiments involving a training paradigm examined the role of adult head movement in early gaze following. In the first experiment, three groups of 9-month-old infants interacted with an adult, who, over a series of trials, presented one of two cues for the appearance of an interesting sight to the side. Two of the groups (nonspontaneous) were composed of infants who were not engaging in gaze following at the start of the session. One group saw the adult produce a head-turn movement to the side; the other saw only the static head orientation at the end of the same movement. The third group (spontaneous), composed of infants who were engaging in gaze following at the start of the session, also saw the adult's static head orientation. Results showed that nonspontaneous infants could learn to follow the dynamic head turn, but not the static head orientation. Spontaneous infants did follow the static head orientation. Given this result, a further group of nonspontaneous 9-month-olds were tested. Using the same paradigm, these infants observed the head-turn movement without the final static head orientation. They also followed gaze at above chance levels. The second experiment involved the same design and procedure as the first, with the exception that a head-tilt movement was substituted for the static head orientation. Again, nonspontaneous infants acquired gaze following with the head turn, but not with the head tilt. Spontaneous infants were able to learn the signal value of the head tilt in the experimental session. A further group of nonspontaneous 9-month-olds was tested in the same paradigm. These infants observed an adult head turn that stopped before reaching the target at 30°. These infants also were able to learn to turn toward the correct target. These results are discussed in the context of the developmental origins of the gaze-following response necessary for joint visual attention and the infant's understanding of attention.

gaze following joint attention movement attention social understanding

Joint visual attention occurs when one person, observing the gaze direction of another, reorients and follows that gaze to the focus of interest. In sharing a focus of visual regard, a variety of forms of communicative exchange about that object or event can then occur. For example, a comment can be passed on the object or an emotional attitude toward that object can be expressed. Joint visual attention is thus a central component of the triadic social relations that occur toward the end of the 1st year of life (Adamson & Bakeman, 1991; Bakeman & Adamson, 1984; Moore & Dunham, 1995).

Critical to the establishment of joint visual attention is the ability to follow the gaze of the interactive partner. The reasons why infants start to follow gaze toward the end of the 1st year of life remain obscure. For some time after the initial documentation of this phenomenon (Butterworth & Cochran, 1980; Lempers, 1979; Lempers, E. R. Flavell, & J. H. Flavell, 1977; Scaife & Bruner, 1975), it was assumed that infants, like older children and adults, understand that when another person produces a head turn, that person must be attending to something interesting in the periphery (Baron-Cohen, 1991; Bretherton, 1991). This explanation is certainly the conclusion to which common sense might lead us. However, there are both theoretical and empirical reasons for believing that such an interpretation is not warranted for the earliest stages of gaze following (Moore & Corkum, 1994; Perner, 1991).

In principle, a number of theoretical interpretations of infant gaze following are possible (Moore & Corkum, 1994). There could be some form of innate orienting response that matures at about 9 months that leads infants to produce an appropriate head turn after observing an adult's head turn. Alternatively, it could be the case that infants follow gaze because they have learned that interesting sights will appear if they turn their own heads after observing an adult turn. Such simple innate reflex or conditioning accounts are perhaps implausible, given the

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flexibility of the behavior. But an account that proposes that infants' attention is cued to locations in peripheral space by adults' gestures is both plausible and consistent with the phenomena (Corkum & Moore, in press).

The empirical evidence on joint visual attention in the 1st year is also inconsistent with the idea that infants understand that the other is attending to something. First, Butterworth and colleagues (e.g., Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; see also Morissette, Ricard, & Gouin-Decarie, 1995) have shown that, initially, when following gaze, infants do not follow the gaze to the particular object that the other is looking at. Rather, they turn to the appropriate side, but then focus their own gaze on the first object that they see, whether or not it is the one at which the adult is looking. Only in the 2nd year will infants locate the particular object to which the other has turned.

Second, the commonsense view holds that the infant understands the psychological relation of "looking." In order to look at something, there must be a direct and unimpeded line of sight between the eyes and the object that is looked at. That joint visual attention occurs through the infant detecting the orientation of the other's eyes has also been assumed to underlie the gaze following which is observable in the 1st year (e.g., Baron-Cohen, 1994). However, there is evidence that infants do not use eye direction when they first start to follow gaze (Corkum & Moore, 1995; Lempers, 1979). For example, Corkum and Moore (1995) found that 12-month-old infants in face-to-face interaction with an adult would turn to follow a head reorientation to the side, even when eye contact was still being maintained with the infant. In contrast, these infants would not redirect their own gaze when the adult shifted her eyes to look to the side but kept her head oriented to the infant. Moore, Corkum, and MacLellan (1996, unpublished work) found that 12-month-olds would also follow a head reorientation even when the adult had closed her eyes before initiating the movement. Sensitivity to eye direction appears to develop in the first half of the 2nd year of life so that by 18 months, there is evidence that infants will follow eye direction alone and will not follow a head orientation if the eyes do not also shift orientation (Butterworth & Jarrett, 1991; Corkum & Moore, 1995; Lempers, 1979).

A third variety of evidence which is consistent with a simpler interpretation of infants' early joint visual attention, is that infants not showing spontaneous gaze following can acquire such behavior in an experimental setting (Corkum & Moore, in press). In the Corkum and Moore study, infants 8–9 months of age were pretested for baseline gaze following. They were then shown an interesting sight to the side, contingent upon the head turn to that side of an adult interactive partner. After four such trials, the infants were tested for up to 20 trials in which they were again shown the adult head turn, but now the appearance of the target only occurred if the infant made the appropriate head turn. Under such conditions, infants who had failed to follow gaze in the baseline phase of the experiment showed a significant improvement in their gaze following during the test phase, and a significant number were able to reach a criterion of five consecutive correct head turns in response to the adult's head turn.

In a subsequent experiment to test whether infants were learning an essentially arbitrary connection between the adult's head movement and the appearance of the target, Corkum and Moore (in press, Experiment 2) compared infant performance when the adult's head turn was toward the side where the target would appear with that when the adult's head turn was towards the opposite side from that where the target would appear. Infants 8–9 months of age were unable to predict the appearance of the target on the opposite side from the adult's head turn. Indeed, infants in this unnatural condition were just as likely to follow the adult's head turn, as those who were in the more natural condition in which the adult turns to the side where the target will appear. This result was achieved despite the fact that none of the infants was engaging in gaze following at the start of the session.

These results, in general, are consistent with the idea that when they first engage in gaze following, infants do not understand that the other person is looking at something. A simpler account of infant abilities is that infants acquire the understanding that adult movements can be used to predict the direction of interesting events. How exactly such prediction is done is unclear from the research conducted to date. This article reports two experiments that investigate whether the motion information in the adult's head turn conveys the necessary directional information.

The role of movement in joint visual attention was first studied by Lempers and colleagues (Lempers, 1979; Lempers et al., 1977) 20 years ago but has been largely ignored since then. In one task, Lempers (1979) presented infants of 9, 12, and 14 months with an interactive partner who reoriented his head and eyes to fixate a target to the side while the infant was distracted, thereby presenting the infant with the final outcome of the head turn without the movement information. He found that no 9-month-olds and only about 50% of 12- and 14-month-olds would turn to locate the target. This work suggests that the movement information is initially very important in infant gaze following.

These experiments further addressed the issue of movement in the earliest stage of gaze following by employing the experimental paradigm introduced by Corkum and Moore (in press) and outlined earlier. In both studies, infants' ability to locate the target was examined given different adult cues. In Experiment 1, we compared infants' performance given a standard head turn with their performance given a static head orientation with no movement information. This approach goes beyond Lempers' work by examining infants' ability to use a static head orientation when its signal value is demonstrated. In Experiment 2, we compared infants' performance with the standard head turn with their performance given an unusual head-tilt movement. In both experiments, the performance of infants who were not showing gaze following at the start of the session was also compared to infants who were engaging spontaneously in gaze following when they commenced the experiment.

EXPERIMENT 1A

We know from earlier research that infants can acquire a gaze-following response in the laboratory when presented with an interesting sight to the side after observing an adult head turn to that side (Corkum & Moore, in press). In this experiment, we were primarily interested in whether infants could similarly acquire a gaze-following response when all they observed of the adult was a static head orientation toward the side. In order to achieve a gaze reorientation without observable movement, the adult's head was obscured during the turn by a hand-held screen.

Method

Participants

Forty-five infants of about 9 months of age (range = 8 months, 2 days to 10 months, 3 days) participated. Infants were divided into three groups on the basis of their performance in the baseline phase of the experiment (see Procedure). Those infants who met criterion for "spontaneous" gaze following were assigned to the spontaneous group. Infants who failed to reach criterion for spontaneous gaze following were randomly assigned to two "nonspontaneous" groups—movement and no movement. There were 15 infants in the spontaneous group with a mean age of 9 months, 15 days. The nonspontaneous movement group had 15 infants with a mean age of 8 months 21 days, and the nonspontaneous no-movement group contained 15 infants with a mean age of 8 months 26, days. All infants were recruited through birth announcements in local newspapers and from lists provided by the local maternity hospital.

Procedure

Infants were tested inside a specially designed area in the laboratory, enclosed with plain curtains. On each side of the area was a toy that served as the target. These toys were identical black and white stuffed dogs (height = 22.5 cm), and each rested on a 32.5 cm diameter turntable located inside a 45-cm × 45-cm × 45-cm black box, mounted on the far side of a black plywood wall. The boxes were each approximately 77.5 cm from the floor, and 1.35 m away from the chair on which the parent and infant sat. A 45-cm × 45-cm Plexiglas window on the front of the box permitted viewing of the toy. A light was mounted on the ceiling of the box, and this light turned on in conjunction with the rotation of the turntable on which the toy rested. An observer located in an adjacent room observed the session on a video monitor and was responsible for remote activation of the targets. Activation depended upon the behavior of both the experimenter and infant, as well as the phase of the session.

During the session, the infant was seated on the parent's lap and was engaged in face-to-face interaction with the experimenter. Parents were asked to close their eyes for the duration of the testing in order not to cue their infant. The experimenter used a combination of vocalization and/or touch (e.g., calling the infant's name and/or tickling the infant's tummy) in order to attract the infant's attention. Each session consisted of a total of 28 trials or changes in the experimenter's direction of gaze either to the right or left, and lasted approximately 10 min. The change in gaze direction occurred once the adult had the infant's attention, and was achieved by the experimenter reorienting her head and eyes approximately 90° to fixate the toy located to the side.

In order that the no-movement cue could be delivered for infants in the spontaneous and nonspontaneous no-movement groups, the experimenter was equipped with a hand-held screen resembling a fan that could be raised to cover her head from the infant's view. The screen was raised by the experimenter once she had the infant's attention, and was up only long enough for her to turn her head to the side in order to fixate the target. The final head orientation was held for 7 s. Once the head turn was completed, the screen was lowered. Because it was important to control for the effects of the screen movement, the experimenter also employed the screen in the movement condition, covering her face for 2 s before lowering the screen. For the nonspontaneous movement group, the head turn was produced in full view after the screen was lowered. Again, the final head orientation was held for 7 s.

For all groups, the 28-trial session was composed of three phases. In Phase 1 (baseline) there were 4 trials of a change in the experimenter's direction of gaze (2 trials to each side), throughout which the targets remained inactive. This phase permitted assessment of spontaneous gaze following. The categorization of infants as spontaneous or nonspontaneous occurred online using the criterion of a difference score equal to or greater than 2. Thus, if the infant turned in the same direction as the adult on at least 2 trials more than she turned in the opposite direction, the infant was classified as spontaneous. The baseline difference score was calculated by the observer who was responsible for activation of the targets. The status of the infant was signaled to the experimenter through the use of a small light fixed above and behind the parent's head so that it was visible to the experimenter but not to the infant. During Phase 2 (shaping), there were also 4 trials (2 to each side), but this time, regardless of the infant's behavior, the target to which the experimenter turned was activated approximately 2 s after the change in the experimenter's direction of gaze. This phase allowed the cue to be presented in association with the activation of the target. Infants had to have turned and seen the activated targets on both sides in order to move onto Phase 3. In fact, all did so within the 4 trials. Finally, during Phase 3 (test), there were 20 trials (10 to each side) during which a toy was activated only if the infant made a head turn that matched the direction of the experimenter's gaze. This phase was subdivided into five, 4 trial blocks, each having two trials to each side. Phase 3 allowed for further shaping of the joint attention response and a test of learning. 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.

Scoring

A coder blind to the nature of the cues demonstrated by the experimenter and naive to the hypotheses of the study scored the videotapes for the direction of the first infant head turn in the horizontal plane to occur during each trial of the test phase. Each infant head turn was then designated either a target or a nontarget response, depending upon whether the infant turned to look at the correct target or the incorrect target, respectively. In keeping with earlier research (e.g., Butterworth & Cochran, 1980; Corkum & Moore, in press), infant head turns in other than the horizontal plane were not scored (e.g., a look up or down would be ignored). A difference score was calculated by subtracting the frequency of nontarget responses from the frequency of target responses demonstrated in each four-trial block of the session. Trials on which no relevant response occurred were not included in the calculation of the difference score. The difference score measure was used to control for possible random head turns to the side on the part of the infant, and was preferred to a percentage measure because the latter is confounded with total head turns. A sample of 30% of the videotapes was randomly selected for reliability coding by a second coder; coefficient kappa was .98.

Results

A one-way ANOVA on baseline performance confirmed that there was a significant difference in initial ability to follow gaze among the three groups, $F(2, 42) = 40.57, p < .001$. The baseline mean difference scores are shown in Table 1. The spontaneous group performed significantly better during baseline than both of the two nonspontaneous groups, which did not differ from each other (Student Newman-Keuls, $p < .05$). Both nonspontaneous groups did not differ significantly from chance performance: [Nonspontaneous movement group, $t(14) = 1.07$, *ns*; Nonspontaneous no-movement group, $t(14) = 1.000$, *ns*], whereas the performance of the spontaneous group did, $t(14) = 12.65, p < .001$.

A two-way mixed ANOVA was calculated with group (nonspontaneous movement, nonspontaneous no movement, and spontaneous) as a between-subjects variable, and difference score in the five 4-trial blocks of the test phase as a within-subjects variable. The means and standard deviations are shown in Table 1. This analysis showed only a main effect for group, $F(2, 42) = 4.87, p <.05$. Planned comparisons (Student Newman-Keuls, $p < .05$) indicated that the nonspontaneous no movement group performed significantly less well in the test phase than both the nonspontaneous movement group and the spontaneous group.

To determine whether the performance of the groups during the test phase provided evidence of learning, the difference scores during the test phase were compared to chance performance. Both the nonspontaneous movement group and the spontaneous group performed better than chance levels, $t(14) = 3.85, p < .01$ and $t(14) = 4.17, p < .01$, respectively, although, the nonspontaneous group did not, $t(14) = 1.03$, *ns*.

Discussion

Three results from this experiment are worth noting. First, we have replicated the finding that infants of about 9 months of age who are not engaging in gaze following can be trained to do so in an experimental setting when given the

Table 1
Mean Difference Scores (Possible Range −4 to +4) and Standard Deviations for Infants in Three Groups During the Baseline and Test Phases of Experiment 1A

Group	Baseline	Test block 1	2	3	4	5
Nonspontaneous movement						
M	.267	.600	.133	1.333	.800	1.267
SD	.961	1.805	1.187	1.113	1.656	2.017
Nonspontaneous no-movement						
M	.200	.600	.267	.400	−.333	−.067
SD	.775	1.454	1.163	2.063	1.175	1.486
Spontaneous						
M	2.667	1.267	1.000	1.267	.800	1.267
SD	.816	1.792	1.254	1.710	1.521	1.486

Note: $n = 15$ in each group.

experience of an adult head turn in association with an interesting sight to the side of the turn. In this experiment, infants in the nonspontaneous movement condition performed significantly above chance during the test phase, despite the possible distraction of the experimenter's head being screened momentarily before each head turn.

Second, the actual head-turn movement appears to be an essential component of the experience for gaze following to be acquired. Infants did not learn to look in the same direction as the adult if they were only presented with the final static head orientation and not the movement. This result is consistent with the research by Lempers (1979), who found no evidence of joint visual attention in 9-month-olds when they only saw the result of an adult's turn. This result extends Lempers' finding in showing that infants at this age do not even use the static head orientation in contexts in which its significance is demonstrated. On face value, this finding is inconsistent with the view of early gaze following which attributes to infants an understanding of the other's attention to an object. The finding is consistent, however, with the attentional cuing account of early gaze following (Corkum & Moore, in press), in that the static form may not cue attention in the way that the dynamic stimulus does.

Third, infants who were already engaging in gaze following did appreciate the significance of the static head orientation. In the test phase, infants in the spontaneous group performed significantly better than those in the nonspontaneous no-movement group, and significantly above chance. Given that there was no improvement across the test phase, and thus no evidence of learning to use the static head orientation during the experiment, it appears that the spontaneous infants already appreciated the signal value of this cue before they entered the laboratory. This result indicates that, although the movement associated with gaze reorientation may be initially crucial in establishing gaze following, it is very quickly the case that infants use head orientation alone in predicting the appearance of interesting sights.

EXPERIMENT 1B

The results of this first experiment were consistent with the idea that the important component of the adult's turn for the onset of gaze following was the movement. If so, then it should perhaps be the case that if the infants only saw the movement without an extended period of head orientation toward the side, then they should still be able to acquire gaze following. In order to test this idea, we tested another group of infants after the first experiment was completed and analyzed. Fifteen 8- to 10-month-old infants (M = 9 months, 9 days) were tested. All were nonspontaneous in the baseline phase according to the criterion employed in the main experiment. The procedure was the same as in the main experiment, except that the adult turned to fixate the target toy at the beginning of each trial in the shaping and test phases, and then raised the hand-held screen to cover her head and held it there for the duration of the 7-s trial. In this way, the infant saw the movement of the head turn, but did not see the static head orientation. Infant head turns were coded in the same way as in the main experiment, and a difference score for each test block was calculated. A one-way repeated measures ANOVA on difference scores in the five test blocks indicated no main effect of block. A t-test against chance showed that performance in the test trials as a whole ($M = 2.0$, $SD = 0.0$) was significantly better than chance, $t(14) = 2.22$, $p < .05$. These results, then, showed a weak but significant tendency to turn in the correct direction when only the movement of the head turn was observed, despite the fact that the adult's head was covered for the rest of the trial.

EXPERIMENT 2A

Experiment 1 examined the importance of the natural head-turning movement for early gaze following. The finding that the head turn movement is important raises the question of what other kinds of movement might be effective. In Experiment 2, we examined whether another movement cue might be as effective for allowing infants to predict the appearance of the targets. The normal head turn involves a rotation of the head in a plane horizontal to the floor with motion toward the side. As a comparison movement, we used a rotation of the head perpendicular to the floor, but still with motion to the side. This head tilt movement involved the ear moving toward the shoulder while the adult continued to face forward and look at the infant.

Method

Participants

Forty-six infants of about 9 months of age participated in this experiment (range = 8 months, 9 days–10 months, 3 days). As in Experiment 1A, infants were again divided into three groups on the basis of their performance in the baseline phase of the experiment. Those infants who met the criterion of a difference score of 2 or more were assigned to the spontaneous group. Infants who failed to reach criterion for spontaneous gaze following were randomly assigned to two nonspontaneous groups: head turn and head tilt. There were 15 infants in the nonspontaneous head-turn group with a mean age of 9 months, 6 days, 16 infants in the nonspontaneous head-tilt group with a mean age of 9 months, 3 days, and 15 infants in the spontaneous group with a mean age of 9 months, 4 days. All infants were recruited from the same sources as in Experiment 1A.

Procedure

The experiment was carried out in exactly the same way as Experiment 1A except for the adult cues provided in the shaping and test phases. Performance was again monitored online during the baseline phase to determine group assignment. Those infants meeting criterion for spontaneous gaze following (match–mismatch difference score ≥ 2) were assigned to the spontaneous head-tilt group. Those infants not meeting criterion were randomly assigned to the two nonspontaneous groups. Infants in the nonspontaneous head-turn group saw a normal head turn during the shaping and test phases. Infants in the other two groups saw the head-tilt gesture whereby the adult tilted her head as far as possible to one side or the other while facing the infant. The head tilt was held for 7 s and then the head returned to the upright position. The hand-held screen was not used in this experiment. Scoring was done in the same way as in Experiment 1. Reliability was assessed on the basis of a random sample of 30% of the videotapes; kappa was .81.

Results and Discussion

Infants' difference scores were analyzed in the same way as in Experiment 1. The one-way ANOVA on baseline performance confirmed that there was a significant difference in initial ability to follow gaze among the three groups, $F(2, 43) = 32.49$, $p < .001$. The baseline mean difference scores are shown in Table 2. The spontaneous group performed significantly better during baseline than both of the two nonspontaneous groups, which did not differ from each other (Student Newman-Keuls, $p < .05$). Only the baseline performance of the spontaneous group differed significantly from chance, $t(14) = 12.16$, $p < .001$ [nonspontaneous head-turn group $t(14) = .43$, *ns*; nonspontaneous head-tilt group $t(15) = .21$, *ns*].

A 3×5 mixed ANOVA with group as the between-subjects variable and test block as the within-subjects variable was performed on the difference scores, which are shown in Table 2. This analysis revealed a marginally significant main effect for group, $F(2, 43) = 2.52$, $p = .092$, and a significant interaction, $F(8, 172) = 2.09$, $p < .05$. Planned contrasts comparing the two nonspontaneous groups showed a main effect, $F(1, 30) = 4.98$, $p < .05$. Univariate ANOVAs for each group showed that although there was no significant block effect for the two nonspontaneous groups, the spontaneous group performed significantly differently across blocks in the test phase, $F(4, 172) = 3.11$, $p < .05$. Comparisons of least square means ($p < .05$) indicated that the spontaneous subjects' performance on the third trial block was significantly

Table 2
Mean Difference Scores (Possible Range −4 to +4) and Standard Deviations for Infants in Three Groups During the Baseline and Test Phases of Experiment 2A

Group	Baseline	Test block 1	2	3	4	5
Nonspontaneous head-turn						
M	.067	.933	−.267	1.067	1.400	1.133
SD	.594	1.486	1.907	1.907	1.882	1.807
Nonspontaneous head-tilt						
M	.062	.438	−.188	−.125	.688	.250
SD	1.181	1.632	1.515	1.784	1.702	1.880
Spontaneous						
M	2.600	.667	.467	1.867	−.333	.267
SD	.828	1.633	1.807	1.959	1.496	2.120

Note: $n = 15$ in nonspontaneous head-turn and spontaneous groups, $n = 16$ in nonspontaneous head-tilt group.

greater than in the second, fourth, and fifth blocks.

The difference scores of the different groups during the test phase was compared to chance performance. Both the nonspontaneous head turn group and the spontaneous group performed better than chance levels, $t(14) = 4.18, p < .01$ and $t(14) = 2.67, p < .05$, respectively. The nonspontaneous head-tilt group did not, $t(15) = 1.12$, *ns*. Given the significant univariate test across block for the spontaneous group, *t* tests against chance were performed for each block; of these tests, only that for the third block was significant, $t(14) = 3.69, p < .01$.

In this experiment, we again replicated the finding that infants not engaging in gaze following can acquire this response in a laboratory setting. However, although a standard head turn has proven to be effective as a cue for the appearance of targets to the side for infants who are not spontaneously engaging in gaze following, the head-tilt movement was not effective. Nonspontaneous infants in this experiment showed no ability to predict the appearance of the target on the basis of the head-tilt movement. Therefore, it seems that these two types of movement are not equivalent as cues for directing the infant's attention. Apparently, the head-tilt movement does not carry directional information in the same way as the head-turn movement.

The performance of the spontaneous group in this experiment was especially interesting. These infants did not use the head-tilt gesture at first, but apparently learned its significance during the experiment. Thus, unlike the nonspontaneous infants presented with the head-tilt movement, the infants who already appreciated the significance of head turns were able to pick up the signal value of the head tilt in this experiment. This process appeared to occur reasonably gradually, in that performance did not reach above chance levels until the third test block. However, any conclusions about the learning pattern must remain tentative given that performance fell again toward the end of the test phase.

Experiment 2B

The results of this experiment show that a movement in the plane parallel to the floor was effective, whereas a movement in the plane perpendicular to the floor was not. In another supplementary group of infants, we attempted to extend this idea by presenting another movement in the plane parallel to the floor. Again, 15 more infants (mean age = 9 months, 14 days) who met the baseline criterion for nonspontaneous subjects were tested. The procedure was the same as in the main experiment. For this group, the adult turned to the side in the shaping and test phases, but stopped at about 30° from the midline and fixated a small mark on the curtain behind the infant. This cue type, therefore, was a head turn in the same plane as the normal full head turn but much abbreviated, and the adult never actually fixated the targets. Infant head turns were coded in the same way as in the main experiment, and a difference score for each test block calculated. A one-way repeated measures ANOVA on difference scores in the five test blocks indicated no main effect of block. A t test against chance showed that performance in the test trials as a whole (mean difference score = 5.2) was significantly better than chance, $t(14) = 4.88$, $p < .001$. This result shows that infants can learn to find the target using an adult head turn, even if that turn is much less than would be required for the adult to fixate the target.

GENERAL DISCUSSION

This work examined a variety of different cues that infants might use to predict the appearance of interesting sights in peripheral locations. Consistent with earlier work (Corkum & Moore, in press), infants who did not understand the significance of adult head turns initially, could acquire such understanding in the context of the experiments. The first experiment demonstrated that the dynamic characteristics of the adult head turn were more important for gaze following than the final static orientation of the head. The second experiment demonstrated that not all head movements are created equal in this regard. The head-tilt movement cue was ineffectual for allowing infants not already engaging in gaze following to find the targets, but head turns parallel to the floor were effective, whether or not the adult fixated the targets. Further investigation might clarify exactly which aspects of the cues were important. For example, it is possible that the necessary directional information is only available from a part of the face, such as the nose moving in the plane parallel to the floor.

The learning pattern seen in the second experiment for the spontaneous group differed somewhat from that seen in the first experiment. In the first experiment, infants in the spontaneous group recognized the signal value of the static head orientation from the start of the test phase in that there was no difference in performance among the various blocks of the test phase. That result would appear to indicate that those infants not only knew to follow head turns at the start of the session, they also knew the value of head orientation. This situation may well have existed because prior experience with joint attention situations involving static head orientations had already occurred. Because it would seem unlikely that the infants who participated in the second experiment would have had any previous experience with head tilts being predictive of the location of interesting sights, they had to learn the signal value of this novel gesture within the experimental setting. However, as noted earlier, it is important to point out that the learning pattern of the spontaneous infants in Experiment 2A was not straightforward. Instead of a linear trend in performance, they showed an improvement and then a decline through the test phase. This pattern may reflect a real change in performance over this phase, but it may also be a random fluctuation in what was an overall above chance performance.

These results indicate that the infants classified as spontaneous were different from those classified as nonspontaneous in their ability to use adult cues to find the target. There are two contrasting interpretations of this finding. The rich (or commonsense) interpretation would have it that the spontaneous infants, but not the nonspontaneous infants, understood that the adult was attending to something. Given that the spontaneous infants in the second experiment learned to use the adult head-tilt movement to locate the target, one would also have to conclude either that the infants understood the tilt to indicate visual attention directly, or that the infants understood that the adult knew where the target was to appear next and was using the tilt to convey this information. In either case, it would be true to say that the infants were able to recognize that the head tilt signified an intentional orientation to an object on the part of the adult. As noted earlier, this account is inconsistent with existing evidence on joint visual attention. Infants' performance in gaze following before the end of the 1st year does not make use of eye direction (Corkum & Moore, 1995; Moore, Corkum, & MacLellan, 1996; Lempers, 1979), and is limited to determining the general direction, and not the exact location, of the target (Butterworth & Cochran, 1980; Morissette, Ricard, & Gouin-Decarie, 1995).

We find an interpretation that attributes rather less sophisticated social understanding to infants at this age more appealing. It has been suggested previously (Corkum & Moore, in press) that by about 9 months of age, infants have developed sufficiently in terms of their attentional skills that they can respond flexibly to two different locations in space given two different directional cues. In line with this account, spontaneous infants would be those who have learned before participating in our studies that adults provide the sort of cues that can be used to find interesting sights. This account places more of the explanatory emphasis on the development of general purpose information-processing abilities applied to social interactive situations. Once these children understand that adults can be used as a cue to interesting targets located at a distance, they are in a position to start to attend to, and make use of, the different actions adults might perform that predict such interesting sights. In the second experiment reported here, the unusual head-tilt gesture is one such gesture. Further research examining the kinds of cues that infants can, and cannot make use of, in this kind of interactive setting will provide a more definitive picture of the kinds of activities that infants may treat as meaningful in this context.

The finding that spontaneous infants can learn to make use of other adult cues in this context may have relevance for how the infant develops an understanding of attention in general (cf. Tomasello, 1995), as opposed to the understanding of visual attention in particular. If a variety of adult behaviors can be used to direct the infant's own visual attention, including not only overt signs of attention such as head turns and points, but also more covert signs such as the head tilt, the infant will be in a position to generalize over these adult activities and perhaps construct a representation of adult attention as a general intentional orientation, rather than one that depends on a particular form of adult behavior, such as head turns. In natural circumstances, it is likely that joint attention starts with the infant following the head turn of others, but as different forms of adult behavior come into play, a more generalized notion of attention, one that is not dependent upon head turns alone, would arise. In short, infants may come to understand attention in others because, toward the end of the 1st year and into the 2nd, they become able to use a variety of adult gestures to pick out objects in the world.

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