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Modulation of attention by socio-emotional scenes in children with autism spectrum disorder

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ABSTRACT

Background: Abnormal attentional processes to socially relevant information may underlie social impairment in Autism Spectrum Disorder (ASD). To examine how these processes are modulated by the emotional salience of the stimuli, we studied the attentional biases to social scenes (happy, sad, and threatening) in ASD children.
Method: An emotional dot-probe task was applied to children (from 6 to 12 years old) with Autism Spectrum Disorder without additional language and/or intellectual impairments (ASD; n = 25) and age/sex-matched controls (n = 25).
Results: ASD children showed an attentional bias toward threatening scenes while typically developing children tended to direct their attention toward sad scenes. There were no differences between groups for happy scenes.
Conclusions: Threatening situations captured greater attention in ASD individuals than in the control participants. Thus, abnormal attention to emotionally relevant situations may negatively affect the ability of ASD children to adapt cognitively and emotionally, particularly in threatening situations.

1. Introduction

Individuals with Autism Spectrum Disorder (ASD) have been characterized by persistent deficits in communication and social interaction (ICD-10; World Health Organization (WHO), 1992). Of note, the ICD-10 criteria for ASD also include circumscribed interests and repetitive behaviors. This latter criterion has been commonly associated with how attention is initially captured by a set of restricted stimuli. Indeed, it has been proposed that ASD children do not attend to relevant information from the social context, which impairs their decision-making processes (Worsham, Gray, Larson, & South, 2015) and, subsequently, their social cognitive development (Klin, Jones, Schultz, & Volkmar, 2003; Guillon, Hadjikhani, Baduel, & Rogé, 2014).

While a number of prior studies have shown abnormalities in the attentional capture of aspects of social environment —in contrast to nonsocial information—in individuals with ASD (e.g., see Elison, Sasson, Turner-Brown, Dichter, & Bodfish, 2012), an unanswered question is how attention is modulated by the emotional salience of the stimuli. Here we focused on ASD

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children because adolescent and adults may have learned to readjust their social behavior and, subsequently, to attend to socially relevant situations (see Elison et al., 2012). Behavioral tasks are an excellent technique for examining how emotionally relevant stimuli capture attention, of which, the most paradigmatic task is the double cueing (or dot-probe) task (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007, for a meta-analysis). In the emotional dot-probe task, two cues (one neutral and the other emotional; e.g., a neutral face and an emotional face) are briefly displayed in different locations on the screen (e.g., left and right). Immediately after the stimuli disappear, a dot probe (target) replaces one of the two cued stimuli. Participants are instructed to press a button to indicate the position in which the target appeared. That is, the dot probe can appear in the location of the emotional cue (i.e., emotion trial) or in the location of the neutral cue (i.e., neutral trial). The interpretation of the latency data in this technique is straightforward (see MacLeod, Mathews, & Tata, 1986): faster responses in emotion trials indicate an attentional bias toward emotional information (i.e., the assumption is that participants shift their attention at the emotional cue), whereas faster responses in neutral trials indicate an attentional bias away from emotional information.

The empirical literature on attentional capture by faces in ASD children is non-conclusive. Hollocks, Ozsivadjian, Matthews, Howlin, and Simonoff (2013) reported negligible attentional biases to happy or threatening faces, whereas other studies reported abnormal processing of distressing (i.e., fearful or angry) faces in ASD individuals (Uono, Sato, & Toichi, 2009; Matsuda, Minagawa, & Yamamoto, 2015). Specifically, Uono et al. (2009) conducted an experiment with ASD adolescents versus a control group in which they employed a modified version of the cueing task. In the Uono et al. (2009) experiment, the cues were dynamic eye-direction of fearful or neutral faces. The control group showed a cueing effect (i.e., faster responses when the eye-direction cue and the target appeared at the same location relative to the opposite location) that was higher for fearful than for neutral faces. However, this cueing effect did not appear in the ASD group. Moreover, Matsuda et al. (2015) conducted an eye-tracking experiment with ASD and typically developing (TD) children that examined gaze behavior toward surprised, happy, neutral, angry, and sad faces. While there were no differences between groups in gaze behavior when looking at faces, ASD children with more severe autistic symptomatology spent less time looking at angry faces than at the other faces (i.e., atypical responses to angry stimuli can be used as an indicator of autism severity). Finally, Corden, Childvers, and Skuse (2008) reported an atypical attentional capture by emotionally distressing words in ASD individuals using an attentional blink paradigm (see also Gaigg & Bowler, 2009, for a similar finding). These findings suggest that atypicalities in how emotional factors modulate attention may extend beyond faces in ASD.

To examine attentional biases in a scenario closer to real-world social situations, other researchers have employed pictures of social scenes instead of faces or words. The rationale is that socio-emotional scenes are important for understanding real-world social difficulties in ASD individuals (Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009), and hence, socio-emotional scenes may provide a more ecologically valid scenario than faces. Recently, Santos et al. (2012) examined selective attention toward social scenes in ASD adolescents and adults as well as in matched TD individuals. Pairs of social scenes (positive–neutral, negative–neutral, or neutral–neutral) were displayed while their eye movements were registered. (Positive and negative scenes were different in valence, but not in arousal.) Results showed that, unlike TD individuals, there was no initial orientation (i.e., first fixation) bias toward negative images in ASD individuals. Importantly, when considering the early capture of attention (i.e., total number of fixations during the 3-s presentation), both the ASD group and the control group showed an attentional bias toward negative scenes. Santos et al. (2012) concluded that ASD individuals were able to redirect their attention to negative scenes similarly to TD individuals.

Taken together, ASD individuals seem to show an attentional bias away from distressing faces (e.g., angry faces, Matsuda et al., 2015; fearful faces, Uono et al., 2009) but, at the same time, they show the typical attentional bias toward negative scenes (Santos et al., 2012). While the Santos et al. experiment offers very valuable information it is not possible to affirm that all social scenes are normally processed in ASD. We must bear in mind that the scenes included in the Santos et al. experiment did not distinguish between high-arousal vs. middle-arousal negative social scenes (i.e., threatening vs. sad images, respectively), thus leaving open the question of whether the attentional biases in social scenes are modulated by negativity or arousal in ASD children. Indeed, as indicated earlier, in Matsuda et al. (2015), ASD children reported differences between distressing (i.e., high arousal) and sad (i.e., middle arousal) faces. The present experiment aims to shed some light on this issue in ASD children by contrasting threatening with sad emotional social scenes.

In sum, in the present experiment, we examined how attentional capture could be modulated by the emotional salience of the stimuli in ASD individuals. To that end, we conducted a dot-probe experiment with emotionally relevant social situations with ASD children, together with a control group of TD children. Finally, what we should also note is that our study is the first aimed at discerning the effect on attentional processing of several types of negative scenes (i.e., threatening [high-arousal] and sad [middle-arousal]) in addition to happy [middle-arousal] scenes.

2. Material and methods

2.1. Participants

Fifty children between 6 and 12 years of age took part in the experiment. Twenty-five children (23 male, 2 female) with a diagnosis of ASD were recruited from the Infant Mental Health Unit, University and Polytechnic Hospital La Fe, Spain (Valencia, Spain). None of them had language and/or intellectual impairments. An additional group of 25 TD children (18 male, 7 female) were recruited via a local primary school. Parental informed consent was obtained for all participants.

Table 1
Demographic and clinical data for the control group and the ASD group.

	Control	ASD	p	η^2
Female (%)	24.1%	10.3%	0.164	
Age	8.79 (1.37)	9.48 (2.50)	0.198	0.029
K-BIT scores	101.23 (11.91)	104.79 (16.52)	0.338	0.016
Vocabulary Subtest	102.34 (13.33)	106.45 (17.86)	0.326	0.017
Matrix Subtest	103.21 (7.09)	104.41 (12.29)	0.649	0.004
CBCL scores				
Anxious/Depressed	55.17 (4.85)	66.00 (9.13)	0.000	0.362
Withdrawn/Depressed	51.97 (4.06)	69.72 (9.72)	0.000	0.595
Somatic Complains	54.41 (5.46)	62.72 (7.63)	0.000	0.315
Social Problem	52.93 (2.42)	67.93 (6.82)	0.000	0.645
Thought Problems	54.41 (5.46)	66.07 (8.53)	0.000	0.406
Attention Problems	52.62 (2.31)	70.34 (11.77)	0.000	0.531
Rule-Breaking Behavior	52.62 (4.12)	59.79 (7.41)	0.000	0.270
Aggressive Behavior	53.26 (2.68)	61.75 (8.29)	0.000	0.329

Note: the p values correspond to Chi-squared test for sex and to *t*-test for the rest of variables.
K-BIT: Kaufman Brief Intelligence Test; CBCL: Child Behavior Check List; ASD: Autism Spectrum Disorder.

No participant exhibited lower intelligence (scoring 80 or less on full-scale intelligence tests) or poor communication (scoring 80 or less on verbal intelligence test) as measured by the Kaufman Brief Intelligence Test (K-BIT; Kaufman & Kaufman, 1983), neurological history, major medical disorders, use of medication that could influence cognition (e.g., psychotropic medication, treatment with corticosteroids), or difficulty in distinguishing colors (e.g., color-blindness). There were no statistically significant differences between groups in age, sex or IQ (see Table 1). All participants in the clinical group had received the ASD diagnosis prior to the study by the referring clinicians. Autism spectrum diagnoses were based on the ICD-10 criteria (WHO, 1992). Additionally, the diagnosis was verified by expert clinical opinion and the Autism Diagnostic Interview—Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994) was applied to parents by a trained clinical psychologist. Other psychiatric diagnoses in ASD children represented additional exclusion criteria. Healthy children were required to report absence of psychiatric history (see Fig. 1 for the selection process of final sample).

In addition, in order to control the subclinical symptomatology in healthy children and check the presence of any syndromes in ASD children, every parent completed the Child Behavior Check List (CBCL; Achenbach, 1991). CBCL obtains parents' information on problem behavior in their offspring at ages between 6 and 18 through eight syndrome scales (Anxious/Depressed, Withdrawal Somatic Complaints, Social Problems, Thought Problems, Attention Problems, Rule-Breaking Behavior, Aggressive Behavior). The demographic and clinical data for the final sample are presented in Table 1.

2.2. Stimuli

The emotional stimuli, which served as cues, were 84 complex scenes selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). We used the same stimuli as Kellough, Beevers, Ellis, and Wells (2008) in an experiment with distressed individuals. These stimuli were categorized by happy, neutral, sad and threatening images[1] and had been rated on a 9-point scale for valence (unpleasant = 1, neutral = 5, to pleasant = 9) and arousal (calm = 1 to excitement = 9) but not for specific emotion categories. Kellough et al. (2008) conducted a pilot study with healthy individuals to identify which emotion category (threat or sadness) best described the unpleasant pictures. The valence ratings for sad (M = 2.4, SD = 0.4) and threatening images (M = 2.6, SD = 0.6) did not differ from each other ($t < 1$), while the valence for happy (M = 7.3, SD = 0.4) and neutral (M = 5.1, SD = 0.2) images were significantly different from the other three categories ($ps < 0.001$). Threatening images (M = 6.7, SD = 0.6) had greater arousal rating and neutral images (M = 2.8, SD = 0.3) had lower arousal rating than the other three categories ($ps < 0.001$), whereas sad (M = 4.9, SD = 0.5) and positive images (M = 4.6, SD = 0.7) did not differ from each other in arousal, $p = 0.240$.

Two scenes appeared as cues in each trial, namely an emotional scene (happy, threatening, or sad) and a neutral scene. Thus, there were three types of experimental trials: 12 happy–neutral, 12 threatening–neutral, and 12 sad–neutral cues. A total of 12 happy, 12 threatening, 12 sad scenes and 48 neutral scenes (36 for control and 12 for practice trials) were chosen. In addition, six pairs of neutral scenes were presented before the experimental trials as a practice block.

[1] We employed the following IAPS images: Sad: 2141, 2205, 2276, 2455, 2700, 2703, 2799, 2900, 3230, 9220, 9421, and 9530; Threatening: 1120, 1300, 2811, 3500, 6260, 6312, 6313, 6350, 6510, 6560, 6562, and 6821; Happy: 1340, 2091, 2165, 2208, 2224, 2299, 2339, 2340, 2501, 4599, 4700, and 8461; Neutral: 2038, 2102, 2190, 2191, 2215, 2235, 2393, 2396, 2397, 2487, 2514, 2516, 2745, 2850, 2880, 5500, 5390, 5731, 5740, 7000, 7004, 7009, 7010, 7041, 7053, 7080, 7090, 7100, 7185, 7187, 7235, 7547, 7493, 7496, 7550, and 7950; Neutral (practice): 2840, 2870, 5130, 7031, 5390, 5395, 5661, 5900, 6000, 6150, 8311, and 9070.

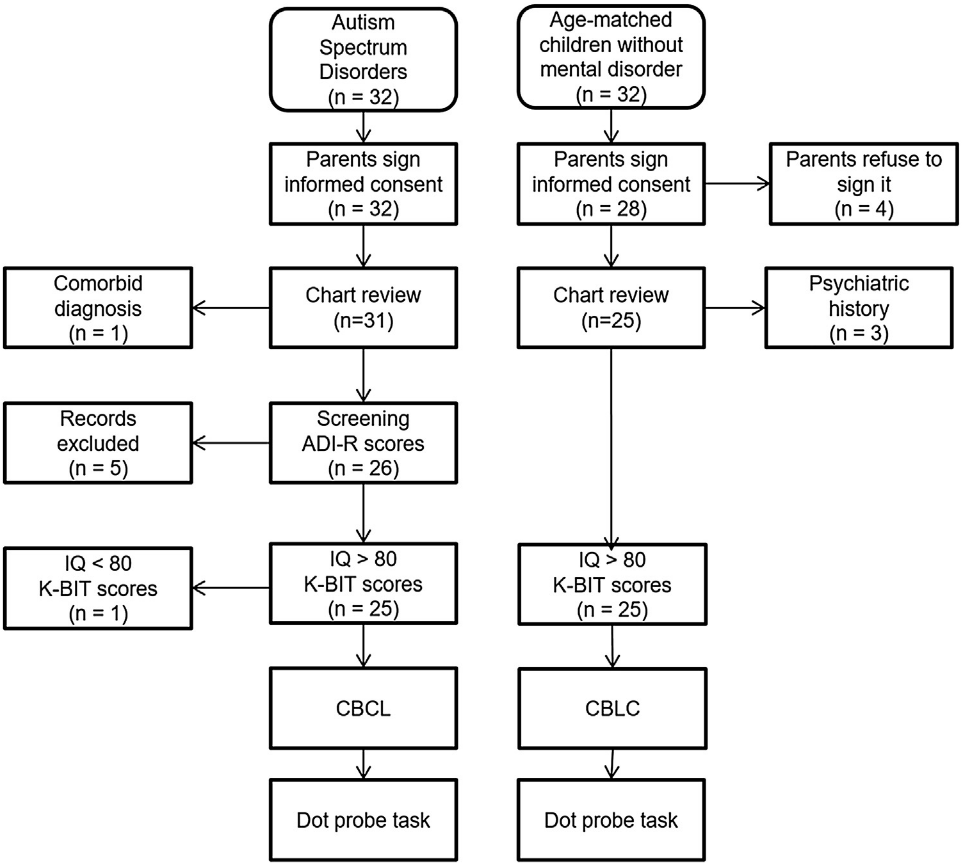

Fig. 1. Selection process of the final sample.

2.3. Procedure

Children were individually assessed in a quiet room. Presentation of stimuli and recording of responses were controlled by DMDX software (Forster & Forster, 2003). In each trial, participants were instructed to look at a fixation point (+) in the center of the screen, which was presented for 500 ms. Then, two cued images were presented simultaneously for 1250 ms at different screen locations (up and down). Immediately after the images disappeared, a green or red square replaced one of the two stimuli, either emotional (i.e., emotion trial) or neutral (i.e., neutral trial)—the green and red squares were presented randomly with equal proportions in each screen location. Participants were instructed to indicate the color of the square by pressing the button "GREEN" or "RED" as quickly and as accurately as possible. The sequence of stimulus presentation is shown in Fig. 2.

The task comprised one practice block followed by nine test blocks composed of 12 experimental trials (4 happy–neutral, 4 threatening–neutral, and 4 sad–neutral), which were randomly displayed within each block. Each pair of cued scenes was presented three times during the experiment. Thus, a total of 114 trials (108 experimental trials + 6 practice trials) were presented. The vertical location and the type of scene (emotional or neutral) replaced by the square were balanced across trials, with the constraint that each type of scene appeared in each of the two positions 50% of the time and the square replaced the emotional cues 50% of the time. The presentation order of the blocks was randomized across participants. The whole session lasted approximately 25–30 min.

2.4. Data analyses

Before calculating bias scores, the data were cleaned following the procedures outlined in previous experiments with ASD individuals (see Marotta et al., 2013). Probe responses were examined for accuracy and incorrect responses were excluded from further analyses. Response times (RTs) of very short duration (< 200 ms) were excluded, as were trials with RTs that exceeded 2.5 standard deviations above the participants' mean. The mean RT under each condition (for happy, threatening, and sad scenes) was calculated for each participant. To control for the overall RT differences between the ASD group and the control group (916 ms and 650 ms, respectively), the proportional difference between the emotion (i.e., where the probe replaced an emotional scene) and neutral trials (i.e., where the probe replaced a neutral scene) was calculated to estimate the

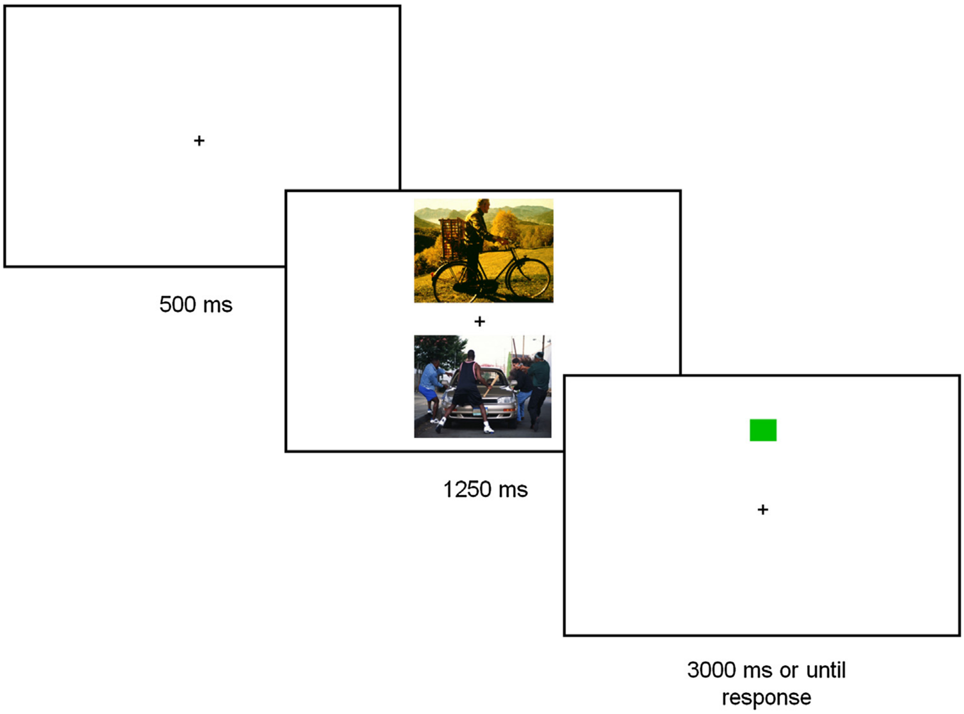

Fig. 2. The stimulus presentation sequence under threatening condition in a neutral trial.

bias scores [(Mean RT neutral trials/Mean RT emotional trials × 100) – 100] (see Behrmann et al., 2006). Positive bias scores indicate an attentional bias toward a particular emotional scene, whereas negative bias scores represent an attentional bias away from one (see MacLeod et al., 1986).

The bias score was analyzed in a 2 (Group: ASD, control) × 3 (Valence: happy, threatening, sad) omnibus analysis of variance (ANOVA), in which Group was a between-subject factor and Valence was within-subject factor. In case of a significant interaction, we conducted simple test effects. To test the presence of attentional biases, the bias score was tested for the difference from zero using one-sample *t*-tests accompanied by Bayesian factors—the scale factor was $r = 0.707$ (from the Cauchy distribution). For instance, a BF_{10} of 15 indicates that, with the current dataset, the alternate hypothesis (H_1) is 15 times more likely than the null hypothesis (H_0) (see Rouder, Speckman, Sun, Morey, & Iverson, 2009, for discussion).

3. Results

Preliminary analyses showed that error rates were very small in both groups (less than 3%) and there were no differences between groups and conditions (all $Fs < 1$). Thus, we focused only on the RTs (see Table 2). The mean (with SE) in proportional RT differences between the neutral and the emotional conditions are shown in Fig. 3.

3.1. Overall analysis

The ANOVA on the bias score failed to show main effects of Valence or Group (both $ps > 0.256$). More importantly, the effect of Valence differed in ASD and TD children, as deduced from the significant Valence × Group interaction, $F(2,93) = 3.62$, $p = 0.031$, $\eta^2 = 0.07$. This interaction revealed that, for threatening scenes, the ASD individuals showed greater bias scores than

Table 2
The mean RTs (with SE) for each condition in the control and the ASD groups.

	Control (n = 25)		ASD (n = 25)	
Valence	Emotion	Neutral	Emotion	Neutral
Happy	665 (17)	665 (16)	932 (76)	944.5 (73)
Sad	662 (14)	680 (15)	962 (73)	954.9 (75)
Threat	667 (16)	674 (16)	951 (73)	1007 (86)

RT: Response Time; SE: Standard Error; ASD: Autism Spectrum Disorder.

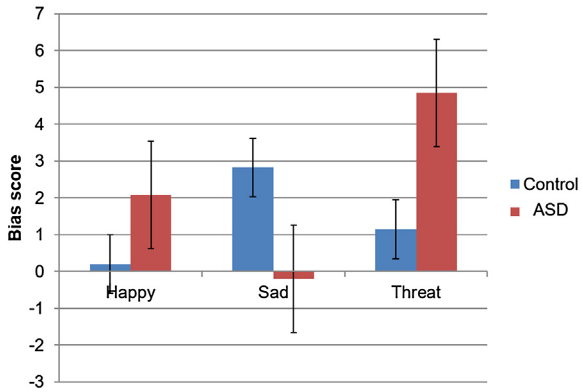

Fig. 3. Proportional differences (with SE) between the emotion and neutral trials for the ASD and the control groups.

the individuals in the control group, $t(48) = 2.36$, $p = 0.037$, $\eta^2 = 0.09$, whereas for sad scenes, individuals in the control group showed greater bias scores than ASD individuals—this difference did not reach the criterion for significance though, $t(48) = -1913$, $p = 0.062$, $\eta^2 = 0.07$. Finally, for happy scenes, there were no differences between the two groups, $t(48) = 1.11$, $p = 0.272$, $\eta^2 = 0.04$.

3.2. Attentional biases

ASD individuals showed bias scores higher than zero for threatening images, $t(24) = -3.31$, $p = 0.003$, $BF_{10} = 13.6$—this corresponds to "strong" evidence in favor of the alternative hypothesis when using Bayes factors, but not for happy or sad scenes (both $ps > 0.160$). The control group showed bias scores higher than zero for sad images $t(24) = 4.75$, $p < 0.001$, $BF_{10} = 334.4$—this corresponds to "decisive" evidence in favor of the alternative hypothesis when using Bayes factors, but not for happy and threatening scenes (both $ps > 0.291$).

To further examine the association between the attentional bias toward threatening images and the behavioral syndromes in ASD children, we computed the Pearson correlation coefficient between the threat-related bias score and the CBCL scores. There were no clear signs of a relationship between these variables (all $ps > 0.140$).

4. Discussion

The main finding of the current dot-probe experiment was that, unlike TD children, ASD children showed an attentional bias toward threatening scenes (i.e., high-arousal and negative images). Furthermore, results showed that TD children, but not ASD children, had a trend to direct their attention toward sad scenes (i.e., middle-arousal and negative images). The attentional bias toward sad rather than threatening scenes in the control group is consistent with previous studies with TD children (Kisley, Wood, & Burrows, 2007). Taken together, the present data showed a dissociation in the attentional biases for negative scenes in ASD and TD children: While ASD children showed a bias toward high-arousal scenes, TD children tended to show a bias toward middle-arousal scenes. We now discuss how these findings help to shed some light on the processing of socio-emotional scenes in ASD children.

In the current dot-probe experiment, ASD individuals showed faster responses when the dot probe appeared in the location of the threatening scene than in the location of the neutral scene. This strongly suggests that ASD children were more likely to shift their attention at the threatening scenes.[2] As anxiety and autism usually co-occur (e.g., see Kerns et al., 2014), and anxiety is frequently associated to more vigilance to threat, we examined whether the participants' CBCL scores (particularly in relation to anxiety/depression) could have had a moderating effect on the bias score for threatening scenes. However, we failed to find a relationship of this component with any behavioral measure in ASD children (see Hollocks et al., 2013, for a similar finding). In addition, it may be important to note that, in an eye-tracking experiment with scenes, Santos et al. (2012) found an attentional bias toward negative images in both the ASD and the control group. Nonetheless, unlike the present experiment, the arousal of negative scenes was not manipulated in their experiment (i.e., threatening and sad images were characterized as "negative" scenes), so that the net result could have been a general bias toward negative images in the two groups.

[2] Importantly, RTs indicate that the ASD children had slower attentional processing of all scenes than controls—note that this difference was higher in threatening condition. As a reviewer pointed out, TD children may have responded quickly based on an automatic affective assessment of the social scene, whereas ASD children may have responded once they figured out what is going on in the scene, thus making some kind of cognitively-derived assessment that requires more time than an automatic response.

Thus, the abnormal attentional bias to high-arousal and negative stimuli in ASD children occurs not only with distressing faces (see Matsuda et al., 2015; Uono et al., 2009), but also with distressing social scenes. Importantly, the direction of this bias with social images was the opposite as that in faces: attention was more captured by threatening scenes than by neutral scenes. An explanation of the apparent divergence in attentional biases in relation to faces and more complex scenes may be attributed to how readily individuals with ASD can perceive the relevant emotions in those stimuli due to a more detailed focused perceptual style. The idea is that a more detailed focused perceptual style may render faces overly arousing, whereas this processing style may render complex scenes less arousing because of difficulties integrating all the information. This interpretation is consistent with the Weak Central Coherence Theory (WCCT; Fritz, 1989), as this theory posits that whereas TD individuals tend to use higher level global processing (i.e., processing not just the shapes of individual features but also the relations among them), ASD individuals tend to use a local features processing (i.e., attending excessively to specific details of complex information and struggling to integrate fragments into a significant whole). Indeed, Isomura, Ogawa, Yamada, Shibasaki, and Masataka (2014) showed that, unlike TD individuals, when ASD individuals attend to threatening stimuli, they extract emotional information from local features. Moreover, recent neuroimaging studies showed that whereas the attention of distressing faces elicits an hyper-reactivity of primary sensory areas in ASD individuals relative to TD individuals (Kleinhans et al., 2010), the attention of threatening social scenes involve weaker functional connections of high-level brain areas in ASD individuals (Dichter & Belger, 2008). Further research is necessary to formally operationalize the distinction between local features and global processing in ASD individuals as a function of the complexity of the different types of stimuli (e.g., faces vs. scenes) and the relevant information that elicits distress.

A limitation of the present study is that our findings may not necessarily generalize to low-functioning ASD individuals, as only ASD individuals without additional language and/or intellectual impairments were assessed. It is also unclear whether older individuals and medicated ASD children would display the same pattern of attentional processing. Thus, further experimentation should examine whether cognitive functioning, medication, and age modulate these attentional biases. Furthermore, as a reviewer indicated, it would be important to include a post-task questionnaire, as this would allow evaluating the understanding of the scenes in ASD individuals. Finally, future research would require a dot-probe design using eye-tracking technology. Of note, while response time (task) only offers one data time at the end of the information processing, eye-tracking system allows monitoring the allocation of visual attention in an online manner.

5. Implications

The present dot-probe experiment showed an attentional bias toward threatening social scenes in ASD children which was absent in TD children—TD children showed a trend to attend to sad scenes instead. From an applied standpoint, these attentional biases may disrupt skill acquisition, especially in threatening situations. Characterizing attentional biases in ASD is not only crucial for advancing theoretical models, but it is also essential to necessary for specifying treatment targets based on training attention (see Klein, MacDonald, Vaillancourt, Ahearn, & Dube, 2009). Training attention control to socio-emotional scenes with computer applications could allow capturing contextual keys to understand emotionally relevant situations, especially those whose content is potentially threatening. Clearly, the examination of whether these training programs can improve symptoms in autistic children is an important issue for future research.

Conflict of interest

The authors declare that they have no conflict of interest.

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