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Development of inhibition of return for eye gaze in adolescents

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ABSTRACT

Gaze is an important cue in social interaction. Gaze direction can attract attention and produce a cuing effect as well as cause inhibition of return (IOR)—a slower response to an item at a previously attended-to location. Because gaze cue is sensitive to an individual's social interaction ability and such ability matures in adolescents, we examined how social attention by gaze cue varies with age. Three typically developing groups—ages 6 to 8, 9 to 12, and 13 to 15 years—were recruited. Each age group had 27 participants. Three main findings were observed. First, younger participants generated greater cuing effects than older ones. Second, reliable gaze-induced IOR was observed only in the 9- to 12-year and 13- to 15-year age groups, whereas the 6- to 8-year age group paid attention to gaze direction regardless of cue duration. Third, the 13- to 15-year age group showed gaze-induced IOR earlier (1200 ms) in the time course than expected (2400 ms). Our results suggest that the inhibition mechanism develops later than the facilitation mechanism in social attention.

Introduction

In social interactions, the eyes play an important role in conveying a person's complex internal states such as attention, desires, beliefs, and emotions (Baron-Cohen, Campbell, Karmiloff-Smith,

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Grant, & Walker, 1995; Frischen, Bayliss, & Tipper, 2007a). Compared with other social animals, humans show much earlier development of sensitivity to another's gaze (Shepherd, 2010). Newborn infants already show preference bias toward faces that directly gaze at them rather than those with an averted gaze (Farroni, Massaccesi, Pividori, & Johnson, 2004). Following others' gazes can be observed in 9-month-old infants (Scaife & Bruner, 1975), and recent studies have even suggested the same for 3- and 4-month-old infants (D'Entremont, Hains, & Muir, 1997). Other studies have shown that 4-month-old infants used an adult's gaze direction as an attentional cue (Hood, Willen, & Driver, 1998), which caused them to prefer the objects being observed rather than those not being gazed at (Reid & Striano, 2005). Thus, it seems that even people who have limited social experience can direct their attention according to another's gaze. The question is whether and how social experience modulates this social attention. In this study, we aimed to explore the developmental trend of gaze-induced attentional shift for school-age children and adolescents.

Gaze-induced attentional shift consists of a facilitation effect and an inhibition effect. First, the facilitation effect, also called the cuing effect, shows that the gaze direction can attract attention in a fast and reliable manner. Friesen and Kingstone (1998) showed that a target at the gazed-at location can be discriminated, located, and detected faster than one on the opposite side. Further investigations showed that the gaze-induced cuing effect persists longer (e.g., 600 ms or longer; Friesen & Kingstone, 1998, 2003; Ristic et al., 2005) than a spatial cue-induced cuing effect; for example, a light flash causes a cuing effect only within 300 ms (Klein, 2000; Posner & Cohen, 1984). A reliable gaze-induced cuing effect can be found by using photos of real faces (Frischen, Smilek, Eastwood, & Tipper, 2007b; Frischen & Tipper, 2004), schematic faces (Friesen & Kingstone, 1998, 2003; Lin, Jingling, & Lin, 2012; Ristic et al., 2005), or even a pair of eyes (Green, Gamble, & Woldorff, 2013; Ristic & Kingstone, 2005). Whether gaze cues attract attention in an automatic manner is under debate (Driver et al., 1999; Friesen, Ristic, & Kingstone, 2004; Green et al., 2013; Hietanen & Leppanen, 2003), although there is no doubt that another person's gaze can capture attention in a reliable and rapid manner.

Gaze directions not only attract attention but also impair it, which is a phenomenon called inhibition of return (IOR). IOR is the delayed response speed to a target if the target was presented at a previously attended location. This phenomenon was originally observed in detection tasks using nonpredictive spatial cues when the cue-to-target onset asynchrony (CTOA) was longer than 400 ms (Klein, 2000; Posner & Cohen, 1984). By using gaze cues, Friesen and Kingstone (1998) elongated the CTOA to 1005 ms and still found no IOR. McKee, Christie, and Klein (2007) used 48 participants and a 2880-ms CTOA, and the gaze cue produced neither facilitation nor IOR. Nevertheless, Frischen and her colleagues (Frischen & Tipper, 2004; Frischen et al., 2007b) suggested that this null observation was due to the use of schematic faces and the absence of orienting away from the gaze direction during the CTOA. By redirecting attention with a blank display after the gaze cue, the gaze directions of real faces induced IOR at 2400 ms. Compared with the spatial cue-induced IOR, however, the gaze-induced IOR is fragile in terms of effect size. For instance, gaze-induced IOR was approximately 6 to 10 ms (Frischen & Tipper, 2004; Frischen et al., 2007a, 2007b), whereas spatial cue-induced IOR varied between 50 and 200 ms (Klein, 2000; Posner & Cohen, 1984). In summary, gaze-induced attentional shift has a cuing effect at short CTOA and an IOR at long CTOA.

Gaze-induced attentional shift is sensitive to the individual's abilities in social interactions. For instance, females generate a larger gaze-induced cuing effect than males (Bayliss, di Pellegrino, & Tipper, 2005), which can be further increased if there is familiarity with the faces (Deaner, Shepherd, & Platt, 2007). In addition, a nonclinical population with high autism traits showed less of a gaze-induced cuing effect than those with lower scores (Bayliss & Tipper, 2005). Furthermore, people with high-functioning autism (Ristic et al., 2005) or attention deficit/hyperactivity disorder (Marotta et al., 2014) did not display the gaze-induced cuing effect. Participants with Asperger's syndrome also lacked gaze-induced IOR (Marotta et al., 2013).

Because social interaction abilities improve with age, we infer that the attentional shift induced by gaze direction should also develop with age. In particular, social interactions increase enormously among adolescents, perhaps because of the increased need to belong to peer groups, dependence on peer learning, and perception of peer pressure (Shaffer & Kipp, 2010). The cortical thickness of brain areas involved in gaze (e.g., the frontal lobe and superior temporal sulcus; Frischen et al., 2007a) also