Research Report

ADULT'S EYES TRIGGER SHIFTS OF VISUAL ATTENTION IN HUMAN INFANTS

Bruce M. Hood,[1] J. Douglas Willen,[1] and Jon Driver[2]

[1]Harvard University and [2]Birkbeck College, University of London, London, United Kingdom

Abstract—*Two experiments examined whether infants shift their visual attention in the direction toward which an adult's eyes turn. A computerized modification of previous joint-attention paradigms revealed that infants as young as 3 months attend in the same direction as the eyes of a digitized adult face. This attention shift was indicated by the latency and direction of their orienting to peripheral probes presented after the face was extinguished. A second experiment found a similar influence of direction of perceived gaze, but also that less peripheral orienting occurred if the central face remained visible during presentation of the probe. This may explain why attention shifts triggered by gaze perception have been difficult to observe in infants using previous naturalistic procedures. Our new method reveals both that direction of perceived gaze can be discriminated by young infants and that this perception triggers corresponding shifts of their own attention.*

The direction of other people's gaze can reveal where they are attending, and thus indicate sources of potential interest or danger in the environment. Gaze monitoring may have played a crucial role in the evolution of socialization (Humphrey, 1976). In infants, the emergence of the tendency to look where another person looks is a fundamental landmark in the development of referential communication. In standard paradigms for measuring this behavior (Butterworth & Jarrett, 1991; Corkum & Moore, 1995; Scaife & Bruner, 1975), normal infants 10 to 12 months old are reliably found to look in the direction toward which adults turn their heads and eyes.

Although the direction of another person's attention can be signaled by a combination of his or her eye, head, and body orientation, adult observers are extremely sensitive to eye direction alone (Anstis, Mayhew, & Morley, 1969). This behavioral sensitivity accords with accumulating evidence for specialized gaze detectors within the primate visual system. Many cells in the monkey superior temporal sulcus respond selectively to the direction of perceived gaze (Perrett & Mistlin, 1990). Furthermore, neuropsychological studies of patients with inferotemporal damage, and related lesion studies with monkeys, also suggest there may be specialized detectors for the direction of perceived gaze within the visual system (Campbell, Heywood, Cowey, & Regard, 1990). In reviewing these data, Baron-Cohen (1995) recently proposed that a modular eye direction detector (EDD) plays a central role in the development of social cognition, and implied that it must be operating before the emergence of joint-attention behaviors toward the end of the 1st year of life.

Empirical studies have consistently suggested that infants do not reliably orient in the direction of adults' attention, as signaled by the eyes alone, until well into the 2nd year of life. Up to that point, socially mediated attention shifts are triggered primarily by perceived head movements. Eye direction alone has not been shown to affect infant orienting until around 18 months (Corkum & Moore, 1995). Thus, there is currently little clear evidence for a very early EDD mechanism triggering shifts of attention. However, analysis of scanning patterns reveals that beginning at age 2 to 3 months, infants preferentially scan the eye region of human faces (Maurer, 1985) and will discriminate between two faces in which the gaze differs (Vecera & Johnson, 1995). Moreover, in an adult-infant interaction paradigm, 3- to 6-month-old infants smile less whenever the adult looks away (Hains & Muir, 1996). This finding reveals that young infants can discriminate perceived eye direction, raising the question of why appropriate orienting in the corresponding direction has not been observed for them to date.

There are several reasons why infants might fail to orient in the direction of perceived gaze within the usual naturalistic paradigms. For example, young infants can have difficulty in disengaging fixation from salient central stimuli (Hood, 1995; Stechler & Latz, 1966), such as the adult's face in interactive paradigms. Also, at 3 months, the ability to make large voluntary saccades is only just emerging (Haith, 1993; Hood, 1995; Johnson, Posner, & Rothbart, 1991). These eye movement restrictions, dictated by cortical laminar development (Johnson, 1990), could lead infants to fail naturalistic tests of whether they look where others look, even if their attention covertly shifts in the appropriate direction. Accordingly, we developed a computerized paradigm to avoid these possible restrictions.

The direction of perceived gaze was manipulated in a digitized adult face (see Fig. 1). Crucially, this central face disappeared after looking to one side, to avoid difficulties in disengaging fixation. Moreover, any attention shifts were measured by the latency and accuracy of saccades to subsequent peripheral probes (Hood, 1995), thus avoiding any requirement for purely voluntary saccades. Finally, only the eyes of the central face moved, in order to test whether an EDD alone can trigger attention shifts in young infants.

EXPERIMENT 1

Method

Subjects

Sixteen healthy, full-term infants ages 10 to 28 weeks (mean age = 18.6 weeks, *SD* = 6.2) were tested; 8 were female. An additional 14 subjects were excluded for failure to complete at least eight test trials because of fussing.

Apparatus

The face used as a cuing stimulus is illustrated in Figure 1. A full-size, color image was frame-grabbed from video and edited. It subtended 14° × 24° at 57 cm on the 94-cm color monitor. Four versions were used: eyes closed, straight, left, or right, with only the eyes differing. The peripheral probe was a moderate-contrast (20%) phase-reversing stimulus (2 Hz) subtending 6.5° × 14° at 17.5° to the left or right. Infants' eye movements were recorded by a centrally mounted camera onto a videotape.

Address correspondence to Bruce M. Hood, Department of Psychology, Harvard University, William James Hall, 33 Kirkland St., Cambridge, MA 02138; e-mail: bmh@wjh.harvard.edu.

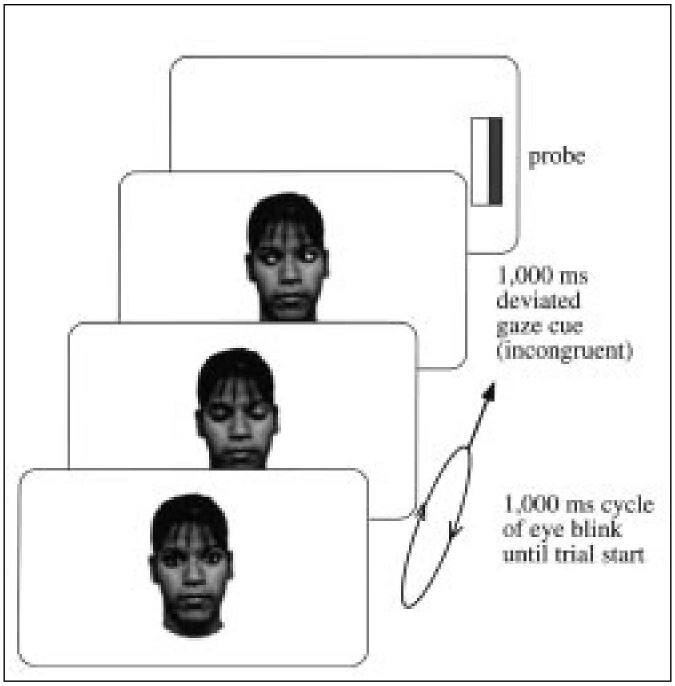

Fig. 1. Example of the stimulus sequence on an incongruent trial in Experiment 1. In Experiment 2, the face remained visible, with eyes open and deviated to the side, during presentation of the probe on some trials.

Design and procedure

Two conditions were randomly interleaved. On *congruent* trials, the computerized eyes looked left or right. The face was extinguished, and a peripheral probe appeared on the corresponding side. On *incongruent* trials, the probe appeared on the side opposite where the eyes had looked. Both trial types were equally likely, so the direction of the eyes was not predictive of the side where the probe would appear.

Infants sat on a holder's lap. The computerized face appeared centrally with the eyes blinking (alternating between eyes straight and eyes closed at 2 Hz; see Fig. 1) until the infant fixated them, whereupon a trial was initiated. The display then changed from eyes closed to eyes left or right for 1,000 ms. The face was then extinguished, and a probe appeared on the congruent or incongruent side until the infant looked to the left or right, or until 5,000 ms had elapsed (time-out). The blinking face then reappeared, and the cycle reiterated. The infant was turned away from the screen every five trials. Testing continued as long as the infant was in a state of alert inactivity (Wolff, 1965). The experimenter was unaware of the probe's location. Saccade onset was determined by the first frame of detectable deviation of the infant's eyes. Raters were blind to target location, and interrater reliability for scoring the direction and latency of the infants' eye movements was 98%.

Results and Discussion

Infants averaged 14.5 scorable trials (SD = 3.4, range: 9–20). There was no systematic difference between left and right probes. Orienting to the probe occurred on 82% of trials (SD = 10.5, range: 67–100). The remainder of trials were errors; the infant oriented to the side opposite the probe. All latencies were logarithmically transformed for analysis. As predicted, infants were faster to orient to the probe on congruent than incongruent trials, $t(15) = 2.1$, $p < .05$, one-tailed (untransformed means of 693 ms vs. 900 ms), revealing that their attention had shifted (Hood, 1995; Posner, 1978) toward where the face looked, even though the probe was just as likely on the other side. The error data also support this conclusion: On incongruent trials, 87.5% of the infants (14/16) made errors, whereas on congruent trials, only 56.3% (9/16) made errors. There were significantly more saccades away from the probe when the face looked away from it (21.4%, SD = 12.7) than toward it (12.8%, SD = 15.5), $t(15) = 1.8$, $p < .05$, one-tailed (see Table 1).

These results go beyond recent findings that 3- to 6-month-old infants can discriminate direct gaze from deviated gaze in a face (Vecera & Johnson, 1995) and smile less when adults avert gaze (Hains & Muir, 1996). Our data show for the first time that such perception of an adult's deviated gaze is sufficient to induce shifts of attention in the corresponding direction by young infants. This implies that they correctly interpret the direction of eye gaze as a cue to shift attention, and are not merely sensitive to visible differences in the eye region.[1]

In the next experiment, we again used our computerized method to examine orienting in response to perceived eye deviation, but within a narrower age group of 3-month-olds. Furthermore, we directly tested whether removing the central face facilitates infants' orienting by circumventing problems in disengaging fixation, as hypothesized earlier.

EXPERIMENT 2

As in the first experiment, infants were presented with a face in which the eyes blinked and then gazed to the left or right before the

Table 1. *Mean percentage of orienting away from the probe (errors)*

	Cue validity	
Condition	Congruent	Incongruent
Face off (Experiment 1)	12.8	21.4
Face off (Experiment 2)	7.5	19.6
Face on (Experiment 2)	9.6	17.5

Note. Percentages are calculated as a proportion of the total number of scorable trials in each condition. Experiment 1 did not have any trials in which the cue face was on the screen while the target was present.

1. One important issue raised during the review process was whether any motion stimulus within the face would cause attentional cuing. We ran an additional nine 3- to 6-month-olds to see whether movement of the tongue would produce cuing. While the effect of gaze cuing was replicated on both the latency (535 ms vs. 717 ms; $t[8] = 2.99$, $p < .01$, one-tailed) and error measures (7.78% vs. 25.1%; $t[8] = 2.46$, $p < .05$, one-tailed), no significant cuing effects were observed for tongue movements on either the latency (719 ms vs. 574 ms; $t[8] = 1.71$, $p > .05$, one-tailed) or error measures (6.33% vs. 10.67%; $t[8] = 0.83$, $p > .05$, one-tailed).

onset of a peripheral probe on the congruent or incongruent side. However, in this second experiment, the face remained visible during the presentation of the probe for approximately half the trials (*face on* as opposed to *face off*), until a response or time-out. Our hypothesis was that there would be less orienting in the face-on trials. We also expected the spatial cuing effect from perceived gaze to be found again, at least for the face-off trials.

Method

Subjects

Subjects were 11 healthy, full-term infants ages 8 to 15 weeks (mean age = 12 weeks, *SD* = 2.3). Six were female. Six additional infants were excluded for failure to complete at least eight test trials because of fussing.

Procedure

Trials were randomly chosen by the computer to be either face off or face on. Face-off trials were the same as trials in Experiment 1. In face-on trials, the central face with deviated eyes remained visible throughout presentation of the probe. Infants were given a short break after 10 trials, briefly returning to the mother before continuing. This minor modification from Experiment 1 improved their compliance.

Results and Discussion

Infants completed an average of 30.4 scorable trials (*SD* = 9.3, range: 13–47). Orienting to the probe occurred on 87.2% (*SD* = 8.0) of face-off trials, a percentage similar to the results for Experiment 1. The remainder of responses for these trials were classified as errors (orienting away from the probe), as there were no time-outs. By contrast, in the face-on trials, orienting to the probe occurred on only 25.9% of trials (*SD* = 25.9). Errors accounted for 13.1% (*SD* = 19.5) of trials, but the majority were time-outs (mean = 61.1%, *SD* = 32.2). Only 2 infants oriented to the probe on more than 50% of face-on trials, making an analysis of latencies for these trials uninformative. An analysis of logarithmically transformed latencies to orient to the probe on face-off trials found a nonsignificant trend in the same direction as the cuing effect of Experiment 1 (i.e., faster latencies on congruent than incongruent trials; untransformed means of 641 ms vs. 751 ms).

The error data for face-off trials replicated the cuing effect from Experiment 1, with 81.8% (9/11) of the infants making errors in the incongruent condition, compared with only 45.5% (5/11) on congruent trials. In face-on trials, 54.5% (6/11) of the infants made errors on the incongruent trials, compared with 36.4% (4/11) on congruent trials, revealing a similar, albeit numerically reduced, pattern. Planned tests revealed significantly more errors (19.6%, *SD* = 14.4) on incongruent trials than congruent trials (7.5%, *SD* = 9.2) in the face-off condition, $t(10) = 2.4$, $p < .05$, one-tailed. Likewise, errors accounted for 17.5% (*SD* = 22.1) of incongruent trials compared with only 9.6% (*SD* = 16.2) of congruent trials in the face-on condition, an effect that was also reliable, $t(10) = 2.8$, $p < .01$, one-tailed (see Table 1).

Thus, leaving the face visible significantly reduced orienting, with most infants continuing to fixate the face for more than 50% of trials. Nevertheless, when errors did occur during face-on trials, they were more likely to be in the direction of perceived gaze than away from it. This error effect was also found in the face-off trials, replicating the finding from Experiment 1.

DISCUSSION

The results show that infants as young as 3 months of age can detect the direction of gaze as indicated by the eyes alone, and that this detection influences their own direction of attention reliably, as revealed by latency and error data from their subsequent orienting to peripheral probes. These experiments provide the first unequivocal support for Baron-Cohen's (1995) hypothesis that an EDD mechanism is present fairly early in development and influences joint attention, in the sense of producing a corresponding shift of the infant's own attention. Future studies could investigate the exact perceptual basis of the mechanism that triggers attention shifts that follow perceived gaze. For present purposes, we can simply conclude that adult eyes evidently have the appropriate properties to trigger such shifts.

Our results also suggest why this early capacity to shift attention in the direction of perceived gaze may be so difficult to uncover within conventional, naturalistic paradigms. In the face-on trials of Experiment 2, the central face remained visible throughout each trial, as in naturalistic paradigms, and orienting was dramatically reduced. This result may reflect limitations of an immature eye movement system, such as difficulties in disengaging fixation from salient central stimuli (in this case, the adult's eyes). Such limitations may be dictated by the laminar development of cortical systems involved in saccade control, as proposed by Johnson (1990).

The sudden disappearance of the central face in the face-off condition is an unnatural event, but may be critical for young infants to exhibit their full capacity. Other recent studies have suggested that the ability to follow another person's attention may arise in infants younger than previously thought, even within naturalistic tasks (Butterworth & Jarrett, 1991; Muir, Hains, Cao, & D'Entremont, 1996). However, prior to the current experiments, such demonstrations have succeeded in triggering attention shifts only by using substantial movements of the adult's head, not by using shifts of gaze alone. It may be that the tendency to remain fixated on the adult's face is reduced when the adult's head deviates substantially from a frontal view so that the two eyes are less visible, because young infants are known to preferentially fixate the eyes on faces (Maurer, 1985). Alternatively, head turns may be more effective than shifts of gaze within naturalistic settings simply because they provide a much stronger motion transient in the direction that the adult turns (Anstis et al., 1969).

Recent findings in much older autistic children show that although they can discriminate other people's gaze direction geometrically, they do not orient correspondingly (Baron-Cohen, 1995; Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995). Our new method provides a sensitive test for the shifts of attention triggered by direction of perceived gaze, and can reveal such shifts even in preverbal infants. This test might be applied to young infants at high risk for autism, to examine recent claims that the disorder is associated with a very early failure of mechanisms involved in gaze following (Baron-Cohen, 1995).

Acknowledgments—The authors gratefully acknowledge Koraly Perez, Robin Leonhardt, and Arlene Dijamco for their help in collecting data. We are especially grateful to Nina Das for providing a captivating face. This research was supported in part by an Alfred P. Sloan fellowship to the first author.

REFERENCES

Anstis, S.M., Mayhew, J.W., & Morley, T. (1969). The perception of where a face or television 'portrait' is looking. *The American Journal of Psychology, 82,* 474–489.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind.* Cambridge, MA: MIT Press.

Baron-Cohen, S., Campbell, R., Karmiloff-Smith, A., Grant, J., & Walker, J. (1995). Are children with autism blind to the mentalistic significance of the eyes? *British Journal of Developmental Psychology, 13,* 379–398.

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.

Campbell, R., Heywood, C., Cowey, A., & Regard, M. (1990). Sensitivity to eye gaze in prospagnosics patients and monkeys with superior temporal sulcus ablation. *Neuropsychologica, 28,* 1123–1142.

Corkum, V., & Moore, C. (1995). Development of joint visual attention in infants. In C. Moore & P. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 61–83). Hillsdale, NJ: Erlbaum.

Hains, S.M.J., & Muir, D.W. (1996). Infant sensitivity to adult eye direction. *Child Development, 67,* 1940–1951.

Haith, M.M. (1993). Future-oriented processes in infancy: The case of visual expectations. In C.E. Granrud (Ed.), *Visual perception and cognition in infancy* (pp. 235–264). Hillsdale, NJ: Erlbaum.

Hood, B.M. (1995). Visual selective attention in infants: A neuroscientific approach. In L. Lipsitt & C. Rovee-Collier (Eds.), *Advances in infancy research* (Vol. 9, pp. 163–216). Norwood, NJ: Ablex.

Humphrey, N. (1976). The social function of intellect. In P. Bateson & R. Hinde (Eds.), *Growing points in ethology* (pp. 303–317). Cambridge, England: Cambridge University Press.

Johnson, M.H. (1990). Cortical maturation and the development of visual attention in infancy. *Journal of Cognitive Neuroscience, 2,* 81–95.

Johnson, M.H., Posner, M.I., & Rothbart, M.K. (1991). Components of visual orienting in early infancy: Contingency learning, anticipatory looking, and disengaging. *Journal of Cognitive Neuroscience, 3,* 335–344.

Maurer, D. (1985). Infants' perception of facedness. In T. Field & N. Fox (Eds.), *Social perception in infants* (pp. 73–100). Norwood, NJ: Ablex.

Muir, D., Hains, S., Cao, Y., & D'Entremont, B. (1996). 3- to 6-month-olds' sensitivity to adult intentionality: The role of adult contingency and eye direction in dyadic interactions [Abstract]. *Infant Behavior & Development, 19*(Special ISIS issue), 300.

Perrett, D.I., & Mistlin, A.J. (1990). Perception of facial characteristics by monkeys. In W.C. Stebbins & M.A. Berkley (Eds.), *Comparative perception: Vol. II. Complex signals* (pp. 187–215). New York: Wiley.

Posner, M.I. (1978). *Chronometric explorations of the mind.* Hillsdale, NJ: Erlbaum.

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

Stechler, G., & Latz, E. (1966). Some observations on attention and arousal in the human infant. *Journal of the American Academy of Child Psychiatry, 5,* 517–525.

Vecera, S.P., & Johnson, M.H. (1995). Gaze detection and the cortical processing of faces: Evidence from infants and adults. *Visual Cognition, 2,* 59–87.

Wolff, P.H. (1965). The development of attention in young infants. *Annals of the New York Academy of Sciences, 118,* 815–830.

(RECEIVED 2/3/97; REVISION ACCEPTED 8/5/97)