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Reduced saccadic inhibition of return to moving eyes in autism spectrum disorders

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ABSTRACT

Inhibition of Return (IOR) refers to slower reaction time to a target presented at the same location as a preceding stimulus. Here, we examine reflexive attention orienting via the saccadic IOR using a shift in gaze direction (i.e. from averted to direct) in faces presented as a peripheral cue, in upright and inverted orientations, in adults with Autism Spectrum Disorder (ASD) and typically developed comparison participants. While both groups showed an IOR in the inverted face condition, this effect was reduced in participants with ASD in the upright face condition, as compared to comparison participants, suggesting that moving eyes do not trigger reflexive exogenous orienting in individuals with ASD. Impaired reflexive orienting to eye gaze might severely compromise the later development of social functions in ASD, such as joint attention, face emotion recognition and mindreading.

1. Introduction

Orienting is a primitive function that allows the shifting of attention towards or away from a source of stimulation in the environment. While endogenous orienting is under the voluntary control of motivational and goal-directed processes, exogenous orienting refers to the reflexive, stimulus-driven allocation of attention in response to the salient features of the environment (Jonides, 1981). Food, predators, playmates, desirable objects, a novel stimulus, or an abrupt change in luminance can be salient cues that capture the observer's attention in an involuntary or automatic manner.

Eye gaze is considered to be a salient social cue that captures visual attention both in a voluntary and automatic manner (Frischen, Bayliss, & Tipper, 2007; Laidlaw, Risko, & Kingstone, 2012). The ability to follow direction of another person's eye gaze arises early in infancy and plays a crucial role in intention attribution, mindreading, and communication. It allows the child to be aware of what another person is attending to and to establish joint attention with others (Butterworth & Jarrett, 1991). Previous studies have shown that this attentional capture is more effective when the gaze shifts is directed towards the observer compared to when the gaze shifts is directed away from the observer (an averted gaze) (Yokoyama, Ishibashi, Hongoh, & Kita, 2011). A direct gaze is detected more readily than an averted gaze, even when gaze discrimination is not the primary task at hand (Senju, Hasegawa, & Tojo, 2005; Doi & Shinohara, 2013). By capturing the observer's attention, direct gaze modulates the observer's subsequent attentional and cognitive processing of perceptual information (Senju & Johnson, 2009).

Autistic spectrum disorder (ASD) is a pervasive developmental disorder characterized by qualitative impairments in communication, social interaction, and a restricted range of interests and stereotyped repetitive behaviors. Reduced sensitivity to gaze direction and eye contact avoidance constitute core features of ASD. There is indeed substantial evidence that children with autism exhibit diminished sensitivity to eye gaze and are impaired in face and gaze processing (Baird et al., 2000; Baron-Cohen et al., 1996). Children with ASD, unlike children with typical development, exhibit a lack of or a delayed ability to follow gaze (Leekam, Hunnisett, & Moore, 1998) or do not show faster detection of direct gaze as compared to averted gaze (Senju, Kikuchi, Hasegawa, Tojo, & Osanai, 2008; Senju, Yaguchi, Tojo, & Hasegawa, 2003). In addition, the processing of direct gaze in ASD is associated with abnormal event-related potentials and atypical brain activation (Senju, Tojo, Yaguchi, & Hasegawa, 2005; von dem Hagen, Stoyanova, Rowe,

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Baron-Cohen, & Calder, 2013). Because eye gaze is a special sort of stimulus that plays a crucial role in the development of joint attention and social functions, it is important to assess whether reflexive orienting to gaze direction is present in individuals with ASD.

The cues triggering exogenous attention are typically non-predictive, and thus observers have no especial incentive to maintain attention at the location being cued for a long time. Therefore, if the target appears at the cued location shortly after the cue onset, reaction times (RTs) are slower than for targets located at an uncued location. This phenomenon, first noted by Posner and Cohen (1984), is called inhibition of return (IOR). IOR is classically attributed to an automatic inhibitory mechanism preventing the return of attention to a previously attended location. This inhibitory mechanism helps the observer to explore the visual environment efficiently, by avoiding repeated processing of the same location (Klein, 2000). According to Lupiáñez, Martín-Arévalo, and Chica (2013), the IOR effect is the result of a cost for detecting the occurrence of new attention capturing information (e.g., the target) at locations where attention has been already allocated in response to a previous salient event (e.g., the cue). The peripheral cue that initially activates the attentional neural network, the ventral fronto-parietal attention network (Corbetta, Patel, & Shulman, 2008), undergoes habituation. When the target later appears at the same location it would not capture attention any more effectively than if it had appeared in a new location. Thus, cued targets are filtered out as less relevant than uncued targets resulting in a long lasting IOR effect.

Theeuwes and Van der Stigchel (2006) showed that IOR can also be elicited by social stimuli. The authors used a modified spatial cuing paradigm in which they presented two peripheral objects (either a face or a non-face) to the left or the right of a central fixation. After a variable stimulus onset asynchrony (SOA), i.e. the time interval between the cue and the target onset, participants had to make a saccade to one of the two locations. The authors observed a delayed response to the peripheral location that previously contained a face stimulus, as compared to the location that contained an object. They concluded that peripheral faces could summon attention with an exogenous event. It is worth noting that the faces had a direct gaze, which could have increased the attentional capture by the peripheral face. In this study, the IOR effect might be attributed to the cost in directing attention towards a peripheral location, previously occupied by a salient object, that automatically captured the observer's attention. Interestingly, Grison, Paul, Kessler, and Tipper (2005) found a greater IOR effect when the faces used as cue and target were upright, than when the cue and/or target faces were inverted. This can be explained by the fact that upright faces are processed holistically, whereas inverted faces sharing similar low-level features are processed like objects, at a local analysis level (Rhodes, Brake, & Atkinson, 1993). Importantly, the neural mechanisms recruited for upright and inverted face processing could be different (Haxby et al., 1999; Sadeh & Yovel, 2010). Thus, the existence of a specialized brain circuit for face processing might explain why the detection of the facial social relevance is compromised and the attentional capture is reduced, when faces are perceived in the inverted orientation (Yin, 1969).

Previous evidence on the ability to orient visuospatial attention to social stimuli, such as faces and eye gaze, in individuals with autism has so far yielded contradictory results. Ristic et al. (2005) found that adults with ASD showed disrupted orienting to gaze only under non-predictive cueing conditions indicating an insensitivity to the social relevance of the gaze in this population. Goldberg et al. (2008) did not find the validity effect in children with ASD in response to non-predictive static drawings of gaze. Conversely, others studies reported a preserved ability to orient visuospatial attention in children with ASD in response to non-predictive gaze cues (Kylliäinen & Hietanen, 2004; Swettenham, Condie, Campbell, Milne, & Coleman, 2003).

Recently, Marotta et al. (2013) investigated manual IOR effect in young individuals with ASD using social and non social stimuli, presented as central eye gaze cue and peripheral cue, respectively. In this study, central cues consisted of a gaze directional shift in the direction of one of two lateral locations (left or right), while peripheral cues consisted on the brightening of one of two peripheral boxes located on the left and on the right of a central fixation cross. Results showed a manual IOR effect for the two cues in the control group while an IOR effect only for peripherally cued locations, but not for the centrally cued locations by eye gaze shifts in the ASD group, likely reflecting a specific social attentional deficit. The authors reported a preserved manual IOR effect in response to non-social cues (Marotta et al., 2013) in line with Rinehart, Bradshaw, Moss, Brereton, and Tonge (2008) who found preserved saccadic IOR effect in young individuals with ASD. More recently, Antezana, Mosner, Troiani, and Yerys (2016) examined the IOR effect using neutral and angry facial expressions in children and adolescents with ASD, as compared to a typically developing group. The authors showed a significantly stronger IOR effect in the ASD participants that correlated positively with their social impairments, as measured by ADOS (Autism Diagnostic Observation Schedule-generic, Lord et al., 2000).

In the current study, we aimed to investigate whether a non-predictive peripheral gaze direction shift would capture reflexive attention orienting in adults with ASD, as compared to a group of typically developed adults. We developed a new adaptation of the Posner's cueing attention-orienting paradigm in which a gaze direction shift (from averted to direct) was used as a peripheral cue to capture the subject's attention. To control whether reduced or absent IOR effect in ASD is specific to eye gaze or whether it reflects a general impairment in reflexive orienting, the same stimuli were presented as cues in the upright and inverted orientation conditions. Given that the occurrence of IOR to a location only follows the reflexive shift of attention to that location, if a shift in gaze direction embedded in a face stimulus does capture spatial attention, similarly to the way attention is attracted by a peripheral abrupt onset, we would expect to observe a stronger IOR effect for valid cues than for invalid cues. Based on previous findings (Grison et al., 2005), the attention orienting in response to eye-gaze should be modulated by face orientation, with greater IOR effect for upright than with inverted faces. Upright faces are processed holistically whereas inverted faces are processed more like other objects, at a local analysis level (Rhodes et al., 1993). Thus, we assumed that inverting the eyes might severely disrupt gaze sensitivity, irrespective of the face orientation, suggesting that some form of relational/configurational mechanism is involved in gaze processing (Jenkins & Langton, 2003). Based on these previous findings, we predicted a stronger IOR effect in response to eye movement in the upright face condition in typically developed participants, relative to the inverted face condition, and absent or blunted IOR effect in participants with ASD reflecting reduced exogenous orienting to eye gaze shift in this population. Moreover, based on previous studies reporting difficulties with saccadic inhibition in ASD (Goldberg et al., 2002; Pieron, Seassau, Leboyer, & Zalla, 2015), we expected to find more anticipation errors or misses in participants with ASD than in the comparison group.

2. Materials and methods

2.1. Participants

Sixteen male participants meeting a clinical diagnosis of ASD participated in the study. All participants received an official