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Cognitive Development

Automatic cueing of covert spatial attention by a novel agent in preschoolers and adults

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ABSTRACT

Both infants and adults exhibit rapid, automatic reorienting of covert spatial attention in the direction indicated by familiar biological signals, such as another individual's gaze, reaches, or points. Recent evidence in adults suggests that these cued responses can be influenced by representations of the other individual's perceptual experiences and capacity for intentional action. However, current developmental results and theoretical accounts of the acquisition and specialization of cued responses are consistent with a cueing mechanism based on leaner representations of perceptually familiar directional signals. The influence of mentalistic attributions on cueing during early childhood is thus unknown. We investigated whether or not abstract attributions of agency to an unfamiliar entity would modulate cueing in 4- to 6-year-old children and adults. When induced to construe a faceless novel entity as an agent, both age groups fixated targets more rapidly when they appeared in locations consistent with the agent's directional orientation; they did not do so when they had no reason to view the entity as an agent. This result provides evidence that 1) the intentional actions of a perceptually unfamiliar agent can guide attentional cueing in adults, and 2) this influence of conceptual assessment on reflexive social attention is present by early childhood.

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1. Introduction

Rapid attentional responses during social interactions are adaptive, helping a person to quickly detect the target of another person's attention or actions. When attentional responses are automatic, an individual may allocate mental resources to broader social cognitive goals, further speeding responsiveness. However, automaticity can be implemented at different points in cognitive processing (e.g., after either sensory stimulation, perceptual representation, or conceptual assessment), each permitting varying degrees of responsive flexibility. Here we consider the extent to which children's abstract representations of agency influence "gaze cueing": a rapid, automatic attentional reorienting response to the direction of another person's line of sight.

Gaze cueing is a form of covert attentional reorienting, occurring without any visible changes in the observer's eye, head, or body orientation (Friesen & Kingstone, 1998; Hood, Willen, & Driver, 1998; Posner 1980). Individuals who are cued in this manner will more rapidly detect and respond to targets at locations that are congruent, as opposed to incongruent, with another's visual perspective. The speed, automaticity, and private nature of gaze cueing all distinguish it from the slower,

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more volitional, and overt reorienting of visual attention observed during bouts of "gaze following," suggesting that different cognitive mechanisms drive these two responses (Frith & Frith, 2003; Meltzoff & Brooks, 2013; Moore & Corkum, 1998).

There are dramatic developmental changes in the inputs that engage automatic covert attention over the course of the lifespan. From birth, infants are cued in the direction of another person's gaze (Farroni, Massaccesi, Pividori, & Johnson, 2004; Hood et al., 1998), but through at least the 4th month these early responses are constrained to particular contexts (e.g., when preceded by direct eye contact) and are strongly determined by physical features of the cue, such as its lateral motion (Farroni, Johnson, Brockbank, & Simion, 2000; Farroni, Mansfield, Lai, & Johnson, 2003; Matsunaka & Hiraki, 2014). By adulthood, however, the mechanisms that support gaze cueing have moved well past these limitations. There are now numerous demonstrations in which adults' gaze cueing appears to be informed by mental attributions made to the gazer. For instance, adults only produce cued responses to another person's gaze when they believe that she can see. Adults are no longer cued in the direction indicated by a gazer's eyes or head when her eyes are covered (Nuku & Bekkering, 2008, 2010), when her line of sight is obstructed (Kawai, 2011), when target objects appear outside of her field-of-view (Schulz, Velichkovsky, & Helmert, 2014; but see also Cole, Smith, & Atkinson, 2015), or when the observer believes that the cueing character is wearing opaque – as opposed to translucent – goggles (Teufel, Alexis, Clayton, & Davis, 2010).

In addition to the ascription of immediate perceptual experiences, gaze cueing in adults is also modulated by the attribution (or reassessment) of a gazer's capacity for intentional action. When adults are told that, despite appearances, a cueing character is a realistic mannequin and not an actual person, gaze cueing is suspended (Wiese, Wykowska, Zwickel, & Müller, 2012). Moreover, when an adult observer is told that a robot (that does not otherwise cue attention) is being controlled by a human agent, the observer's attention will be cued in the direction that the robot's eyes appear to point (Wiese et al., 2012). Together, these findings suggest that, by adulthood, gaze cueing may be conceptually rich, incorporating representations of a cueing character's perceptual abilities and mental capacities. However, little is known about how children's cued responses achieve similar sophistication.

The acquisition and specialization of cued responses to gaze and other signals is typically described as a process of "overlearning." According to this account, repeated encounters with a directionally predictive cue will eventually organize an automatized attentional reorienting response to it (Ristic & Kingstone, 2005; Rombough, Barrie, & Iarocci, 2012; Vecera & Rizzo, 2006). Such learned associations occur during infancy (Sobel & Kirkham, 2012) and their automatization may indeed explain some developmental changes in the inputs that engage rapid attentional reorienting (e.g., the reduced role of eye contact and motion by early childhood). However, it is less clear how overlearning can explain top-down influences on the initiation of automatic reorienting in adulthood, such as its flexible modulation by mentalistic attributions. In these cases, the cued response cannot be triggered by sensitivity to inputs described in wholly perceptual terms (e.g., "things with eyes"). Rather, the engagement of a cued response must also draw upon more abstract information that helps to identify reliable directional cues, such as a conceptual understanding of others' intentionality and perceptual experiences.

Current evidence for early cueing to gaze and other directional signals is consistent with the involvement of such conceptual considerations, but can also be explained by leaner accounts of perceptual overlearning. For instance, although infants between 5 and 7 months begin to show spontaneous covert reorienting in the direction indicated by either a grasping hand or a pointing gesture (Bertenthal, Boyer, & Harding, 2014; Daum & Gredebäck, 2011; Daum, Ulber, & Gredebäck, 2013; Rombough et al., 2012; Wronski & Daum, 2014), it is unclear how infants' representations of these cues engage their automatic attentional responses. During these same ages, infants do interpret familiar manual gestures as goal-directed in tasks that do not measure automatic attentional reorienting (Woodward, 1998, 1999). However, a rapid, overlearned reorienting response may not draw upon such interpretations; instead, attentional reorienting mechanisms may merely treat these actions as perceptually familiar cues that have previously provided meaningful directional information, without first considering the goal-directedness of a grasping hand or the referential intent of a pointing finger.

Although gaze cueing and gaze following are distinct forms of attentional reorienting, researchers that previously investigated the basis for infant gaze following faced a similar interpretive challenge to the one we have posed here. In that literature, it seemed plausible that infants who overtly look where another person looks have simply learned that human head turns provide useful directional information (Butterworth & Jarrett, 1991; Moore, 2006; Moore, Angelopoulos, & Bennett, 1997). However, infants will follow the implied "gaze" of an entirely novel, faceless entity when they have reason to view it as an agent. This demonstrates that gaze following need not depend upon learning about a class of perceptually-defined signals, such as "human head turns" (Beier & Carey, 2014; Deligianni, Senju, Gergely, & Csibra, 2011; Johnson, 2000; Johnson, Slaughter, & Carey, 1998; Movellan & Watson, 1987). Rather, when infants follow the rotational motion of a novel entity, they do so because they view it as an intentional agent[1] – i.e., the sort of thing that possesses a meaningful attentional orientation (Johnson, 2003; Luo & Baillargeon, 2010) or that behaves with referential intent (Gergely, 2010). This work examining the abstract attributions that motivate overt gaze following in infants provides a useful framework for assessing the conceptual richness of cued covert reorienting in early childhood.

In the present study, we adopt the same novel agent manipulation employed in earlier observations of gaze following to investigate whether abstract attributions of intentional agency engage automatic, covert reorienting in both preschool-

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[1] We use the term "intentional agent" to refer to a broad set of entities whose behaviors, and thus their internal states, bear an "aboutness" relation to a target. Viewing a novel entity as either a goal-directed, perceiving agent or as a communicating agent (or both) is an abstract attribution that goes beyond perceptual descriptions of an agent's behaviors.