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Gradual improvement in fine-grained sensitivity to triadic gaze after 6 years of age

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ABSTRACT

The current research compared the ability of adults and children to determine where another person is looking in shared visual space (triadic gaze). In Experiment 1, children (6-, 8-, 10-, and 14-year-olds) and adults viewed photographs of a model fixating a series of positions separated by 1.6° along the horizontal plane. The task was to indicate whether the model was looking to the left or right of one of three target positions (midline, 6.4° left, or 6.4° right). By 6 years of age, thresholds were quite small ($M = 1.94°$) but were roughly twice as large as those of adults ($M = 1.05°$). Thresholds decreased to adult-like levels around 10 years of age. All age groups showed the same pattern of higher sensitivity for central targets than peripheral targets and of misjudging gaze toward peripheral targets as farther from midline than it really was. In subsequent experiments, we evaluated possible reasons for the higher thresholds in 6- and 8-year-olds. In Experiment 2, the thresholds of 6-year-olds did not improve when the range of deviations from the target position that the model fixated covered a much wider range. In Experiment 3, 8-year-olds were less sensitive than adults to small shifts in eye position even though the task required only matching faces with the same eye position and not determining where the person was looking. These findings suggest that by 6 years of age, children are quite sensitive to triadic gaze, which may support inferences about others' interests and intentions. Subsequent improvements in sensitivity involve, at least in part, an increase in sensitivity to eye position.

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Introduction

The direction of an individual's gaze can provide a useful cue to the target of his or her attention and thereby can allow inferences about his or her interests and intentions. Dyadic gaze indicates whether an individual is making eye contact and, hence, attending to the observer. In contrast, triadic gaze indicates where someone is looking in shared visual space and, hence, which object he or she may be thinking about. In the current research, we investigated developmental changes in sensitivity to triadic gaze.

Judgments of triadic gaze require the observer to trace the direction of gaze along an invisible line running from the gazer's eyes to a position in shared visual space. When the eyes rotate while the head maintains a forward orientation, adults judge the horizontal position of the eyes from the position of the iris within the visible part of the sclera. The distribution of luminance across the eye can also influence adults' perception of gaze direction because darkening the sclera on one side of the iris causes large shifts in the perceived direction of gaze toward the darkened region (Ando, 2004). In tasks restricting head movement, adults are able to detect horizontal deviations of gaze of 0.3° to 2° (depending on viewing distance and stimulus quality) from a target at midline. For targets in the near periphery, adults have slightly poorer sensitivity (Symons, Lee, Cedrone, & Nishimura, 2004) and tend to overestimate the direction of gaze as being more peripheral than it actually is (e.g., gaze toward a target 10° from midline is judged to be 15° from midline) (Anstis, Mayhew, & Morley, 1969).

Development of sensitivity to triadic gaze

From an early age, infants shift their gaze in the direction of an adult's eye movements, but over the first 4 months the critical cue seems to be lateral motion rather than changes in gaze direction (Farroni, Mansfield, Lai, & Johnson, 2003). Newborns (Farroni, Massaccesi, Pividori, & Johnson, 2004) and 4-month-olds (Farroni, Johnson, Brockbank, & Simion, 2000) look more quickly toward a peripheral target when it is preceded by an eye movement in that direction in a centrally presented face. At both ages, eliminating motion by having the eyes move behind closed eyelids eliminates the cuing effect. Even at 4 or 5 months of age, infants shift their gaze in the direction of a lateral movement of the head even when the eyes did not move (Farroni et al., 2000). Lateral motion of the eyes could even account for why by 6 months of age infants reliably follow gaze to the correct side of the visual field, locating the true target of gaze when it appears first in the scanning path but not when it is farther to the side (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991). It could also reflect imitation of the adult's eye/head orientation (Meltzoff & Moore, 1977).

After 6 months of age, infants respond to more than lateral motion of the head/eyes; they follow gaze to specific objects outside their visual field even if the object of fixation is not first in the scanning path (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; Corkum & Moore, 1998). By 8 months of age, infants respond as though they expect gaze to be directed to an object that is visible to the looker that need not be visible to the infant. This was evident in an experiment that presented infants with an experimenter repeatedly looking toward the right side or left side behind an occluder and then lifted the occluder to reveal an object on either the fixated or nonfixated side. Although they spent more time looking at the object than at the empty side, both 8- and 12-month-olds looked longer at the empty side when the observer had been fixating it than when he or she had not (Csibra & Volein, 2008). By 9 months of age, infants appear to encode the relation between the direction of gaze and a specific object. After viewing an experimenter repeatedly fixating one of two objects, 9-month-olds looked longer when the experimenter fixated the same object in a different location than when the experimenter fixated the other object in the previous location of fixation (Johnson, Ok, & Luo, 2007; see also Senju, Csibra, & Johnson, 2008). At 18 (but not 12) months of age, infants follow an adult's gaze to objects located behind the infant when the visual field is empty (Butterworth & Jarrett, 1991). These patterns may reflect an understanding of gaze as the act of looking toward a point of interest (e.g., Butler, Caron, & Brooks, 2000), but they could merely reflect an adjustment of the infant's gaze-following strategy to better reflect the conditions under which gaze following has led to objects that interest the infant (e.g., Csibra & Volein, 2008). Collectively, the findings suggest that sensitivity to