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Impaired representational gaze following in children with autism spectrum disorder

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ABSTRACT

Using eye-tracking methodology, we compared spontaneous gaze following in young children with Autism Spectrum Disorder (mean age 5.8 years) to that of typically developing children (mean age 5.7 years). Participants saw videos in which the position of a hidden object was either perceptually visible or was only represented in another person's mind. The findings indicate that children with Autism Spectrum Disorder were significantly less accurate in gaze following and observed the attended object for less time than typically developing children only in the Representational Condition. These results show that children with Autism Spectrum Disorder are responsive to gaze as a perceptual cue although they ignore its representational meaning.

1. Introduction

Gaze following is a foundation of human social cognition (Shepherd, 2010). Gaze following develops from a low-level perceptual mechanism to a representational mechanism (Butterworth & Jarrett, 1991). Between 6 and 12 months of age, infants consider gaze as a directional cue that draws attention to a section of the visual field (Butterworth & Jarrett, 1991). Just before 1 year of age, infants follow the direction of another person's head toward objects or events more frequently if the partner's eyes are open rather than closed. This indicates that infants consider the partner as a psychological-perceptual agent (Brooks & Meltzoff, 2014). Typically developing infants show a prolonged exploration of an attended object indicating a referential understanding of gaze (Brooks & Meltzoff, 2005).

Twelve to eighteen-month-old infants follow the gaze toward objects or events positioned outside their visual field (Butterworth & Jarrett, 1991; Moll & Tomasello, 2004). Infants understand that the gaze points to a target that is represented in another person's mind (Perner, 1991). Thus, infants ascribe a referential meaning to another person's gaze toward a hidden object (Csibra & Volein, 2008). By 18 months of age, infants appreciate that the eye gaze of other people is related to attention and intentions (Gazzaniga, 2008; Tomasello, Carpenter, Behne & Moll, 2005).

These abilities allow infants to compare their own experience with the behavior of the communicative partner (Gallese & Goldman, 1998). Taking part in joint attention provides opportunities to develop mentalistic abilities in infancy (Meltzoff & Gopnik, 1993; Mundy, Sigman, & Kasari, 1993).

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Researchers studied gaze following as a root of Theory of Mind in individuals with Autism Spectrum Disorder (ASD) (Baron-Cohen, 1995). Individuals with ASD show a reduced ability to judge the direction of other people's gaze in behavioral tasks (see Nation & Penny 2008 for a review). Even though they can compute the direction of eye gaze in non-mentalistic contexts, they are developmentally delayed in gaze following in mentalistic situations (Leekam, Baron-Cohen, Perrett, Milders, & Brown, 1997; Leekam, Hunnisett & Moore, 1998).

Individuals with Autism Spectrum Disorder might fail behavioral tasks due to their difficulties in social interactions (Tager-Flusberg, 1996). To address this theory, researchers evaluated gaze-following abilities with eye-tracking paradigms that did not require participants to provide declarative answers. This research was done in individuals with ASD (e.g. Klin, Jones, Schultz, Volkmar, & Cohen, 2002) and in those with high familial risk of ASD (e.g. Gliga, Senju, Pettinato, Charman & Johnson, 2014). Eye tracking studies indicate a reduced voluntary exploration of the attended objects in response to static gaze cues in individuals with Autism Spectrum Disorders (Fletcher-Watson, Findley, Leekam, & Benson, 2009; Freeth, Chapman, Ropar, & Mitchell, 2010; Riby, Hancock, Jones, & Hanley, 2013). This suggests that individuals with Autism Spectrum Disorder process gaze direction differently from typically developing individuals, missing its referential implication (Freeth et al., 2010). Eye tracking studies using videos of complex social scenes indicate that adults and children with Autism Spectrum Disorders spontaneously follow the gaze cues less often compared to typically developing controls (see Falck-Ytter & von Hofsten, 2011 for a review). Young toddlers later diagnosed with Autism Spectrum Disorder (Bedford et al., 2012) and 3-year-old low functioning children with Autism Spectrum Disorder (Falck-Ytter, Thorup & Bölte, 2014) look at referential objects for significantly shorter time compared to controls in eye tracking studies showing dynamic social scenes. This suggests that individuals with Autism Spectrum Disorder may process gaze direction as a directional signal but not as a referential cue (Bedford et al., 2012). The question remains whether individuals with Autism Spectrum Disorder are responsive to gaze as a directional cue even though they may ignore its representational meaning.

To our knowledge, no previous eye-tracking study has investigated whether the representational processes underlying gaze following might be impaired in individuals with Autism Spectrum Disorder. Here, we investigated gaze following toward hidden objects in high functioning children with Autism Spectrum Disorder using eye-tracking technology. We hypothesized that individuals with Autism Spectrum Disorder would show impaired representational gaze-following compared to typically developing controls.

2. Methods

2.1. Participants

Participants were 25 children with Autism Spectrum Disorder (mean age 5.8 years, SD 1.3, age range 4.3–8.6 years) matched for chronological age with 25 typically developing controls (mean age 5.7 years, SD 1.3, age range 3.8–8.6 years). Children with Autism Spectrum Disorder were diagnosed by expert clinicians according to DSM-IV (American Psychiatric Association, 2000) criteria and Autism Diagnostic Observation Schedule (ADOS) scores (Lord, Rutter, DiLavore & Risi 2005). All the participants with ASD were verbal. Their non-verbal cognitive functioning was assessed using the Visualization and Reasoning (VR) battery of the Leiter-R scale (Roid & Miller, 2002). It was in the normal range (range 89–128; mean IQ = 104.92; SD = 11.761). The TD group consisted of a group of typically developing students in mainstream education. Neither teachers nor parents reported any concerns about possible learning disabilities in these children. None of the children were involved in any diagnostic processes for learning disabilities or any other clinical condition. Written informed consent to take part in the study was obtained from the parents of all participants. All participants had normal or corrected-to-normal vision. No participants were excluded from the study. All participants attended to the trials presented.

2.2. Apparatus and stimuli

We recorded eye movements with a Tobii-T60 eye-tracker (Tobii Technology). Participants sat on an adjustable chair at a distance of about 65 cm from the 17" TFT monitor with a resolution of 1280×960 pixels. The eye-tracker registered participants' gaze points at a rate of 60 Hz (one every 17 ms), with an accuracy of 0.5°. An experimenter operated the eye-tracker from a laptop computer non visible to the child. Preliminarily to the test session, each participant completed a five-point calibration phase. After successful completion of the calibration phase, subjects were told to freely observe the stimuli displayed on the screen.

The stimuli were a series of four videos ($29.8 \times 22.5^{\circ}$ of visual angle in size) that were presented on the screen of a Tobii T60 eye tracker. In each video, a female actor sat at a table facing the viewer. The actor engaged in a gaze following task. As shown in Fig. 1a, first, the actor showed an object, and then she hid the object under one of two identical opaque cups as shown in Fig. 1b. As shown in Fig. 1c, the actor shuffled the cups three times. Then she paused, and after 3 s, she looked directly at the camera as shown in Fig. 1d. She then gazed three times toward the cup that covered the object (see Fig. 1e). Finally, she lifted the cups one after the other showing where the object was hidden.

We manipulated the video segment displaying the shuffling into two conditions. As shown in Fig. 1c, in the Perceptual Condition, children saw the shuffling prior to the actor's gaze cueing. As shown in Fig. 2, in the Representational Condition, children did not see the shuffling preceding the actor's gaze cueing because it was hidden behind an opaque screen. Thus,