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REPORT

A perceptual–attentional explanation of gaze following in 3- and 6-month-olds

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Abstract

Two experiments were conducted with 3- and 6-month-olds using a standard gaze following procedure with targets to examine the possibility that perceptual–attentional constraints may affect young infants' gaze following. In Experiment 1, either moving or stationary targets were positioned at 15° from the infants' midline. In Experiment 2, stationary targets were positioned at either 25° or 40° from the infants' midline. Gaze following was evaluated with three criteria. Infants made significantly more correct responses to the 15° stationary targets than all other response types combined. When targets were moving or further away, infants made significantly more correct than incorrect responses when they made a turn; however, they did not make significantly more correct responses across all trials. It is argued that the infants' responses are indicative of perceptual–attention constraints operating where the adult head and eye turn shifts infants' attention to the side but whether the infants then 'gaze follow' depends on the structure of the environment as well as the infants' ability to disengage attention and initiate saccadic eye movements.

The ability to follow another person's gaze has been used by some as the operational definition of joint attention (e.g. Butterworth & Cochran, 1980). Conceptually, joint attention is said to occur when two individuals simultaneously attend to each other and some third object. The capacity to engage in joint attention is thought to be a major advance in the infant's communicative functioning and Bruner (1983) suggests that joint attention is a precursor to language development. Indeed, a number of studies have shown joint attention to be related to language learning. For example, infants are more successful in learning novel words when engaged in joint attention (Tomasello & Farrar, 1986; Dunham, Dunham & Curwin, 1993), will attend to adult gaze direction when the adult utters a novel word (Baldwin, 1991; 1993), and appear to understand the adult's referential intent when looking at, and labeling, a novel object (Moore, Angelopoulos & Bennett, 1998). Although there is debate about whether successful gaze following *per se* is sufficient evidence that joint attention has occurred (see the accounts of Baron-Cohen, 1994, versus Corkum & Moore, 1995), there does seem to be agreement that gaze following is related to joint attention.

Scaife and Bruner (1975) established what has since become the standard procedure for examining gaze following ability in infants. They had infants participate in an interaction with an adult where, once the adult had established eye contact, the adult turned his head 90° to fixate a target not visible to the infant. After reestablishing eye contact, the procedure was repeated once. Using a criterion of at least one head turn in the correct direction, 30% of their 2- to 4-month-olds followed the adult's gaze. This number increased with age so that, by 11–14 months, all of their infants followed the adult's gaze. Unfortunately, this criterion includes chance performance and does not take into account incorrect head turns, making it difficult to interpret the results.

More recent reports where researchers have utilized this procedure with a more valid criterion indicate that the earliest incidents of gaze following may be found when targets are present. For example, Corkum and Moore (1995) conducted a number of studies where targets were absent and found no evidence of spontaneous gaze following before 10–12 months of age. In their procedure, adults turned to look at a location 61° from the infants' midline but no target was present.

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These researchers examined difference scores between correct and incorrect turns with differences significantly above zero indicating successful gaze following. Their results consistently show that infants below 10–12 months do not gaze follow in the absence of targets; however, infants between 6 and 9 months could be conditioned to gaze follow, with the 6-month-olds showing less success than the 9-month-olds (Corkum & Moore, 1995, 1998).

This late onset of gaze following contrasts with the findings of those who have employed targets in their experimental procedure. Butterworth and his colleagues (Butterworth & Cochran, 1980; Butterworth & Grover, 1990; Butterworth & Jarrett, 1991) conducted the most extensive studies on infant gaze following when targets were present. They tested 6- to 18-month-olds in face-to-face interactions with their mothers. Periodically their mothers turned to look at one of a series of targets positioned from 25° to 150° on either side of the infant's midline. The 6-month-olds turned to look in the same direction as their mothers, but only reliably localized the targets closest to midline. When the mother looked at a more peripheral target, performance was at chance. The 12-month-olds localized any target in front of the infant, but still did not localize targets behind them. Finally, between 12 and 18 months of age, infants started localizing objects behind them.

Two other papers which reported on gaze following to targets reported gaze following to develop later than the 6 months reported by Butterworth. However, the authors of both of these papers used a more stringent criterion to define 'success'. Lempers (1979) studied infants between 9 and 14 months of age. He stipulated that gaze following had to be immediate and had to last for a few seconds but did not control for incorrect turns. Morissette, Richard and Gouin-Decarie (1995) studied infants between 6 and 18 months of age in a longitudinal design. They compared correct versus incorrect turns but included trials where the infant made no response in their incorrect responses. Both authors reported no gaze following until 12 months of age.

Recently, D'Entremont, Hains and Muir (1997), using a procedure with highly visible targets, reported successful gaze following in 3- to 6-month-olds. In their procedure, an adult sat facing an infant and interacted until eye contact had been established. The interacter then turned her head 90° to the side to talk to one of two puppets which were held up at shoulder height. The puppets swayed slowly from side to side, independent of the interacter. The direction of the first infant eye turn following an adult head turn was recorded as either correct, incorrect or no turn. Their procedure differed from previous studies by using targets which were moving and by placing the targets much closer to the infant's midline and to the infant. Their results showed that infants at both ages made significantly more correct turns than turns in the incorrect direction or no turns combined. This study is important because it is the only study other than that done by Scaife and Bruner (1975) to show gaze following in infants younger than 6 months of age using this paradigm.

Combined, the studies to date suggest that gaze following in infants younger than 12 months of age is highly dependent on the nature and location of targets; but what type of mechanism might account for this? Butterworth (Butterworth & Grover, 1990; Butterworth & Jarrett, 1991) suggested that gaze following at the earliest ages (6–12 months) is characterized by an 'ecological' mechanism. Under this mechanism, the adult head turn serves as a cue to the infant to shift attention elsewhere. The structure of the environment 'completes for this infant the communicative function of the adult's signal' (Butterworth & Grover, 1990, p. 611). The saliency of the target in the environment is what captures the infant's attention and allows the gaze following response to be completed. This perceptual–attentional system (Moore, 1999) may be driven in part by the infant's peripheral vision. Thus, at the early stages of gaze following, infants might be expected to localize targets close to their midline but not when the targets are further away. Butterworth's findings that infants first localize targets in front of them but not behind them supports this hypothesis. There is also some support for the operation of perceptual–attentional constraints from studies which examined infants' ability to gaze follow when there were multiple targets in front of the infant. However, since in neither case did the authors test infant ability to gaze follow to single targets present, we do not know how successful the infants might have been in gaze following to the more distal target. The results of D'Entremont *et al.* (1997) are also not inconsistent with the operation of attentional–perceptual constraints but do not allow for an adequate evaluation of this hypothesis, since only one distance was measured. An adaptation of the procedure to include single targets at multiple distances would allow for a better test of the possibility that attentional–perceptual factors affect gaze following performance.

In the present work we examined the possibility that gaze following is influenced by perceptual–attentional constraints in 3- and 6-month-old infants. Two variables, motion and distance of targets, were manipulated in order to vary the saliency of targets within a gaze following paradigm. In all experiments, as in D'Entremont *et al.*'s study (1997), puppets served as targets; however, one important change was introduced to the procedure. In D'Entremont *et al.* an experimenter held the puppets. Although all attempts were made to ensure that the puppets moved independently of infant or adult behaviour, it is possible (but not likely) that the experimenter inadvertently influenced infant behaviour. To control for this possibility, the puppets in the present experiments were mounted on posts. The puppets were either moving or stationary and their locations were 15°, 25° or 40° from either side of the infant's midline. Also, in Butterworth's studies the targets were positioned in quadrants of the room so that there was always a negative correlation between visual angle and distance of target from the infant. The targets in the current study were positioned along an imaginary semicircle so that the distance from infant to target (radius) remained constant. Finally, the use of different criteria for defining successful gaze following in the literature has created confusion regarding the age of onset of gaze following. Hence, three different criteria were examined and are reported.

Experiment 1

Experiment 1 had two purposes. The first purpose was to replicate the findings of D'Entremont *et al.* (1997) with puppets mounted on posts rather than being held up by the experimenter. The second purpose was to extend their findings by comparing infant responses to moving versus stationary targets. The puppets were positioned 15° to the left and right of the infant's midline to approximate the distance used by D'Entremont *et al.* (1997).

Method

Participants

Forty-seven infants and their mothers were recruited through birth announcements in a local newspaper. All infants were from middle-class, two-parent, Caucasian families. Data from two infants were lost due to fussiness and from four infants due to experimenter error, leaving 41 infants with usable data. The mean age of the 3-month-olds was 3 months 8 days ($SD = 5$ days) while the mean age of the 6-month-olds was 6 months 12 days ($SD = 10$ days).

Apparatus

All sessions took place at the end of a small room with the infant seated in an Evenflo infant seat mounted on a table 80 cm away from the adult. A wooden tri-fold screen was used to block visual distractions from the remainder of the room. A Panasonic AG-455MP video camera recorded the image of the infant and a Panasonic WV-3150 video camera recorded the image of the adult. The images from these two cameras were combined into a split screen image by a Digital AV Mixer WJ-AVE5 special effects generator and a Panasonic SVHS VCR was used to record the final, combined image. Two puppets in the shape of puppy's heads were mounted on motors which allowed the puppets to oscillate slowly back and forth. The puppets and motor were then mounted on posts 112.5 cm high. The total height of the posts and motors was 122.5 cm. The posts were positioned 80 cm away from, and at 15° to the left and right of, the infant's midline with the 'face' of the puppet facing toward the infant.

Procedure

After obtaining informed consent, the mother was asked to place her infant in the infant seat. A female adult stranger then sat between the two puppets facing the infant. Prior to arrival, the infants were assigned to either a moving or a stationary group. Once the adult was seated, the puppets began to oscillate for the moving group; for the stationary group, the puppets remained stationary. The adult interacted with the infant until eye contact was established. She then turned her head to look at, and talk to, one of the puppets for about 10 s before turning back to interact with the infant. This was designated as one trial. This object referencing went on for 4 min with at least two turns to each side for a minimum of four trials. The turns followed either a left–right–right–left or a right–left–left–right pattern, with direction of first turn randomly decided before the infant arrived. The interaction was videotaped and the video records were scored as follows: the sound was turned down, the infant's image was covered and the time and direction of adult head turns were recorded by the first author. A naive, independent observer was then given the times (but not directions) of the adult head turn. This naive observer then viewed the tapes with the sound turned down and the adult's image covered and recorded the direction of the first infant eye turn occurring after the adult head turn. Thus, the observer was aware that a trial had occurred but was blind to the direction of the adult head turn. The record of adult head turns was then matched to infant eye turns to determine whether the direction of the first infant eye turn matched the adult head turn. Any trials where infant eye turns preceded an adult head turn were excluded from analysis. A trial was scored as correct if eye turns were judged to be directed toward the same side as the adult head turn and incorrect if eye turns were judged to be directed toward the opposite side to the adult head turn. When the infant continued to look toward the adult during the head turn, the trial was scored as no turn. A fourth category called 'look aways' was also scored. These occurred on trials where the infant looked somewhere other than at the adult or in the horizontal plane. These usually consisted of the infant looking down toward his or her feet or at the seat. An independent observer who was also blind to the condition and naive to the hypotheses coded a random sample of 25% of the tapes. Inter-rater reliability calculated using Cohen's kappa was 0.91.

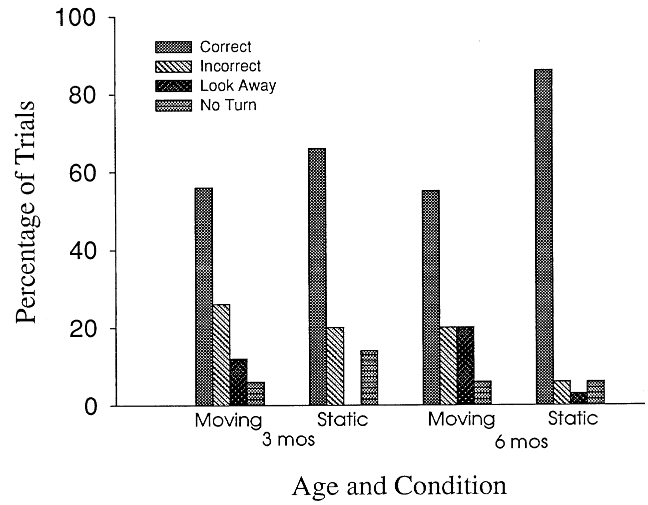

Figure 1 *Response type as a percentage of all trials for 3- and 6-month-olds with targets at 15° from the infants' midline in the moving and stationary conditions.*

Criteria

Three separate criteria were used in the data analyses. The first criterion involved only those trials where the infant made a head turn. This criterion consisted of determining whether correct turns were significantly different from incorrect turns. This is the least strict criterion since it does not take into account the other response categories, no turn and look aways. The second criterion involved all trials. This criterion consisted of determining whether correct trials were significantly different from the sum of incorrect, no turn and look away responses. This is the most stringent criterion. The third criterion involved only correct responses. This criterion consisted of determining whether correct turns were significantly different from chance, assuming that the infant had four response options available. This criterion lies somewhere between the most stringent and the least stringent criterion.

Results

The distribution of responses across the four groups is shown in Figure 1. A 2 (age: 3 vs 6) × 2 (condition: moving vs stationary) × 2 (side: left vs right) analysis of variance (ANOVA) revealed no significant main effects or interactions for turns to the left versus right ($m = 2.05$; SD = 1.4; $m = 2.10$; SD = 1.18; for turns to the left and right, respectively). There were a total of 207 trials across all infants. Of those trials, 63% of infants' first eye turns were in the same direction as the adult head turn. Eliminating the look away and no turn trials, there were 170 trials were the infants actually made an eye turn. Of those, 77% of infants' first eye turns were in the same direction as the adult head turn. Thus, the majority of infant responses were correct eye turns.

Latency to turn left versus right was examined with a 2 (age: 3 vs 6) × 2 (condition: moving vs stationary) × 2 (side: left vs right) ANOVA. There were no significant differences between latency to turn left versus right; however, there was a significant condition effect. Infants had shorter latencies when the targets were stationary ($m = 5.38$ s; SD = 3.59 s; $m = 2.54$ s; SD = 2.03 s; for moving versus stationary targets, respectively; $F(1, 32) = 16.08$, $p < 0.001$). Latency to correct versus incorrect target was examined with a 2 (age: 3 vs 6) × 2 (condition: moving vs stationary) × 2 (correctness: correct vs incorrect) ANOVA. Results indicated a correctness by condition interaction ($F(1, 17) = 4.98$, $p < 0.05$). Simple effects testing revealed shorter latencies to the incorrect side when targets were moving ($m = 5.33$ s; SD = 3.12 s; $m = 3.19$ s; SD = 2.80 s; to correct versus incorrect side, respectively; $F(1, 19) = 6.56$, $p < 0.05$) but no difference in latencies to correct versus incorrect targets when targets were stationary ($m = 2.16$ s; SD = 1.53 s; $m = 2.30$ s; SD = 1.49 s; to correct versus incorrect side, respectively; $F(1, 19) = 0.02$, $p = 0.90$).

Criterion 1

Following criterion 1, a 2 (age: 3 vs 6) × 2 (condition: moving vs stationary) × 2 (correctness: correct vs incorrect) ANOVA was conducted on infant eye turns on those trials where the infants actually turned. Age and condition were between-subjects effects while correctness was a within-subjects effect. The results are shown in Figure 2(a). Analyses revealed no age or condition effects; however, there was a significant correctness effect ($F(1, 37) = 50.44$, $p < 0.01$). When the

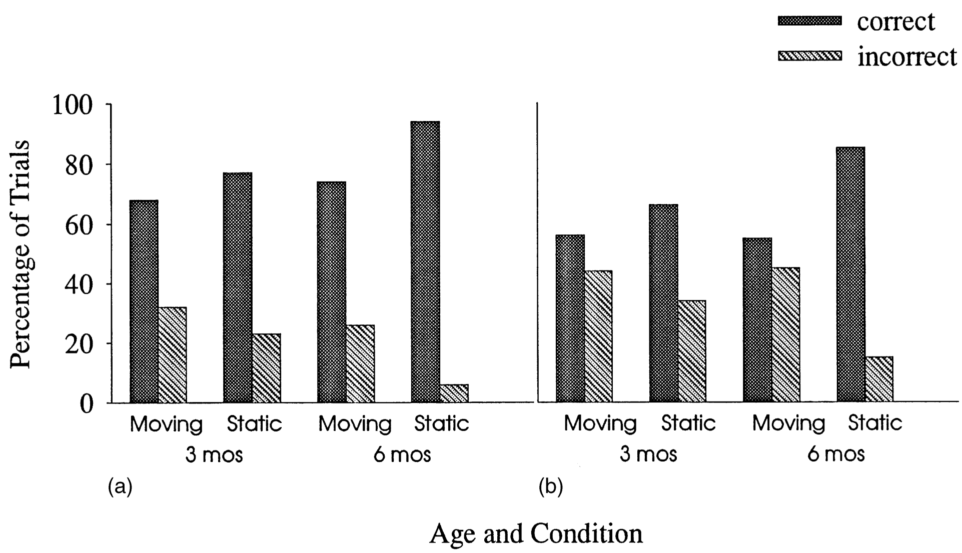

Figure 2 *Correct and incorrect responses for 3- and 6-month-olds with targets at 15° from the infants' midline in the moving and stationary conditions as a percentage of only those trials where the infant made an eye turn (a) and as a percentage of all trials where incorrect is the sum of incorrect, look away and no turn responses (b).*

infants made an eye turn, they made significantly more correct than incorrect turns.

Criterion 2

Analyses for criterion 2 involved all trials. A 2 (age: 3 vs 6) × 2 (condition: moving vs stationary) × 2 (correctness: correct vs incorrect) ANOVA was conducted on infant eye turns where incorrect responses were defined as the sum of the incorrect, look away and no turn responses. Results can be seen in Figure 2(b). There were significant condition ($F(1, 37) = 6.03, p < 0.05$) and correctness ($F(1, 37) = 12.97, p < 0.01$) effects as well as a significant interaction between condition and correctness ($F(1, 37) = 4.30, p = 0.05$). Simple effect testing revealed that infants made significantly more correct than incorrect responses when the puppets were stationary ($F(1, 18) = 22.84, p < 0.01$) but not when they were moving ($F(1, 21) = 0.99, p > 0.05$). There were no age effects.

Criterion 3

Assuming that infants had four response options (correct, incorrect, no turn, look away), correct responses were evaluated to determine if they occurred significantly more often than would be expected by chance. Each group was examined separately using t tests. The 3-month-olds made more correct responses than would be expected by chance both when targets were moving ($t = 2.95, p < 0.05$) and when they were stationary ($t = 5.84, p < 0.001$), as did the 6-month-olds ($t = 4.05, p < 0.01$; $t = 7.23, p < 0.001$; for moving and stationary targets respectively).

Discussion

Both the 3- and 6-month-olds were successful in following an adult head and eye turn toward a puppet positioned at 15° from the infants' midline. These results are similar to D'Entremont *et al.*'s (1997) results; they reported 73% of infants' first eye turns were in the correct direction (66% of all trials) and this experiment found 77% of infants' first eye turns were in the correct direction (63% of all trials). Moreover, the present experiment eliminates the possibility that the experimenter inadvertently affected the results of D'Entremont *et al.* by holding the puppets since the puppets were mounted on posts in the present experiment and any movement was completely independent of the experimenter. The fact that infants did not make significantly more correct than incorrect responses to moving targets when their responses across all the trials are considered is counterintuitive, given that infants tend to perform better with moving than stationary stimuli. The effect of the moving targets seems to have been to increase the number of look away responses. Perhaps the moving targets created somewhat of a stimulus overload or a fatigue response, such that the infants spent more time looking at themselves than at the targets or the experimenter.

Experiment 2

Having replicated the results of the original D'Entremont *et al.* (1997) study, Experiment 2 was conducted to investigate the effect of distance of the target on the infants' ability to gaze follow. Stationary targets were used since the results of Experiment 1 indicated that infants were more successful in gaze following when the targets were stationary. Also, the shorter latencies to incorrect targets could have indicated that the movement was distracting to the infants and thus interfering with a cognitive response to the head turn. As before, puppets were mounted on posts, but this time the posts were positioned at either 25° or 40° from the infants' midline. The same three criteria for evaluating the infants' responses were used as in Experiment 1.

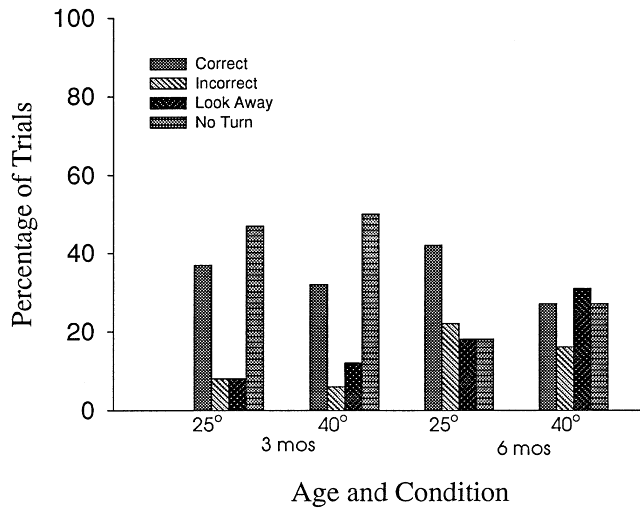

Figure 3 *Response type as a percentage of all trials for 3- and 6-month-olds with targets at 25° versus 40° from the infants' midline.*

Method

Participants

Thirty-nine infants and their mothers were recruited through birth announcements in a local newspaper. All infants were from middle-class, two-parent, Caucasian families. Data from one infant were lost due to experimenter error, leaving 38 infants with usable data. The mean age of the 3-month-olds was 3 months 6 days (SD = 9 days) while the mean age of the 6-month-olds was 6 months 8 days (SD = 10 days).

Apparatus and procedure

The apparatus and procedure were identical to Experiment 1 except that the posts with the puppets were placed at either 25° or 40° from the infants' midline and they were always stationary. The tapes were coded and analysed as in Experiment 1. Inter-rater reliabilities on a random sample of 25% of the tapes yielded a Cohen's kappa of 0.84.

Results

Figure 3 shows the distribution of all responses. There were a total of 167 trials across all infants. There were no differences in the number of turns to the left ($m = 0.95$; SD = 1.21) versus turns to the right ($m = 1.18$; SD = 1.18) as measured by a 2 (age: 3 vs 6) × 2 (condition: moving vs stationary) × 2 (side: left vs right) ANOVA. As can be seen in Figure 3, the proportion of correct turns was lower than in Experiment 1 (35% of all trials). Infants made far fewer turns when the targets were further away (81 turns). Nevertheless, infants were still correct on 72% of those trials where they made a response.

A 2 (age: 3 vs 6) × 2 (condition: moving vs stationary) × 2 (side: left vs right) ANOVA conducted on latency to turn left ($m = 5.04$ s; SD = 3.56 s) versus right ($m = 3.80$ s; SD = 3.07 s) revealed no significant main effects or interactions. Similarly, a 2 (age: 3 vs 6) × 2 (condition: moving vs stationary) × 2 (correctness: correct vs incorrect) ANOVA conducted on latency to turn toward the correct target ($m = 4.59$ s; SD = 2.65 s) versus the incorrect target ($m = 5.05$ s; SD = 5.79 s) also revealed no significant main effects or interactions.

Criterion 1

A 2 (age: 3 vs 6) × 2 (distance: 25 vs 40) × 2 (correctness: correct vs incorrect) ANOVA was used to examine infant responses on only those trials where infants made a turn. Results indicate that infants made significantly more correct than incorrect responses ($F(1, 34) = 19.92$; $p < 0.001$). This can be seen in Figure 4(a). There were no effects of age or distance of target on responding.

Criterion 2

When we define incorrect responses as the sum of incorrect, no turn and look away responses, the picture changes somewhat. A 2 (age: 3 vs 6) × 2 (distance: 25 vs

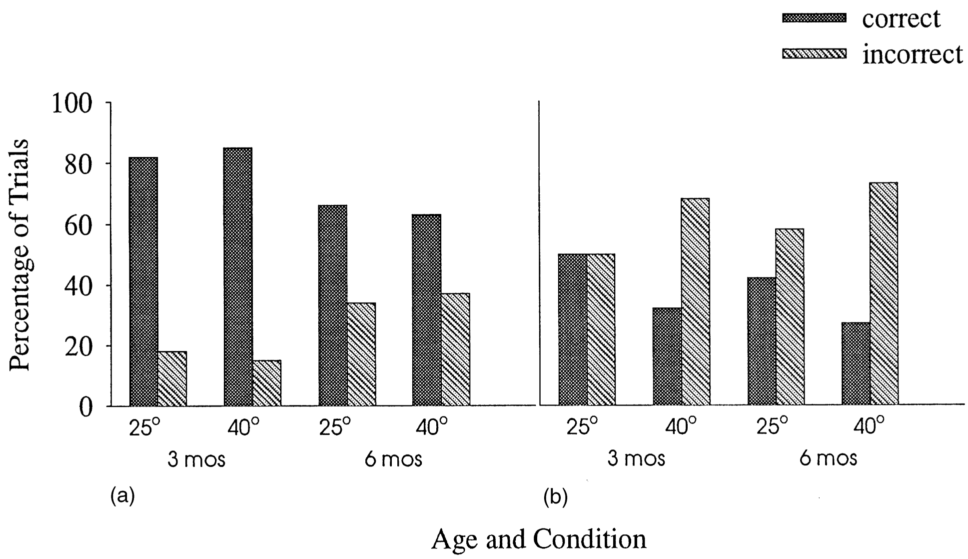

Figure 4 *Correct and incorrect responses for 3- and 6-month-olds with targets at 25° versus 40° from the infants' midline as a percentage of only those trials where the infant made an eye turn (a) and as a percentage of all trials where incorrect is the sum of incorrect, look away and no turn responses (b).*

40) $\times$ 2 (correctness: correct vs incorrect) ANOVA was conducted with this more stringent definition of incorrect responses. As can be seen in Figure 4(b), infants made significantly more incorrect than correct responses ($F(1, 34) = 14.37$; $p < 0.001$).

Criterion 3

t tests were again used to determine if correct responses were significantly greater than expected by chance, assuming that infants had four response options (correct, incorrect, no turn, and look away). None of the *t* tests reached significance indicating that, over all the trials, the infants did not make significantly more correct responses than expected by chance.

Discussion

Infants were successful in following an adult's head and eye turn to targets at 25° and 40° from their midline when measured by the least stringent criterion: correct versus incorrect turns. However, they were not significantly above chance performance and they did not make more correct responses than incorrect responses when incorrect responses were defined as the sum of incorrect, look away and no turn responses. In fact, under this latter, most stringent, criterion, infants made more incorrect than correct responses. In other words, the increased distance in this second experiment made the task harder for the infants. This was revealed not by an increase in the incorrect response rate but, rather, by an increase in the number of extraneous responses.

General discussion

These data support the hypothesis that gaze following in very young infants is initially constrained by perceptual–attentional factors and is dependent to some degree on environmental support. Moreover, the data indicate the importance of examining different criteria for defining gaze following 'success'. Had the only criterion been correct versus incorrect turns, ignoring the other response types, the conclusion would have simply been that young infants are able to gaze follow to moving and stationary targets at distances ranging from 15° to 40° from the infant's midline. By examining different criteria and by looking at all four response types, a better picture of young infants' gaze following has been obtained. It was determined that motion and distance of targets did have an effect on infant responding: when targets were stationary and at 15° from the infants' midline, infants were able to gaze follow to the correct target, and they did this significantly more than all other response types combined. However, when the targets were moving, or when they were moved further away, although the infants turned significantly more often in the correct direction *when they made a turn*, they did not look significantly more often in the correct direction *across all of the trials*.

The commonsense view of gaze following holds that, when the infant sees the adult turn his or her head, the infant has understood that the adult has turned to *look at* something and the infant is turning to look too (e.g. Bretherton, 1991; Baron-Cohen, 1994). In other words, the infant has understood or represented the adult as a being, separate from self, who is able to see objects. The infant has then, by analogy, also represented self as able to see objects (Moore & Corkum, 1994). Moore and Corkum (1994) have argued that this is a lofty claim for infants of this age. Specifically, they noted that, at this age, infants' cognitive abilities are not advanced enough to reason simultaneously about self and other with regard to an object (Perner, 1991), nor do they reason about both agents *and* objects during causal events (Cohen & Oakes, 1993), both of which would be necessary under the commonsense view.

A simpler explanation is that the infants were merely imitating the adult; however, the adult's response consisted of a head and eye turn whereas the infant response for the most part consisted of only an eye turn without accompanying head turns. Another possibility is that the infants were tracking the adult's nose or trying to maintain eye contact as she turned her head. There are two counter-arguments to this explanation. First, the latencies for eye movements were more than 2 s (particularly latencies to correct turns when the targets were moving and latencies to the further targets, which ranged between 3 and 5 s). When compared to latencies for infants to turn their heads to off-centre sounds (about 1 s), tracking does not seem a likely explanation. Second, Hains and Muir (1996) had adults interact with infants while averting their head and/or eyes to the side. No target was visible to the infants in their study. These authors found no evidence to suggest that infants turned their heads or eyes to the same side as the adult. Infants simply reduced smiling at the adult, while gaze to the adult did not change. It seems unlikely that the presence or absence of targets would affect a tracking response and, if infants had been trying to maintain eye contact with the adult, their duration of gaze at the adult would have decreased during the adult gaze avert conditions in the Hains and Muir (1996) study.

A third possibility is that the adult's head turn served as a cue for an infant eye turn and the infants simply learned that if they made an eye turn following an adult head turn an interesting sight would occur (Moore & Corkum, 1994). In other words, this is simply a conditioned response. This argument does not explain the results because correct and incorrect turns were not differentially reinforced by the experimenter and the targets were identical on both sides. Of course, the learning may have taken place before the infants came into the laboratory. Moore and Corkum (1994) initially proposed that during social interactions mothers naturally bring interesting objects to their infants' attention. Eventually, these objects will be somewhat in the periphery and so the mother will have to turn her head. The infant then begins to associate the mother's head turn with an interesting sight. In support of their argument, Corkum and Moore have repeatedly demonstrated that gaze following to distal targets can be learned by about 8 months of age (Corkum & Moore, 1995, 1998; Moore & Corkum, 1998). However, their ability to learn depends on whether the cue is natural or unnatural. Infants learned to gaze follow to a head turn in the same direction as the adult but failed to learn to gaze follow to the opposite side to the adult in an operant conditioning procedure, arguing against a simple learning mechanism as the sole explanation for gaze following (Corkum & Moore, 1998).

The operation of perceptual–attentional constraints is supported by examining the different response types and comparing different criteria, as was done in this paper. Many people have disregarded the trials where infants failed to turn. One exception to this was Morisette *et al.* (1995) who included no response in their incorrect category. These authors assumed that no response indicated that the infants misunderstood the adult's cue. However, no response may reflect difficulty disengaging attention. Hood, Willen and Driver (1998) used a computerized display to show 3-month-olds a still picture of an adult's face with forward facing, blinking eyes. On test trials, the adult's eyes would orient to the left or right and then a peripheral probe would appear on either the congruent or incongruent side. They found that infants made faster eye movements to congruent than incongruent probes but that the effect was significantly attenuated if the central face stimulus remained on-screen during the probe trial. That is, the infants were not able to disengage their attention from the central stimulus when it remained on the screen.

In the traditional gaze following paradigm, the face remains in the central vision (albeit at a different orientation). The face is a powerful attention grabber for infants and, as noted by Hood *et al.* (1998), young infants may have difficulty disengaging their attention. Trends in the current data support this. For example, when the targets were moved further away, the percentage of no turns increased substantially, particularly for the 3-month-olds. Their percentage of no turns increased from 10% when the targets were at 15° to 50% when the targets were at 40°, while the 6-month-olds' percentage of no turns increased from 6% when the targets were at 15° to 23% when the targets were at

40°. The increased distance also had an opposite effect on the percentage of incorrect responses at the two ages: the 3-month-olds' incorrect responses decreased with the increasing distance of targets while the 6-month-olds' incorrect responses increased.

These results suggest that infants require the presence of peripheral stimuli to attract their attention and when it is not there the infants have trouble disengaging their attention. The 3-month-olds may have more trouble than the 6-month-olds in disengaging their attention since they were more prone to increased no turns when the targets were moved further away, and may be more affected by distractions since, when they did make a response on the 15° trials, they tended to make somewhat more errors than the 6-month-olds. When the 3-month-olds disengage, perhaps they are visually tracking the movement as it occurs. With less distractions at the further distance, the effect would be to decrease their incorrect responses. In contrast, the 6-month-olds may be less affected by these perceptual–attentional constraints. When they disengage, the net effect for them would be to decrease their correct responses and increase their incorrect responses, relative to the 3-month-olds. This explanation is speculative, but it does fit with what is known about infants' ability to disengage attention and their ability to initiate voluntary saccadic movements, both of which show major improvements between 3 and 6 months of age (Johnson, Posner & Rothbart, 1991; Haith, 1993; Hood, 1995).

The implication of this argument is that the ecological mechanism proposed by Butterworth (Butterworth & Grover, 1990; Butterworth & Jarrett, 1991) is strongly influenced by the infants' perceptual–attentional skills. Under this proposal, the adult head turn serves to shift infants' attention to one side or the other, and then whether infants 'gaze follow' depends on their ability to disengage attention from a central stimulus, their ability to program saccadic eye movements, and whether there is something further in the environment to help attract their attention away from the central stimulus. The ability to disengage attention may also depend on auditory localization cues. In previous uses of this paradigm, experimenters stopped talking when they turned their heads, whereas the experimenter continued talking in the current study. Although some influence of auditory localization cannot be entirely ruled out in this study, it is unlikely to be the single causal factor in gaze following: research on infant audition has indicated that the smallest angular shift in sound location away from midline that 6-month-olds can discriminate reliably is 12°–14° (Ashmead, Clifton & Perris, 1987; Morrongiello, 1988) while the angular shift created by turning one's head is much smaller. Even if auditory localization plays some role in this process, it does not diminish the possibility of the operation of perceptual–attentional constraints: it becomes one of the perceptual parameters to examine in the future. Our task, as developmental psychologists, is to determine which perceptual–attentional constraints are important and when these give way to allow gaze following to be largely determined by social understanding. There are two possible avenues to guide this search. One avenue is to explore the attentional or other perceptual factors influencing gaze following with carefully controlled factorial manipulation of variables. The other avenue is to focus on joint attention as a communicative process and to look at the links between early communicative skills and various measures of joint attention, including gaze following. These should not be mutually exclusive; only by focusing on the interrelation between cognitive and social development will we understand the development of joint attention and how early gaze following fits into the developmental picture.

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