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Emotional Face Processing in Autism Spectrum Condition: A Study of Attentional Orienting and Inhibitory Control

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Abstract

A core feature of Autistic Spectrum Condition (ASC) is the presence of difficulties in social interactions. This can be explained by an atypical attentional processing of social information: individuals with ASC may show problems with orienting attention to socially relevant stimuli and/or inhibiting their attentional responses to irrelevant ones. To shed light on this issue, we examined attentional orienting and inhibitory control to emotional stimuli (angry, happy, and neutral faces). An antisaccade task (with both prosaccade and antisacade blocks) was applied to a final sample of 29 children with ASC and 27 children with typical development (TD). Whereas children with ASC committed more antisaccade errors when seeing angry faces than happy or neutral ones, TD children committed more antisaccade errors when encountering happy faces than neutral faces. Furthermore, latencies in the prosaccade and antisaccade blocks were longer in children with ASC and they were associated with the severity of ASC symptoms. Thus, children with ASC showed an impaired inhibitory control when angry faces were presented. This bias to negative high-arousal information is congruent with affective information-processing theories on ASC, suggesting that threatening stimuli induce an overwhelming response in ASC. Therapeutic strategies where train the shift attention to emotional stimuli (i.e. faces) may improve ASC symptomatology and their socials functioning.

Keywords Autism spectrum condition · Eye-tracker · Attentional orienting · Inhibitory control · Antisaccade task · Emotional faces

A core feature of Autism Spectrum Condition (ASC) is the presence of deficits in social interactions (American Psychological Association (APA), 2013). It has been suggested that an underlying mechanism of this atypical development of social interaction skills is an abnormal attentional processing of socially relevant information (Keehn et al., 2013). Indeed, individuals with ASC may lack attentional orienting toward socially relevant stimuli, such as emotional faces (Chawarska et al., 2012; Waters et al., 2008). Moreover, they may also show problems in voluntarily redirecting their attention to more adaptive environmental stimuli and in inhibiting contextually inappropriate responses. (Goldberg et al., 2002; Guillon et al., 2014; Hill, 2004; Hutton & Ettinger, 2006; Lopez et al., 2005; South et al., 2007). Therefore, examining attentional switching to socially relevant stimuli is an important avenue to elucidate the mechanisms underlying social dysfunction in ASC. In the present antisaccade eye-tracking experiment, both attentional orienting and inhibitory control were assessed by displaying faces (angry, happy, and neutral). We focused on children with ASC because they have not yet learned to modulate their attention shift toward emotional faces (Bastiaansen et al., 2011; Beall et al., 2008).

In an antisaccade task, participants are instructed to look at a fixation point in the center of the screen. Then, a peripheral visual stimulus appears on either side of the screen (right or left). Participants are required to make one of two eye movements in two separate experimental blocks. In the prosaccade block, the participant's task is to move the eyes toward the stimulus. In the antisaccade block, the participant's task is to move the eyes to the opposite side of the stimulus. Thus, different types of eye movements are required for each block. The prosaccade block involves the

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facilitation of attentional orientating because it requires the participant to direct attention to the stimulus (Yiend, 2010). Conversely, the antisaccade block requires the inhibitory control of the initial orienting of attention toward the stimulus at the earliest stage of processing, in which the subjects cannot adopt a premeditated strategy of avoidance of the stimulus (Yiend, 2010).

Previous research using antisaccade tasks with individuals with ASC has employed non-social neutral stimuli (e.g., light-emitting diodes LEDs or geometric shapes such as squares or circles). Results showed a higher error rate in the antisaccade block than the control group, which was interpreted as due to inefficient inhibitory control (Goldberg et al., 2002; Luna et al., 2007; Manoach et al., 2004; Minshew et al., 1999; Mosconi et al., 2009). Although the latency data were not entirely consistent, most studies showed slower responses for adolescent and young adults with ASC relative to those with TD (Goldberg et al., 2002; Manoach et al., 2004; Mosconi et al., 2009; but see Luna et al., 2007; Minshew et al., 1999). Critically, the antisaccade task can be modified by substituting the neutral peripheral target with an emotional stimulus (e.g., angry or happy faces) to examine how socially relevant targets can modulate attentional shifting (Bastiaansen et al., 2011; Beall et al., 2008; Derakshan et al., 2009; Guillon et al., 2014; Luna et al., 2007; Manoach et al., 2004; Minshew et al., 1999; Mosconi et al., 2009; Yiend, 2010). However, to our knowledge, there are no published antisaccade studies with emotional stimuli in individuals with ASC.

Prior research using emotional stimuli in individuals with ASC has typically examined the spatial location of attention to several emotional stimuli, as in free-viewing tasks (Matsuda et al., 2015; Wagner et al., 2013) or emotional dot-probe tasks (García-Blanco et al., 2017; Ghosn et al., 2019; Hollocks et al., 2013; Uono et al., 2009). For instance, in an eye movement study conducted by Wagner et al. (2013), children with ASC fixated for a longer time on happy faces than fearful and neutral faces. Matsuda et al. (2015) found that children with severe ASC showed an attentional bias away from angry faces but not away from happy or sad faces. Similarly, most dot-probe studies also found an attentional bias away from angry faces in children with ASC (García-Blanco et al., 2017b; Ghosn et al., 2019; Uono et al., 2009; but see Hollocks et al., 2013). Therefore, when the spatial location was considered, using dot-probe and eye-movement tasks, individuals with ASC appeared to avoid angry faces. Notably, these tasks only provide information about the allocation of spatial attention (Posner & Dehaene, 1994). However, it has been suggested that, among attentional processes, impaired inhibitory control is the greatest vulnerability factor for mental disorders (Beck, 1976).

At a theoretical level, affective information-processing theories posit that disruptive emotional states (e.g., high distress) can impair the ability to ignore irrelevant information that attracts attention, which may cause problems inhibiting dysfunctional dominant responses (Beck, 1976). In the case of individuals with ASC, the Intense World Theory (Markram, 2007; Markram & Markram, 2010) posits that threatening (i.e., negative high-arousal) stimuli abnormally attract attention and induce an overwhelming distressing response. This theory, grounded on neuroimaging studies, proposes that attention to threatening faces in individuals with ASC overstimulates the amygdala in the earliest stages using bottom-up processing (Kleinhans et al., 2010). As a result of this overstimulation, in an attempt to regulate their personal distress, top-down processing would move attention away from threatening faces at subsequent processing stages (Smith, 2009).

This assumption is in line with the above-mentioned free-viewing dot-probe studies (García-Blanco et al., 2017b; Ghosn et al., 2019; Uono et al., 2009), and eye-tracking experiments (Matsuda et al., 2015; Wagner et al., 2013). However, if individuals with ASC are instructed to inhibit their initial orienting toward angry faces at the earliest stages of attention as required by the antisaccade task, they may have problems ignoring such faces as a result of the salience of these threatening stimuli during the bottom-up processing, as suggests the Intense World Theory (Markram, 2007; Markram & Markram, 2010). Therefore, difficulties ignoring threat-related information at the earliest stages of processing in ASC may evoke extreme distress, triggering socio-emotional problems (Zhao et al., 2016).

To our knowledge, the present antisaccade eye-tracking experiment is the first to examine attentional shifting in terms of attentional orienting and inhibitory control to emotional faces (angry, happy, and neutral) in children with ASC. The hypotheses are the following: First, because of inefficient attentional shifting, the ASC group would perform more poorly in antisaccade blocks (i.e., slower responses or higher error rate) and in prosaccade blocks (i.e., slower responses) than the TD group —this pattern would replicate earlier research with non-emotional stimuli (Goldberg et al., 2002; Luna et al., 2007; Manoach et al., 2004; Minshew et al., 1999; Mosconi et al., 2009). Second, because of an abnormal salience of threat-related information in bottom-up processing in individuals with ASC (Intense World Theory, Markram, 2007; K. Markram & Markram, 2010), inefficient inhibitory control at the earliest stages of attention would be indicated by greater latencies of correct antisaccades or antisaccade errors for angry faces than for happy or neutral ones. Similarly, faster prosaccades for angry faces would reflect an abnormal initial attraction. Third, we expect the severity of ASC symptoms to be associated with the attentional bias to angry faces (i.e., increased error rates in antisaccade blocks) (García-Blanco et al., 2017b; Ghosn et al., 2019; Hollocks et al., 2013; Uono et al., 2009) or with a slowed attentional shifting (i.e., slower antisaccade latencies) (Hill, 2004; Lopez et al., 2005; South et al., 2007).

Methods

Participants

A total of 56 participants were initially recruited: 29 participants diagnosed with ASC constituted the experimental group, and 27 TD participants constituted the control group. Both groups were comparable in age, sex, and Intelligence Quotient (IQ). The ASC group was recruited from a tertiary hospital, and the control group was recruited from a local school. Parental informed consent was obtained for all participants. The Ethics Committee at the Health Research Institute authorized the study.

The inclusion criteria were age between 8 and 18 years of age, no intellectual or verbal disability, absence of comorbid psychiatric diagnosis in the ASC group, and absence of psychiatric history in the TD group. The participants of the ASC group were diagnosed and derived by their personal psychiatrist. ASC diagnosis criteria were based on the DSM-5 (American Psychological Association (APA), 2013). This diagnosis was verified by an expert clinical assessment through the Autism Diagnostic Interview—Revised (ADI-R) (Rogers, 2000), a specialized clinical assessment tool designed to diagnose autism from the age of two, providing three domains: Language/Communication, Reciprocal Social Interactions, and Repetitive Behaviors/Interests ($\alpha = 0.92$). Comorbid diagnosis for the ASC group and psychiatric history for the TD group were carefully verified by chart review. Additionally, none of the participants of the two groups exhibited low IQ or verbal disability scores lower than 80, as measured by the Kaufman Brief Intelligence Test (K-BIT; Kaufman, 1997). K-BIT is an intelligence screening measure for verbal and nonverbal abilities for individuals 4–90 years of age ($\alpha = 0.97$). Finally, parents of both groups completed the Child Behavior Checklist (CBCL; Achenbach & Edelbroch, 1991) to control for the severity of behavioral symptoms in the ASC group and to exclude children with significant behavioral problems in the TD group. The CBCL collects information from parents on behavioral problems in children aged 4 to 18 years through eight syndrome scales, including Anxious/Depressed, Withdrawal Somatic Complaints, Social Problems, Thought Problems, Attention Problems, Rule-Breaking Behavior, and Aggressive Behavior ($\alpha = 0.95$). A typical score > 70 in any CBCL syndrome for the TD group was an exclusion criterion. The presence of neurological history, major medical disorders, use of medication that could influence cognition (e.g., psychotropic medication, treatment with corticosteroids), major ocular illness, or difficulty distinguishing colors (e.g., color blindness) were considered exclusion criteria. After considering the exclusion criteria, the final sample comprised 29 ASC participants and 27 TD individuals. The sample selection process is described in Fig. 1.

Materials

An eye tracker system (SMI RED250) was used to register the participant's eye movements, allowing a wide range of free head movements. The gaze-point position was estimated at 250 Hz. For the experimental phase, 90 faces from the FACES database were selected as the stimuli (Ebner et al., 2010). The selected faces represented angry, happy, and neutral emotions. Thirty faces were selected for each emotional valence; half were female, and the other half were male. The faces corresponded to young, middle-aged, and older people. The stimuli were resized to 50 × 77 mm, and the non-facial features were edited out.

The task was divided into two blocks (prosaccade and antisaccade). Each block was composed of nine practice trials to guarantee that all participants clearly understood directions and 60 randomized experimental trials (20 angry, 20 happy, and 20 neutral). The order of the prosaccade and antisaccade blocks was counterbalanced. At the beginning of each trial, there was a blank screen for 600 ms as an inter-trial interval. A fixation point (12 × 12 mm) appeared at the center of the screen for 1600 ms to avoid any initial viewing biases. Then, a face appeared on one side of the screen (left or right with equal probability) at 13.1° away from the fixation point for 1600 ms. In the prosaccade block, participants had to look at the central fixation point, and once the face appeared, they had to redirect their gaze toward the face. In the antisaccade block, participants also had to look at the central fixation point; instead, in the prosaccade block, they had to redirect their gaze toward the opposite position on the screen. This task is a customized version of the experimental task employed in a previous study on attentional bias in bipolar disorder (García-Blanco et al., 2013).

Procedure

After the parents signed an informed consent form, they responded to a clinical interview and the CBCL and ADI-R (in the case of the ASC group). Simultaneously, the K-BIT scale was applied to the children by a clinical psychologist. Then, all children completed the experiment in a dimly lit room while the experimenter monitored the stimulus presentation. Participants sat at a distance of 60 cm away from the screen in a height-adjustable chair. First, a calibration was conducted to ensure that the recording error was less than 1.5° visual angle of the calibrating point. After calibration, instructions appeared on the screen, followed by the task.

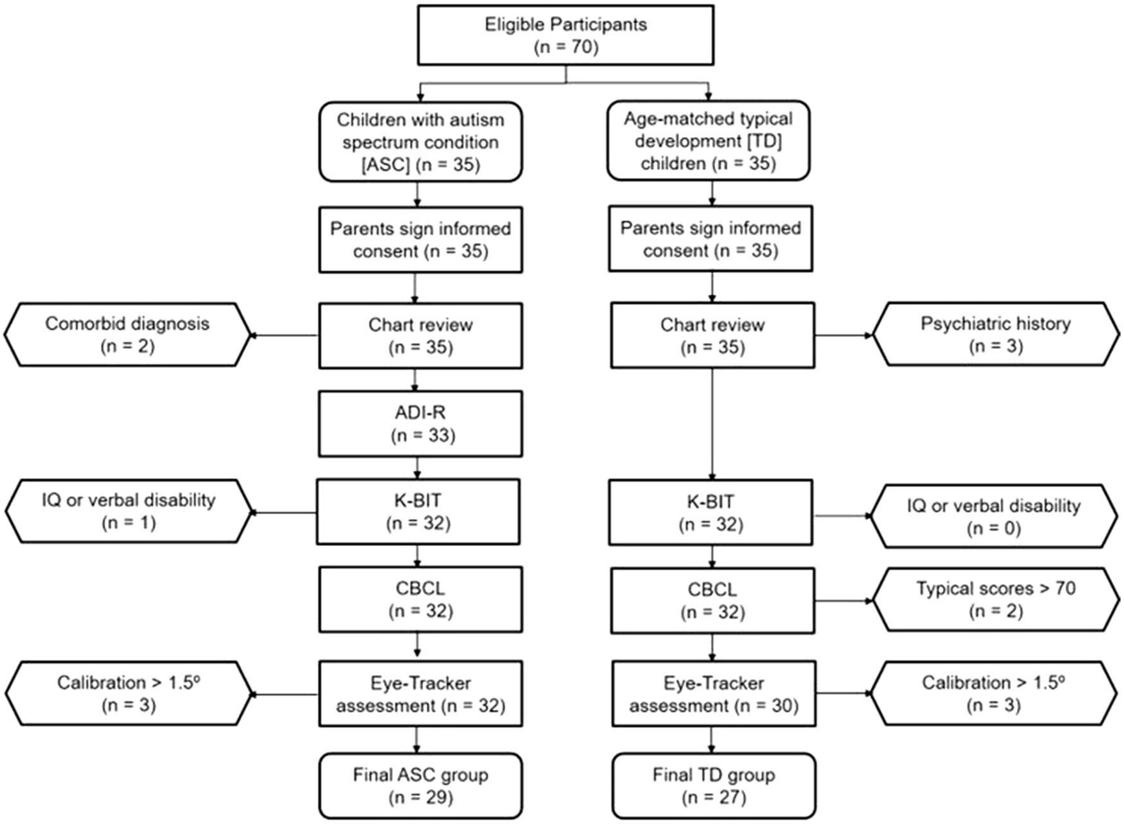

Fig. 1 Selection process of the final sample

Data Analysis

Correct responses included in the analysis were based on the direction and latency of the saccade. The saccade direction had to be 30°/s or more, and its latency had to be between 70 and 700 ms. Thus, anticipatory saccades (< 70 ms) and late saccades (> 700 ms) were discarded. In addition, recordings of eye movements were not included if the initial fixation was not within 3.1° from the fixation point. Furthermore, short saccades of less than 6.3° in the x-axis (< 5%) were also excluded (Mueller et al., 2010). Several measures were computed in the eye-tracking study: (a) the percentage of errors in prosaccade and antisaccade blocks; and (b) the mean of correct saccade latencies in each block. For each participant, the percentage of errors was calculated from the number of erroneous saccades on the trials of the same valence of emotional faces. A similar analysis was done to obtain the mean correct saccade latencies of the trials per valence.

Prosaccade and antisaccade blocks were examined separately into two omnibus analyses of variance (ANOVA) where Group (ASC vs. TD) was a between-subjects factor, and Valence (angry, happy, neutral) was a within-subject factor. The dependent variables were the percentage of errors in the antisaccade block and the mean correct saccade latencies in both prosaccade and antisaccade blocks. The error rate in the prosaccade block (< 2.2% for each group) was extremely low and not further analyzed. When the effects were significant in the three-level factor (i.e., Valence), and to control for type I error, we conducted pairwise tests using the Bonferroni correction. Pearson correlation coefficients were computed to examine the relationship between attentional biases and ADI-R scores in the ASC group.

Results

Table 1 shows socio-demographic and clinical details in both groups.

Means and standard deviations for percentage of error and latencies for each group are displayed in Table 2.

Percentage of Errors in the Antisaccade Task

The ANOVA revealed a Group effect, $F(1,54) = 8.82$, $p = .004$, $\eta2 = 0.140$, and a Valence effect, $F(2,108) = 8.63$, $p < .001$, $\eta2 = 0.138$. Importantly, these main effects were modulated by the Valence x Group interaction,

Table 1 *Demographic and clinical data*

	TD group (n = 27)	ASC group (n = 29)	p
% Female	37%	17.5%	0.07
Age	13.59 (3.89)	13.62 (2.53)	0.97
K-BIT scores	103.09 (3.27)	98.50 (9.54)	0.15
Vocabulary subtest	104.82 (1.80)	102.89 (10.67)	0.60
Matrix subtest	99.91 (5.01)	99.00 (12.14)	0.82
ADI-R			
Social interactions	–	15.97 (5.48)	
Communication	–	13.10 (4.77)	
Repetitive behaviour	–	5.38 (2.77)	
Evidence before 36 months	–	3.10 (1.63)	
CBCL			
Anxiety	2.17 (2.50)	8.90 (4.78)	< 0.001
Depression/Withdrawn	2.17 (2.80)	6.79 (3.89)	< 0.001
Somatic complaints	1.56 (1.82)	3.24 (3.00)	0.037
Social problems	2.22 (2.13)	9.21 (3.74)	< 0.001
Thought problems	1.44 (1.54)	5.10 (3.09)	< 0.001
Attention problems	3.56 (2.64)	11.34 (4.25)	< 0.001
Rule-breaking behaviour	1.56 (1.38)	4.38 (2.97)	< 0.001
Aggressive behaviour	3.72 (2.65)	10.48 (6.96)	< 0.001

TD Typical Development; *ASC* Autism Spectrum Condition; *SD* Standard Deviation; *CBCL* Child Behaviour Checklist; *ADI-R* Autism Diagnostic Interview-Revised; K-*BIT* Kaufman Brief Intelligence Test

$F(2,108) = 6.30$, $p = .003$, $\eta 2 = 0.104$. This interaction showed a Valence effect for the ASC group, $F(2,56) = 0.10$, $p = .001$, $\eta^2 = 0.224$: children with ASC showed more antisaccade errors to angry faces than to neutral faces ($p = .010$) and happy faces ($p = .001$)—the comparison between happy and neutral faces was not significant ($p = 1.00$). For the TD group, the Valence effect was also significant, $F(2,52) = 6.83$, $p = .002$, $\eta^2 = 0.208$, but the nature of the effect was different: Bonferroni-corrected t-tests showed that children with TD committed more antisaccade errors to happy faces than to neutral stimuli ($p = .009$), whereas the other comparisons did not approach significance (both $ps > 0.10$) (See Fig. 2).

Latencies of Correct Responses in the Antisaccade Block

The ANOVA revealed a significant effect of Group, $F(1,54) = 8.94$, $p = .004$, $\eta^2 = 0.142$: correct latencies were longer in the ASC group than in the TD group (394 vs. 321 ms, respectively). The effect of Valence reached statistical significance, $F(1,54) = 3.23$, $p = .044$, $\eta^2 = 0.056$, but theBonferroni-corrected t-tests revealed no-significant comparison ($ps > 0.09$; 352 ms for happy faces, 368 ms for neutral faces, and 354 for angry faces). Finally, the Group x Valence interaction did not approach significance ($F < 1$).

Latencies of Correct Responses in the Prosaccade Block

The ANOVA only showed a significant Group effect, $F(1,54) = 5.91$, $p = .018$, $\eta 2 = 0.099$: latencies were higher in the ASC group (264 ms) than in the TD group (206 ms). Neither the effect of Valence nor the interaction between the two factors approached significance (both Fs < 1).

Associations Between ASC Symptoms and Attentional Biases

None of the bivariate Pearson correlations between the percentage of antisaccade errors to angry faces and ADI-R scores were significant (all $ps > 0.28$). Nonetheless, slower antisaccade latencies were associated with higher Social Interaction problems ($r = .436$, $p = .018$ –see Fig. 3) and Evidence before 36 months in the ADI-R sub-scales ($r = .462$, $p = .012$) –no other associations were significant (all $ps > 0.07$). Similarly, higher prosaccade latency was associated with Evidence before 36 months ADI-R

Table 2 *Mean (standard deviation) for percentage of errors and mean correct response latency in anti and prosaccade blocks for each stimulus valence*

Valence	Antissacade block				Prosaccade block			
	Mean latency (ms)		% of errors		Mean latency (ms)		% errors	
	TD	ASC	TD	ASC	TD	ASC	TD	ASC
Angry	317 (89)	390 (99)	10.48 (17.99)	33.55 (31.38)	202 (77)	266 (104)	5.30 (16.37)	0.90 (3.02)
Happy	312 (89)	393 (100)	14.44 (17.95)	23.79 (26.47)	207 (87)	266 (104)	1.22 (4.51)	0.59 (1.76)
Neutral	335 (96)	402 (106)	5.41 (11.88)	22.69 (22.52)	210 (90)	267 (99)	0.00 (6.72)	2.73 (6.72)

TD Typical Development; *ASC* Autism Spectrum Condition

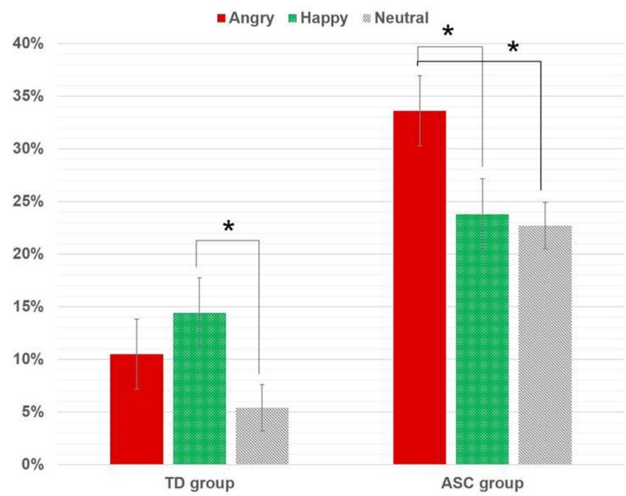

Fig. 2 *Percentage* of errors in the antisaccade block for each valence in the Typical Development (TD) group and the Autism Spectrum Condition (ASC) group

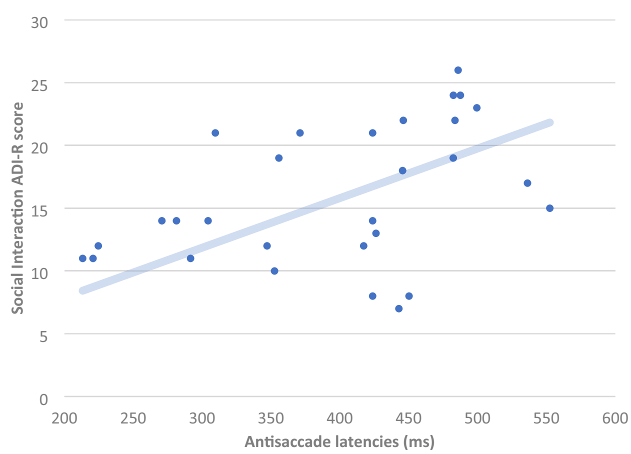

Fig. 3 Regression plot between antisaccade latencies and ADI-R Social Interaction score

sub-scale ($r = .463$, $p = .011$) –no other correlations were found ($ps > 0.077$).

Discussion

This is the first eye-movement experiment to examine inhibitory control when emotional faces (angry or happy vs. neutral) are displayed to children with ASC. The three main findings are the following: First, compared to children with TD, children with ASC showed slower inhibitory control and slower initial orienting, thus extending prior research with neutral stimuli (Mosconi et al., 2009). Second, the valence of the faces modulated the percentage of antisaccade errors in children with ASC and TD differently. Whereas children with ASC committed more antisaccade errors to angry faces than to happy and neutral faces, children with TD committed more antisaccade errors to happy faces than to neutral faces Finally, a third relevant finding was that, in both antisaccade and prosaccade blocks, the slower the latencies on attentional shifting to faces, the higher the ASC symptoms. As discussed below, all these findings are important to characterize how emotional faces are processed in the initial stages of attentional processing in children with ASC.

Firstly, similar to the studies that used antisaccade tasks with individuals with ASC employing only neutral stimuli, children with ASC showed a higher error rate in the antisaccade block than children with TD (Goldberg et al., 2002; Luna et al., 2007; Manoach et al., 2004; Minshew et al., 1999; Mosconi et al., 2009), thus suggesting that children with ASC have inefficient inhibitory control of attention. It should be noted that this is considered a key executive function involved in inhibiting inappropriate behaviors to respond more adaptively to environmental stimuli (Goldberg et al., 2002). Furthermore, in the latency data, we found slower responses in both prosaccadic and antisaccadic blocks in ASC children than in TD children. Notably, a higher latency in prosaccade block in children with ASC is a marker of slow initial attentional orientating (Goldberg et al., 2002; Mosconi et al., 2009). Furthermore, the higher latencies in antisaccade block for children with ASC demonstrate their slow inhibitory control (Manoach et al., 2004; Mosconi et al., 2009). Taken together, these findings can be explained in terms of atypical attentional shifting in ASC (Falck-Ytter et al., 2013). Individuals with ASC show a decreased functioning of subcortical structures, as in the cerebellum, that regulate the timing of motor movements, which can be associated with worse performance in prosaccade blocks (Théoret et al., 2001). Moreover, poor outcomes in antisaccade blocks have been associated with decreased functional connectivity in two cortical regions critical for the inhibitory control of attention: the frontal eye field and the dorsal anterior cingulate cortex (Agam et al., 2010).

Secondly, in the TD group, the percentage of antisaccade errors was greater for happy faces than for neutral faces. In contrast, in the ASC group, the percentage of antisaccade errors was greater for angry faces than for happy or neutral faces. In children with TD, the difficulty in inhibiting responses to happy faces can be readily explained in terms of a protective positive attention bias—note that similar evidence was found with an emotional go/no-go task (Hare et al., 2005; Schulz et al., 2007). Importantly, in children with ASC, the Intense World Theory can easily accommodate the difficulty of ignoring angry faces at the earliest stages of attention (Markram, 2007; Markram & Markram, 2010). The idea is that individuals with ASC have a high sensitivity to threatening information during bottom-up processing, as it elicits high distress. Therefore, children with ASC had difficulty ignoring angry faces during initial orienting at the earliest stages of attention. Notably, this attraction of threatening stimuli during initial orienting was not reflected by faster prosaccade latencies for angry faces. Thus, the percentage of antisaccade errors may be a more sensitive measure to examine attentional bias at the earliest stages of attention than latencies –note that children with ASC were reasonably fast in their responses (264 ms). Critically, as was mentioned in the Introduction, the apparent inconsistency with the attentional bias away from threat-related information found in previous free-viewing eye-tracking or dot-probe tasks (García-Blanco et al., 2017b; Ghosn et al., 2019; Matsuda et al., 2015; Uono et al., 2009; Wagner et al., 2013) can also be captured by the Intense World Theory (Markram, 2007; Markram & Markram, 2010). Specifically, at later processing stages, individuals with ASC may avoid this information through top-down processing to reduce their distress (Smith, 2009).

Thirdly, ASC symptom severity was associated with slower latencies in both antisaccades and prosaccades. These slower latencies were linked to impairments in social interactions and an early manifestation of ASC symptoms. This pattern is consistent with the idea that social-emotional deficits in ASC may result from atypical attentional shifting to socially relevant stimuli (Liang & Wilkinson, 2018; Norbury et al., 2009; Sacrey et al., 2014). Indeed, it has been proposed that slower orienting to faces is a key underlying mechanism in the symptomatology characteristic of young children and adults with ASC (Dawson et al., 2005). This could explain why the severity of social-emotional symptoms in ASC was associated with the flexibility and efficiency of visual orienting to faces (i.e., slower latencies) rather than an impaired inhibitory control (i.e., higher antisaccade errors) (Hill, 2004; Lopez et al., 2005; South et al., 2007).

The present experiment comes with certain limitations. The sample in the present study consists of children with ASC without language problems and intellectual impairments. Thus, our findings cannot be generalized to the whole ASC population. Furthermore, the results cannot be generalized to all the distressing stimuli, such as disgust or fear, or other negative middle-arousal stimuli (i.e., sad faces). Finally, it would be important to study, in future research, the location of the first fixation within the different areas of the face with similar attentional tasks (i.e., eyes, mouth) (Isomura et al., 2014; Wieckowski & White, 2017).

To sum up, this study adds to previous studies on inhibitory control in ASC that have examined the role of emotional stimuli (angry, happy, neutral) in children. Children with ASC showed an inefficient inhibitory control, which was especially salient with angry faces. This bias toward threatening information is congruent with those affective information-processing theories on ASC (Intense World Theory, Markram, 2007; K. Markram & Markram, 2010), which posit that negative and high-arousing stimuli induce an overwhelming response and cause an abnormal processing of this type of information at the earliest stages of attention during bottom-up processing. Additionally, children with ASC showed longer latencies than children with TD in prosaccade and antisaccade blocks. Interestingly, slow attentional orienting and slow inhibitory control were associated with ASC symptoms severity. Thus, at an applied level, if individuals with ASC are trained to shift their attention to emotional stimuli such as faces, this would potentially improve their social functioning (Guillon et al., 2014). Indeed, a recent meta-analysis suggests potentially beneficial therapeutic interventions for children with ASC in enhancing their attentional focus on faces and modifying their responses to threatening information (Guillon et al., 2014). In this sense, clinicians should design specific treatments that target threat desensitization and management to cope with emotional faces (Waters et al., 2008), as this could potentially improve socio-emotional development in children with ASC (Guillon et al., 2014).

Author Contributions A.G-B., and M.P. designed the larger study from which this data was taken. A.G-B. and R.S-L. developed the concept for the current paper. R.S-L., A.M-G., and J.A. collected the data. L.S. analyzed the data. R.S-L., M.P., D.P., M.V., and A.G-B. wrote sections of the paper. All authors discussed the results and implications and edited the manuscript at all stages.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

References

Achenbach, T. M., & Edelbroch, C. S. (1991). *Manual for the child behavior checklist and revised child profile*. Burlington: University of Vermouth.

Agam, Y., Joseph, R. M., Barton, J. J. S., & Manoach, D. S. (2010). Reduced cognitive control of response inhibition by the anterior

cingulate cortex in autism spectrum disorders. *Neuroimage*, *52*(1), 336–347. https://doi.org/10.1016/j.neuroimage.2010.04.010.
American Psychological Association (APA). (2013). *Diagnostic and statistical manual manual of mental disorders* (5th ed.). Washington, D.C.: American Psychiatric Association.
Bastiaansen, J. A., Thioux, M., Nanetti, L., Van Der Gaag, C., Ketelaars, C., Minderaa, R., & Keysers, C. (2011). Age-related increase in inferior frontal gyrus activity and social functioning in autism spectrum disorder. *Biological Psychiatry*, *69*(9), 832–838. https://doi.org/10.1016/j.biopsych.2010.11.007.
Beall, P. M., Moody, E. J., McIntosh, D. N., Hepburn, S. L., & Reed, C. L. (2008). Rapid facial reactions to emotional facial expressions in typically developing children and children with autism spectrum disorder. *Journal of Experimental Child Psychology*, *101*(3), 206–223. https://doi.org/10.1016/j.jecp.2008.04.004.
Beck, A. T. (1976). *Cognitive therapy and the emotional disorders*. New York: New American Library.
Chawarska, K., MacAri, S., & Shic, F. (2012). Context modulates attention to social scenes in toddlers with autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *53*(8), 903–913. https://doi.org/10.1111/j.1469-7610.2012.02538.x.
Dawson, G., Webb, S. J., & Mcpartland, J. (2005). Understanding the nature of Face Processing Impairment in Autism: Insights from behavioral and electrophysiological studies. *Developmental Neuropsychology*, *27*(3), 403–424. https://doi.org/10.1207/s15326942dn2703_6.
Derakshan, N., Salt, M., & Koster, E. H. W. (2009). Attentional control in dysphoria: An investigation using the antisaccade task. *Biological Psychology*, *80*(2), 251–255. https://doi.org/10.1016/j.biopsycho.2008.09.005.
Ebner, N. C., Riediger, M., & Lindenberger, U. (2010). FACES-a database of facial expressions in young, middle-aged, and older women and men: Development and validation. *Behavior Research Methods*, *42*(1), 351–362. https://doi.org/10.3758/BRM.42.1.351.
Falck-Ytter, T., Bölte, S., & Gredebäck, G. (2013). Eye tracking in early autism research. *Journal of Neurodevelopmental Disorders*, *5*(1), 28. https://doi.org/10.1186/1866-1955-5-28.
García-Blanco, A. C., Perea, M., & Salmerón, L. (2013). Attention orienting and inhibitory control across the different mood states in bipolar disorder: An emotional antisaccade task. *Biological Psychology*, *94*, 556–561. https://doi.org/10.1016/j.biopsycho.2013.10.005.
García-Blanco, A. C., Yáñez, N., Vázquez, M. A., Marcos, I., & Perea, M. (2017). Modulation of attention by socio-emotional scenes in children with autism spectrum disorder. *Research in Autism Spectrum Disorders*, *33*, 39–46. https://doi.org/10.1016/j.rasd.2016.11.002.
García-Blanco, A., López-Soler, C., Vento, M., García-Blanco, M. C., Gago, B., & Perea, M. (2017b). Communication deficits and avoidance of angry faces in children with autism spectrum disorder. *Research in Developmental Disabilities*, *62*, 218–226. https://doi.org/10.1016/j.ridd.2017.02.002.
Ghosn, F., Perea, M., Castelló, J., Vázquez, M., Yáñez, N., Marcos, I., Sahuquillo, R., Vento, M., & García-Blanco, A. (2019). Attentional patterns to emotional faces Versus scenes in children with Autism Spectrum disorders. *Journal of Autism and Developmental Disorders*, *49*(4), 1484–1492. https://doi.org/10.1007/s10803-018-3847-8.
Goldberg, M. C., Lasker, A. G., Zee, D. S., Garth, E., Tien, A., & Landa, R. J. (2002). Deficits in the initiation of eye movements in the absence of a visual target in adolescents with high functioning autism. *Neuropsychologia*, *40*(12), 2039–2049. https://doi.org/10.1016/S0028-3932(02)00059-3.
Guillon, Q., Hadjikhani, N., Baduel, S., & Rogé, B. (2014). Visual social attention in autism spectrum disorder: Insights from eye tracking studies. *Neuroscience and biobehavioral reviews* (Vol. 42, pp. 279–297). Amsterdam: Elsevier. https://doi.org/10.1016/j.neubiorev.2014.03.013
Hare, T. A., Tottenham, N., Davidson, M. C., Glover, G. H., & Casey, B. J. (2005). Contributions of amygdala and striatal activity in emotion regulation. *Biological Psychiatry*, *57*(6), 624–632. https://doi.org/10.1016/j.biopsych.2004.12.038.
Hill, E. L. (2004). Executive dysfunction in autism. *Trends in cognitive sciences* (Vol. 8, pp. 26–32). Amsterdam: Elsevier. https://doi.org/10.1016/j.tics.2003.11.003
Hollocks, M. J., Ozsivadjian, A., Matthews, C. E., Howlin, P., & Simonoff, E. (2013). The relationship between attentional bias and anxiety in children and adolescents with autism spectrum disorders. *Autism Research*, *6*(4), 237–247. https://doi.org/10.1002/aur.1285.
Hutton, S. B., & Ettinger, U. (2006). The antisaccade task as a research tool in psychopathology: A critical review. *Psychophysiology*, *43*(3), 302–313. https://doi.org/10.1111/j.1469-8986.2006.00403.x.
Isomura, T., Ogawa, S., Yamada, S., Shibasaki, M., & Masataka, N. (2014). Preliminary evidence that different mechanisms underlie the anger superiority effect in children with and without autism spectrum disorders. *Frontiers in Psychology, 5*, 461. https://doi.org/10.3389/fpsyg.2014.00461
Kaufman, A. S. (1997). K-BIT. *Test Breve De Inteligencia De Kaufman [Kaufman brief IntelligenceTest (K-BIT)]*. TEA.
Keehn, B., Müller, R. A., & Townsend, J. (2013). Atypical attentional networks and the emergence of autism. *In Neuroscience and Biobehavioral Reviews, 37*(2), 164–183. https://doi.org/10.1016/j.neubiorev.2012.11.014
Kleinhans, N. M., Richards, T., Weaver, K., Johnson, L. C., Greenson, J., Dawson, G., & Aylward, E. (2010). Association between amygdala response to emotional faces and social anxiety in autism spectrum disorders. *Neuropsychologia*, *48*(12), 3665–3670. https://doi.org/10.1016/j.neuropsychologia.2010.07.022.
Liang, J., & Wilkinson, K. (2018). Gaze toward naturalistic social scenes by individuals with intellectual and developmental disabilities: Implications for augmentative and alternative communication designs. *Journal of Speech Language and Hearing Research*, *61*(5), 1157–1170. https://doi.org/10.1044/2018_JSLHR-L-17-0331.
Lopez, B. R., Lincoln, A. J., Ozonoff, S., & Lai, Z. (2005). Examining the relationship between executive functions and restricted, repetitive symptoms of autistic disorder. *Journal of Autism and Developmental Disorders*, *35*(4), 445–460. https://doi.org/10.1007/s10803-005-5035-x.
Luna, B., Doll, S. K., Hegedus, S. J., Minshew, N. J., & Sweeney, J. A. (2007). Maturation of executive function in Autism. *Biological Psychiatry*, *61*(4), 474–481. https://doi.org/10.1016/j.biopsych.2006.02.030.
Manoach, D. S., Lindgren, K. A., & Manoach, D. S. (2004). Deficient saccadic inhibition in Asperger's disorder and the social-emotional processing disorder. *Journal of Neurology, Neurosurgery and Psychiatry*, *75*, 1719–1726. https://doi.org/10.1136/jnnp.2003.025981.
Markram, H. (2007). The intense world syndrome—an alternative hypothesis for autism. *Frontiers in Neuroscience, 1*(1), 77–96. https://doi.org/10.3389/neuro.01.1.1.006.2007
Markram, K., & Markram, H. (2010). The intense world theory—A unifying theory of the neurobiology of autism. *Frontiers in Human Neuroscience*. https://doi.org/10.3389/fnhum.2010.00224
Matsuda, S., Minagawa, Y., & Yamamoto, J. (2015). Gaze behavior of children with ASD toward pictures of facial expressions. *Autism Research and Treatment, 2015*, 617190. https://doi.org/10.1155/2015/617190
Minshew, N. J., Luna, B., & Sweeney, J. A. (1999). Oculomotor evidence for neocortical systems but not cerebellar dysfunction in

autism. *Neurology*, *52*(5), 917–922. https://doi.org/10.1212/wnl.52.5.917.

Mosconi, M. W., Kay, M., Seidenfeld, A., Guter, S., Stanford, L. D., & Sweeney, J. A. (2009). Impaired inhibitory control is associated with higher-order repetitive behaviors in autism spectrum disorders. *Cambridge Org*. https://doi.org/10.1017/S0033291708004984.

Mueller, S. C., Ng, P., Temple, V., Hardin, M. G., Pine, D. S., Leibenluft, E., & Ernst, M. (2010). Perturbed reward processing in pediatric bipolar disorder: An antisaccade study. *Journal of Psychopharmacology*, *24*(12), 1779–1784. https://doi.org/10.1177/0269881109353462.

Norbury, C. F., Brock, J., Cragg, L., Einav, S., Griffiths, H., & Nation, K. (2009). Eye-movement patterns are associated with communicative competence in autistic spectrum disorders. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *50*(7), 834–842. https://doi.org/10.1111/j.1469-7610.2009.02073.x.

Posner, M. I., & Dehaene, S. (1994). Attentional networks. In *Trends in Neurosciences* (Vol. 17, Issue 2, pp. 75–79). Elsevier Current Trends. https://doi.org/10.1016/0166-2236(94)90078-7.

Rogers, S. J. (2000). Diagnosis of autism before the age of 3. *International Review of Research in Mental Retardation*, *23*, 1–31. https://doi.org/10.1016/s0074-7750(00)80004-x.

Sacrey, L. A. R., Armstrong, V. L., Bryson, S. E., & Zwaigenbaum, L. (2014). Impairments to visual disengagement in autism spectrum disorder: A review of experimental studies from infancy to adulthood. *Neuroscience and biobehavioral reviews* (Vol. 47, pp. 559–577). Amsterdam: Elsevier. https://doi.org/10.1016/j.neubiorev.2014.10.011

Schulz, K. P., Fan, J., Magidina, O., Marks, D. J., Hahn, B., & Halperin, J. M. (2007). Does the emotional go/no-go task really measure behavioral inhibition? Convergence with measures on a non-emotional analog. *Archives of Clinical Neuropsychology*, *22*, 151–160. https://doi.org/10.1016/j.acn.2006.12.001.

Smith, A. (2009). The empathy imbalance hypothesis of autism: A theoretical approach to cognitive and emotional empathy in autistic development. *Psychological Record*, *59*(3), 489–510. https://doi.org/10.1007/BF03395675.

South, M., Ozonoff, S., & Mcmahon, W. M. (2007). The relationship between executive functioning, central coherence, and repetitive behaviors in the high-functioning autism spectrum. *Autism*, *11*(5), 437–451. https://doi.org/10.1177/1362361307079606.

Théoret, H., Haque, J., & Pascual-Leone, A. (2001). Increased variability of paced finger tapping accuracy following repetitive magnetic stimulation of the cerebellum in humans. *Neuroscience Letters*, *306*(1–2), 29–32. https://doi.org/10.1016/S0304-3940(01)01860-2.

Uono, S., Sato, W., & Toichi, M. (2009). Dynamic fearful gaze does not enhance attention orienting in individuals with Asperger's disorder. *Brain and Cognition, 71*(3), 229–233. https://doi.org/10.1016/j.bandc.2009.08.015

Wagner, J. B., Hirsch, S. B., Vogel-Farley, V. K., Redcay, E., & Nelson, C. A. (2013). Eye-tracking, autonomic, and electrophysiological correlates of emotional face processing in adolescents with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *43*(1), 188–199. https://doi.org/10.1007/s10803-012-1565-1.

Waters, A. M., Mogg, K., Bradley, B. P., & Pine, D. S. (2008). Attentional bias for emotional faces in children with generalized anxiety disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, *47*(4), 435–442. https://doi.org/10.1097/CHI.0b013e3181642992.

Wieckowski, A. T., & White, S. W. (2017). Eye-Gaze Analysis of Facial Emotion Recognition and expression in adolescents with ASD. *Journal of Clinical Child and Adolescent Psychology*, *46*(1), 110–124. https://doi.org/10.1080/15374416.2016.1204924.

Yiend, J. (2010). The effects of emotion on attention: A review of attentional processing of emotional information. *Cognition and Emotion*, *24*(1), 3–47. https://doi.org/10.1080/02699930903205698.

Zhao, X., Zhang, P., Fu, L., & Maes, J. H. R. (2016). Attentional biases to faces expressing disgust in children with autism spectrum disorders: An exploratory study. *Scientific Reports, 6*(1), 19381. https://doi.org/10.1038/srep19381