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Visual Search and Emotion: How Children with Autism Spectrum Disorders Scan Emotional Scenes

Lisa Maccari · Augusto Pasini · Emanuela Caroli · Caterina Rosa · Andrea Marotta · Diana Martella · Luis J. Fuentes · Maria Casagrande

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Abstract This study assessed visual search abilities, tested through the flicker task, in children diagnosed with autism spectrum disorders (ASDs). Twenty-two children diagnosed with ASD and 22 matched typically developing (TD) children were told to detect changes in objects of central interest or objects of marginal interest (MI) embedded in either emotion-laden (positive or negative) or neutral real-world pictures. The results showed that emotion-laden pictures equally interfered with performance of both ASD and TD children, slowing down reaction times compared with neutral pictures. Children with ASD were faster than TD children, particularly in detecting changes in MI objects, the most difficult condition. However, their performance was less accurate than performance of TD children just when the pictures were negative. These findings suggest that children with ASD have better visual search abilities than TD children only when the search is particularly difficult and requires strong serial search strategies. The emotional–social impairment that is usually considered as a typical feature of ASD seems to be limited to processing of negative emotional information.

L. Maccari · E. Caroli · A. Marotta · M. Casagrande (✉)
Dipartimento di Psicologia, "Sapienza" Università di Roma, Via dei Marsi, 78, 00185 Rome, Italy
e-mail: maria.casagrande@uniroma1.it

A. Pasini · C. Rosa
Child Neurology and Psychiatry Unit, Department of Neuroscience, "Tor Vergata" University of Rome, Rome, Italy

D. Martella
Facultad de Ciencias Jurídicas y Sociales, Carrera de Psicología, Universidad Autónoma de Chile, Temuco, Chile

L. J. Fuentes
Facultad de Psicología, Universidad de Murcia, Murcia, Spain

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Introduction

Autism spectrum disorders (ASDs) is a class of complex, neurodevelopmental disorders that share marked qualitative impairments in social interactions and communication, often characterized by the presence of repetitive behaviours and restricted interests (APA 2000, 2013). According to the severity of the impairment in one or some of the aforementioned disorders, as well as on linguistic abilities, the DSM-IV distinguishes between autism (with low or high functioning) and Asperger syndrome (Bryson et al. 2004). Since the eighties, the incidence of autism has remarkably increased (Newschaffer et al. 2007). A systematic review of epidemiological surveys of autistic disorder worldwide reports a median prevalence of ASD of 62/10,000 (Elsabbagh et al. 2012). Currently, DSM-V (APA 2013) combines several mental ASD diseases that were separate in DSM-IV (APA 2000). One critical point that led to the different ASD classification concerns the existence of compensatory mechanisms that during development might have masked symptoms and basic cognitive dysfunctions.

From a cognitive point of view, deficits in attentional mechanisms seem to be crucial to explain a number of symptomatic behaviors in ASD individuals, such as salient or intense stimulus avoidance, persistence of repetitive activities, and restricted patterns of interest. Visual search abilities (i.e., the attention-dependent ability to find a target within a display consisting of distracting stimuli) have been largely tested to assess attention functioning in ASD, with rather controversial results. Whereas some studies point out that people with ASD have enhanced performance on visual search tasks when focused attention is a major requirement (O'Riordan et al. 2001; Plaisted et al. 1998; Remington et al. 2012), others studies instead, report either no differences between participants with ASD and healthy matched controls (Iarocci and Burack 2004; Leekam et al. 2000), or impaired performance in the ASD participants (Fletcher-Watson et al. 2006).

Attention-dependent visual search abilities have also been tested through the use of the flicker task (Rensink 2000; Rensink et al. 1997, 2000) in studies with children showing either neurotypical (Fletcher-Watson et al. 2009; Shore et al. 2006), or atypical (Burack et al. 2009; Kikuchi et al. 2009; Maccari et al. 2012; New et al. 2010) development. In the flicker task, pictures of daily life scenes are used to test visual search efficiency (Rensink 2000) by assessing change blindness performance. Change blindness is defined as the surprising inability to detect large changes occurring between two consecutive views of a particular scene (Simons and Levin 1997). In a prototypical experiment, two versions of a picture are employed, which are identical except in a specific detail. Each picture lasts 240 ms, and the two versions of the picture alternate repeatedly separated by a brief grey screen (lasting 80 ms) that hinders automatic detection of the change. The observers are told to explore the scene in searching for the change between the two pictures until they detect it. As the task uses pictures of real-world scenes, participants tend to give priority to some areas of the scene than to others (Rensink et al. 1997). Consequently, they usually detect changes in objects of central interest (CI) faster than changes in objects of marginal interest (MI) (Rensink et al. 1997). Both perceptual and semantic characteristics of the visual scene might be taken to create a sort of priority list that determines what objects are expected to be attended to first. Changes in objects of CI involve the gist portion of the pictures, and they are usually efficiently detected (Rensink et al. 1997). Changes in objects of MI are more difficult to detect and require serial visual search, and therefore performance is expected to be less efficient.

When the flicker task has been used for assessing focused attention in people with ASD, mixed results have been reported. Slower response times (RTs) in the ASD group than in the control group have been reported (Kikuchi et al. 2009), with greater difficulty in detecting MI changes in the former compared with the latter group of participants (Fletcher-Watson et al. 2006). In contrast, other studies have shown a general advantage of ASD participants in change detection performance when the task used film clips (Smith and Milne 2009), and a specific advantage in detecting MI changes when a flicker task was employed (Fletcher-Watson et al. 2012). However, other studies failed to replicate such differences in performance between people with ASD and controls (Burack et al. 2009). As it has been suggested by Ames and Fletcher-Watson (2010), the inconsistent findings could be due to differences in methodology among the studies. For instance, one such difference in the methodology used concerns the type of stimuli. The flicker task allows assessing visual search abilities through the use of pictures of real-world rather than schematic objects. This constitutes a clear advantage in comparison with the standard visual search paradigm as to testing attention functioning in children (Berger et al. 2000). But the flicker task also facilitates the use of emotional pictures in the experimental design, and therefore it constitutes an excellent way of assessing how emotion-laden stimuli affect attention functioning. A recent study shows that the presence of emotional stimuli facilitates (i.e., speeds up responses) change detection performance in healthy adults (Graham 2008).

Deficits in processing emotional information in ASD participants have been well documented (Bachevalier and Loveland 2006; Begeer et al. 2006; Dawson et al. 2004; Hall et al. 2003; Harms et al. 2010; Losh and Capps 2006; Loveland et al. 1997; Rieffe et al. 2007). For instance, people with ASD have difficulties in describing and identifying their own emotions (Hill et al. 2004), recognizing facial expressions (Bal et al. 2010; Corden et al. 2008; Wallace et al. 2008; Law Smith et al. 2010), being attracted by facial stimuli (Begeer et al. 2006; Kikuchi et al. 2009; Marotta et al. 2013), in emotional awareness (Silani et al. 2007), and in responding to emotional pictures (Wilbarger et al. 2009). In addition, they show differences in psychophysiological (Bölte et al. 2008), neural (Batty et al. 2011; Dawson et al. 2004; Harms et al. 2010) and eye movement (Batty et al. 2011) responses to emotional stimuli. Several authors have pointed out that the emotion-related deficits are part of the well-known social impairment typically associate to ASD (Bölte et al. 2008; McIntosh et al. 2006; White et al. 2007). However, such impairment has not always been supported by the experimental research (see Castelli 2005; Jones et al. 2011; Tracy et al. 2011, and Williams and Happé, Williams and Happé 2010, for recent failures to observe emotional impairment in ASD participants).

The current study used the flicker task with ASD children. We assessed change detection performance by using daily life scenes, assumed to increase motivation for the task, with or without emotional load. As far as we know, this is the first study aiming to assess whether emotional stimuli affect visual search abilities in ASD children. If as it has been suggested ASD children show superior visual search abilities through biases toward local processing of scenes, higher change detection performance should be observed in this group of participants, as the details of the scene would be priorized. In contrast, if ASD children manifest deficits in either attention shifting (Casey et al. 1993; Courchesne et al. 1994; Leekam and Moore 2001; Wainwright-Sharp and Bryson 1993) or attention disengagement (Hughes and Russell 1993; Landry and Bryson 2004), lower performance in detecting changes in MI objects is expected in this group of participants, but not in detecting changes in CI objects.

Regarding the reported emotional impairment in ASD (Bormann-Kirschkel et al. 1995; MacDonald et al. 1989; Batty et al. 2011), we hypothesize that searching for changes on emotion-laden scenes will be more compromised in ASD children than in typical developing children. Given the observed ASD people's difficulty in processing negative emotion (Ashwin et al. 2006; Bacon et al. 1998; Sigman et al. 1992), we expect change detection performance being affected in children with ASD particularly when assessed with negative pictures.

Method

Participants

A total of 44 children, 22 (age range 7–13; mean age = 9.86 years, SD = 2.03) with a diagnosis of ASD [nine males and three females with Asperger's disorder (AS); and nine males and one female with high functioning autism (HFA)], and 22 with typical development (TD; 9.78 years, SD 2.10) participated in the study. Intelligence assessment for the ASD group was first carried out through the Wechsler Intelligence Scale for Children-III Edition (WISC-III; Wechsler 1991). Children diagnosis of ASD was made by a child psychiatrist according to the criteria of DSM-IV-TR (American Psychiatric Association 2000), and after an extensive diagnostic evaluation that took into consideration a review of prior records (developmental history and child psychiatric and psychological observations). The symptomatic valuation and the severity of the patients' syndrome was estimated through the Childhood Autism Rating Scale (CARS; Schopler et al. 1998), the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 1999), the Autism Diagnostic Interview-Revised (ADI-R, Lord et al. 1994), and the Australian Scale for Asperger's Syndrome (ASA, Garnett and Attwood 1998).

The CARS is a behavioral rating scale of child/adolescent behavior with suspect of pervasive developmental disorder (PDD) in a number of contests with different social valence. The ADOS is a direct observation of child/adolescent behavior with suspect of PDD in relation to many structured activities with elevated social and relational valence. The ADI-R consists of a standardized semistructured interview for parents of ASD children, in the areas of communication, social skills, and restricted, repetitive and stereotyped behaviors. The ASA is a questionnaire/interview for parents to detect the presence of Asperger's syndrome symptoms. None of the participants had associated medical disorders at the time of testing. In addition, all participants exhibited normal cognitive and language skills according to their ages, and attended to standard schools. None of the participants were medicated. The inclusion criteria to participate in the study were the diagnosis of ASD; absence of any neurological disease, mental retardation, and co-morbid disorders; no history of drug abuse or cerebral injury; and total IQ score greater than 85 according to the WISC. Total IQs of children with ASD were in the normal range (Full-scale IQ: Mean = 105.74, SD = 9.11; Verbal IQ: Mean = 106.03, SD = 13.17; Performance IQ: Mean = 105.03, SD = 10.48). Typically developing (TD) were matched in both gender and age with ASD children, and were selected from a larger group of 136 children recruited from the public schools "Istituto P.M. Corradini" and "G. Sinopoli" in Rome. Children from the control group had no history of cerebral injury, or other neurological or psychiatric disorders. Both clinical and control children were administered the Raven Matrices test in order to assess IQ. Children aged 11 years and older had a full-scale IQ that fell above the 75th percentile on the Progressive Standard Matrices (PSM; Raven et al. 1990, 1993), and children aged 10.5 years or younger had an IQ greater than 80 on the Progressive Colored Matrices (PCM; Raven et al. 1990, 1993). Participants' demographic information is reported in Table 1. The Child Psychiatry and Neurology Institute Ethical Committee approved the study. All parents or legal caregivers of children gave written informed consent before testing.

Table 1 Participant demographic and descriptive characteristics

Variables	ASD		TDC		ANOVA results	
	Mean	SD	Mean	SD	F	*p*
Age	9.86	2.03	9.78	2.10	<1	–
PCM and PSM correct responses	36.22	7.12	36.13	6.98	<1	–
Males/females	18/4		18/4			
Full-scale IQ	105.74	9.11				
Verbal IQ	106.03	13.17				
Performance IQ	105.03	10.48				

ASD autism spectrum disorders, *TDC* typical developing children, *PCM* progressive colored matrices, *PSM* progressive standard matrices, *IQ* intelligence quotient

Apparatus and Materials

Stimuli were presented on a high definition CRT 21-in. monitor with a Pentium-based computer system (running at 100 MHz). E-Prime software controlled the presentation of the stimuli, timing operations and data collection. Responses were gathered with a standard keyboard.

Stimuli used in the experiment consisted of either emotionally laden or neutral pictures selected from the International Affective Picture System (IAPS; Lang et al. 2008). We chose 6 negative (IAPS number: 1930, 1120, 2810, 9421, 9050, 9480), 6 neutral (7150, 5020, 7100, 7510, 7130, 2320) and 6 positive (5480, 1750, 8490, 1920, 8620, 1710) pictures from the subset thought to be more appropriate for children. From the total set only three negative, one neutral, and two positive pictures contained faces. Pictures were selected on the basis of their normative valence ratings from the IAPS technical manual. The mean valence ratings were 3.34 for negative, 7.55 for positive and 5.55 for neutral pictures (scale ranging from 0 to 9; 0 = negative valence, 9 = positive valence).

Pictures measured 640 × 480 pixels. We created an additional version of each picture by removing a single object using Photoshop. To select CI and MI changes, we followed the method suggested by Rensink et al. (1997). The method allows the researcher to change the attentional aspect of the picture, although it does not provide any way of controlling for changes that may affect the emotional content of the pictures.

An independent group of 23 adults (mean age 22.38 ± 3.45) viewed each picture for 3 s and provided a brief written description of the scene. Objects mentioned by no more than two participants were defined as MI objects, whereas those mentioned by all participants were defined as CI objects. Half of the changes referred to MI objects and to CI objects the other half. Changes in experimental picture consisted in removing one object from the scene, and the size of the changes averaged 50 × 50 pixels, approximately.

Procedure

Children were tested individually in a silent and dimly illuminated room. On each trial, an original and modified version of a picture alternated repeatedly (240-ms display time), separated by a gray screen (80 ms), until the participant detected the change (see Fig. 1). Children were instructed to press the space bar as soon as they detected that one object was changing in the picture, and then they were told to verbally describe such change. An experimenter noted whether they accurately named the changing object. Two pictures were used for practice. One depicted the Italian actor Roberto Benigni jumping on his chair during the Oscar Award ceremony, and the other depicted three racecar drivers holding a trophy.

After practice, children completed 18 experimental trials randomly arranged for each participant. ASD children performed the task in the Sant' Alessandro Clinic in Rome, and children from the control group performed the task at school.

Data Analysis

A *Group* (Asperger, High Functioning Autism, TDC) × *Change Type* (CI, MI) × *Valence* (Negative, Neutral, Positive) mixed analysis of variance (ANOVA) was carried out on both change detection RTs and errors. To prevent any bias in faster responding in children showing a greater number of failures to detect the change, we replaced failed trials with the mean RT + 2 SD for that particular condition (see Maccari et al. 2012, for a similar method). Replacement was done in 85 trials (21 %) for children with ASD, and in 54 trials (14 %) for children in the TDC group, out of 396 (18 pictures × 22 participants) trials in total.

Since the preliminary analyses on both RTs and correct responses showed no differences between the Asperger and High Functioning participants (their performance was practically the same), we entered the factor *Group* into the statistical analyses with just two levels (ASD, TDC).

Results

Mean RTs (±*SD*) and mean errors are reported in Table 2.

Response Time

Children with ASD were faster to detect changes in the pictures than their TD peers (19,470 ms vs. 28,440 ms; $F_{1,42} = 12.32$; $p < .001$; $\eta^2 = .41$). All participants detected changes in CI objects faster than changes in MI objects (14,806 ms vs. 33,104 ms; $F_{1,42} = 97.78$; $p < .0001$; $\eta^2 = .70$). The main effect of *Valence* was also significant ($F_{2,84} = 18.12$; $p < .001$; $\eta^2 = .30$) showing faster RTs for neutral (17,371 ms) than for both negative (24,577 ms; $F_{1,42} = 21.53$; $p < .0001$; $\eta^2 = .34$) and positive (29,917 ms; $F_{1,42} = 25.80$; $p < .0001$; $\eta^2 = .86$) pictures. Also, RTs for positive pictures were significantly slower than RTs for negative pictures ($F_{1,42} = 6.18$; $p < .02$; $\eta^2 = .13$). However, differences due to the emotional valence of pictures were modulated by the type of change, as confirmed by the statistically significant *Valence* × *Change Type* interaction ($F_{2,84} = 17.53$; $p < .001$; $\eta^2 = .29$). The analysis of the interaction showed that significant differences were observed between changes in CI objects and changes in MI objects for both neutral ($F_{1,42} = 76.97$; $p < .0001$; $\eta^2 = .65$) and positive ($F_{1,42} = 58.13$; $p < .0001$; $\eta^2 = .58$) pictures, but not for negative pictures ($F_{1,42} = 2.63$; $p = .11$). An inspection to Fig. 2 reveals that in the case of positive pictures differences between the two types of changes were due mainly to larger RTs in detecting changes in MI objects, in comparison with

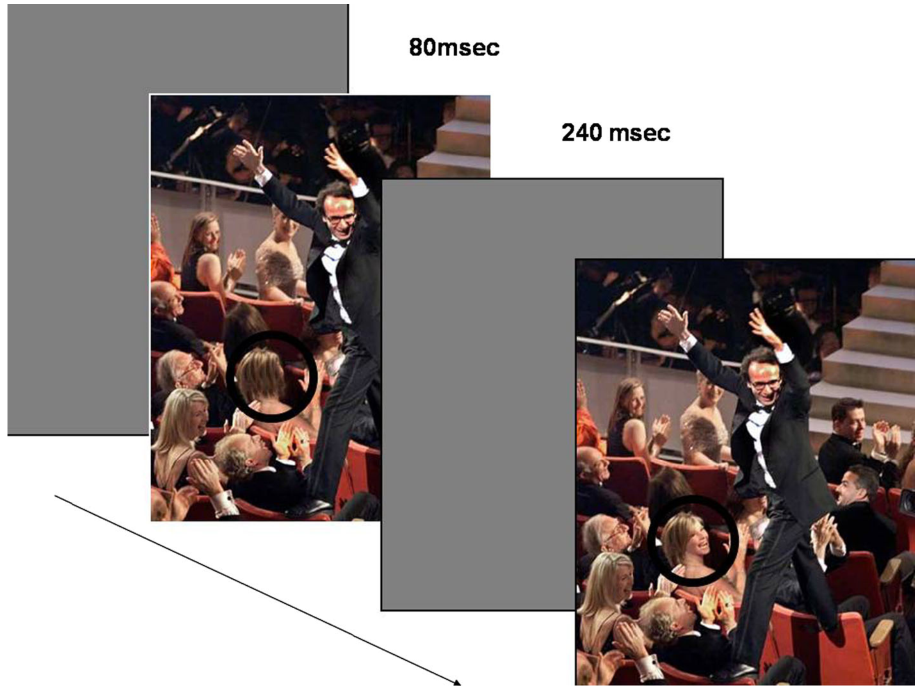

Fig. 1 Graphic representation of the experimental procedure. The cycle repeats until the participant detects the change

Table 2 Mean RTs, standard deviations (between parentheses), and mean number of errors, as a function of CI and MI changes in children with ASD and TDC

		NEG		NEU		POS	
		CI	MI	CI	MI	CI	MI
ASD	RT	19.022 (13.627)	16.942 (12.076)	6.438 (3.034)	21.174 (12.999)	12.531 (9.443)	40.711 (27.837)
	Errors	.68	1	.09	.59	.27	1.23
TDC	RT	25.510 (14.073)	36.834 (14.854)	7.956 (5.901)	33.915 (18.587)	17.380 (9.898)	49.048 (25.165)
	Errors	.45	.36	. 0	.59	.18	.86

NEG negative, *NEU* neutral, *POS* positive, *CI* central interest, *MI* marginal interest

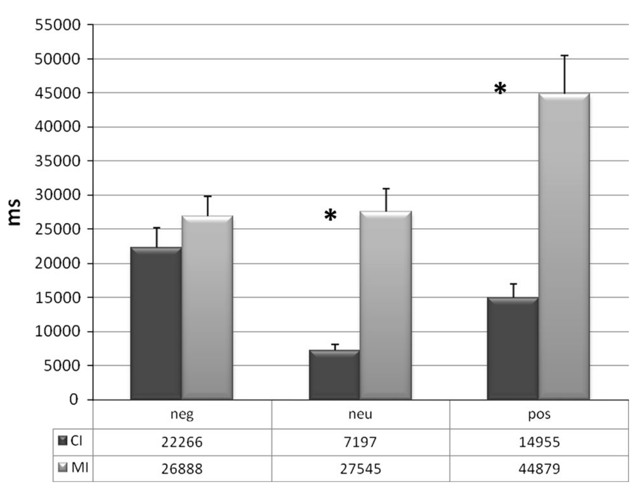

Fig. 2 Mean RTs in detecting changes in CI or MI objects embedded in negative, neutral or positive pictures. *Error bars* represent the standard error for each condition. *$p < .001$

both neutral ($F_{1,42} = 14.65$; $p < .001$; $\eta^2 = .26$) and negative ($F_{1,42} = 19.48$; $p < .0001$; $\eta^2 = .32$) pictures. In contrast, in the case of negative pictures the lack of differences between the two types of changes were due to larger RTs in detecting changes in CI objects in comparison with both neutral ($F_{1,42} = 47.05$; $p < .0001$; $\eta^2 = .53$) and positive ($F_{1,42} = 14.91$; $p < .001$; $\eta^2 = .26$) pictures. In other words, detecting changes in MI objects was mainly affected by positive pictures, whereas detecting changes in CI objects was mainly affected by negative pictures.

The *Group* × *Change Type* interaction was also significant ($F_{1,42} = 6.41$; $p < .02$; $\eta^2 = .13$). The differences between the two groups were only observed when detecting changes in MI objects, being ASD children faster than TCD children ($F_{1,42} = 12.26$; $p < .001$; $\eta^2 = .23$). The two groups did not differ when detecting changes in CI objects (see Fig. 3). No other interactions were found significant.

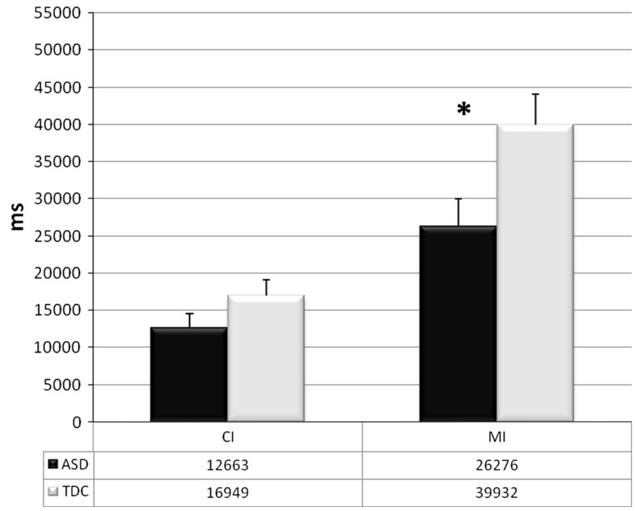

Fig. 3 Mean reaction times shown by Autism Spectrum Disorders' children (ASD) and TD children (TDC) in detecting changes in objects of CI or MI. *Error bars* represent the standard error for each condition. **p* < .001

Errors

A first analysis showed that in general the mean number of errors for the ASD group (21 %) was significantly larger than for the TD group (14 %) ($F_{1,42} = 4.83$; $p < .05$; $\eta^2 = .10$). Regarding analyses on mean number of errors, we observed significant main effects of *Group* ($F_{1,42} = 4.82$; $p < .04$; $\eta^2 = .10$), *Change Type* ($F_{1,42} = 36.29$; $p < .0001$; $\eta^2 = .46$), and *Valence* ($F_{2,84} = 10.19$; $p < .001$; $\eta^2 = .20$). Children with ASD made more errors than TD children (0.64 vs. 0.41). Consistent with the RT analysis, children were less accurate when detecting changes in MI than in CI objects (0.77 vs. 0.28). Number of errors was larger with emotional pictures than with neutral pictures (Mean negative = 0.62; Mean positive = 0.64; Mean neutral = 0.32; $F_{1,42} = 15.17$; $p < .001$; $\eta^2 = .27$ and $F_{1,42} = 17.51$; $p < .001$; $\eta^2 = .29$, respectively), but not significant differences were found between the two emotional pictures ($F < 1$). The *Valence* x *Change Type* interaction was significant ($F_{2,84} = 8.95$; $p < .001$; $\eta^2 = .18$). Children were more accurate when detecting changes in CI than in MI objects for both neutral ($F_{1,42} = 26.41$; $p < .0001$; $\eta^2 = .39$) and positive pictures ($F_{1,42} = 28.29$; $p < .0001$; $\eta^2 = .40$); but not for negative pictures ($F < 1$). The *Group* x *Valence* interaction was marginally significant ($F_{2,84} = 2.92$; $p = .059$; $\eta^2 = .07$, Fig. 4). Figure 4 reveals that children with ASD made more errors than TD children just for negative pictures ($F_{1,42} = 11.47$; $p < .005$; $\eta^2 = .21$); but they did not differ when pictures were either positive ($F_{1,42} = 1.82$; $p = .18$) or neutral ($F < 1$). None of the other interactions reached statistical significance (*ps* > .05).

Discussion

In the present study we used the flicker task to investigate the relationship between visual attention and emotional processing in children diagnosed with ASD. To accomplish that aim, we designed a version of the flicker task that allowed us to assess participants' ability to detect changes in objects embedded in pictures representing real-world scenes. Scenes might contain either emotion-related or non-emotion (neutral) information. As far as we know, change detection blindness with emotional laden stimuli has not been investigated yet in association with children diagnosed with ASD, and therefore the present research may contribute to further understand some basic cognitive mechanisms associated with the disease.

Regarding the flicker task, the present results replicated the main findings consistently observed with such task (Shore et al. 2006; Fletcher-Watson et al. 2009). All children showed a strong change blindness effect, and also clear differences in the efficiency to detect changes in CI and MI objects were observed. Detection of changes in CI objects occurred faster than changes in MI objects. This latter finding agrees with the assumption that changes in CI objects pop out from the picture, leading to automatic capture of attention. In contrast, slower detection in changes occurring in MI objects suggests that participants were using serial top-down visual search strategies (Rensink 2000). In the absence of a change in a CI object that rapidly attracts the observers' attention, a serial top-down search to detect a change in a MI object is then expected to occur. By implementing a serial search strategy, the observers actively explore new locations in the scene until a change is detected (Caplovitz et al. 2008). We assume that the search strategy is implemented in a top-down manner for at least two reasons: (a) It is goal directed, that is, it is aimed to search for changes outside the center-of-interest area of the scene; and (b) it is driven by implicit information about the portion of the scene previously explored (Wolfe et al. 2003). Once the general schema of the scene has been extracted, knowledge-based information can be used to help guide attention (Henderson 2003).

Importantly, the efficiency to automatically capture changes in CI objects was interfered with when negative pictures were presented, whereas the efficiency to search for changes in MI objects was interfered with when positive pictures were used. This pattern of emotion-related interference effects contrasts with that of emotion-related facilitation effects observed by Graham (2008). However, the differences in the stimuli used as well as the age of the participants might account for such different results.

Regarding the effects of negative scenes, the observed lack of any difference in detecting changes in CI and MI objects puts some limits to the generalization of Rensink

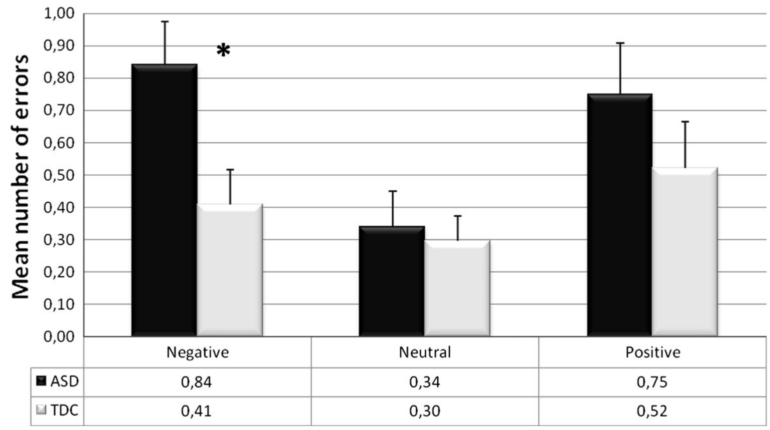

Fig. 4 Mean number of errors committed by Autism Spectrum Disorders' children (ASD) children and typically developing children (TDC) when searching for changes in negative, neutral or positive pictures. *Error bars* represent the standard error for each condition. $*p < .001$

et al.'s (1997) hypothesis. This result suggests that when pictures were negative, children failed to create a priority list that determined which items had to be attended first. In addition, the slower RTs in detecting changes in CI objects when the pictures were negative compared with when they were either neutral or positive may have been determined by the strong emotional impact of such pictures causing interference with the task, preventing to extend the visual search to the entire image. However, we can interpret also this result in light of the mobilization-minimization hypothesis (Taylor 1991). Such hypothesis argues that emotions evoke strong and rapid physiological, cognitive, emotional, and social responses (i.e., the mobilization of the organism). That rapid reaction is followed by physiological, cognitive, and behavioral responses that damp down, minimize, and even erase the impact of that event (i.e., the minimization phase). This pattern of mobilization-minimization appears to be greater for negative than for positive events. Accordingly, when responses associated to the negative and positive stimuli are compared throughout a timeline, responses associated to negative stimuli are greater than the associated to positive stimuli during the mobilization phase, but they are smaller later on, during the minimization phase. This temporal pattern fits well with the present results. Larger interference effects due to negative stimuli are observed firstly during the detection changes in CI objects. Then, larger interference effects due to positive stimuli are observed later on during the detection of changes in MI objects.

The flicker task has also proved to be useful to dissociate attention-based visual search performance in children with ASD from performance of TD children. Whereas children from the two groups did not differ in their ability to detect changes in CI objects, analysis of RTs showed that ASD children were faster in detecting changes in MI objects. Faster responses in children with ASD have been also reported in other tasks thought to tap focused attention abilities (Fletcher Watson et al. Fletcher-Watson et al. 2012; Maccari et al. 2012; Smith and Milne 2009), or requiring responding to conjunctive targets in visual search tasks (O'Riordan 2004; Plaisted et al. 1998). These results seem to support the "weak central coherence" hypothesis (Frith 1989), which suggests that ASD is characterized by a detailed-focused processing style (Happé and Frith 2006). However, two current findings led us to rule out such hypothesis. First, the ASD participants' advantage in speeded responses occurred at the expense of an increase in the number of errors, putting into question any superiority of ASD children, compared with TD children, in visual discrimination abilities (O'Riordan 2004; Remington et al. 2012), or in enhanced perception of stimulus features (Joseph et al. 2009). Second, both groups of participants showed similar CI/MI change detection ratios. This suggests that all children followed similar search strategies, which consisted in allocating their attention primarily to CI objects.

One main finding of the present research concerns the effect of emotion-laden information in the ability of ASD children to detect changes in the scenes. Although several studies have confirmed an emotional deficit in ASD children (Bachevalier et al. 2006; Begeer et al. 2006; Harms et al. 2010; Losh and Capps 2006), a key question is whether the deficit is associated with processing the social rather than the emotional features of the stimuli employed. Both features are difficult to uncouple and it might account for the mixed results that have been reported on the emotional deficits associated with ASD (Harms et al. 2010; Williams and Happé 2010). In reviewing the literature about emotion processing in people with a diagnosis of ASD, spared emotional processing has been observed: when nonsocial stimuli are used (South et al. 2008); in automatic imitation of emotional facial actions (Press et al. 2010); in physiological (skin conductance) responses to emotions (Shalom et al. 2006); in the recognition of emotional expressions (Castelli 2005; Tracy et al. 2011; Jones et al. 2011; Williams and Happé 2010); and in the effects of emotion on memory tasks (Maras et al. 2012). Results from the aforementioned studies cast some doubts on the existence of an emotional deficit associated with ASD. However, emotional processing deficits in ASD are evident when faces are used as social stimuli (Batty et al. 2011; Kennedy and Adolphs 2012; Tottenham et al. 2013; Whalen 2013). For instance, Heerey et al. (2003) found that ASD children are significantly less able than controls to identify expressions of embarrassment and shame, but they did not differ when participants had to recognize nonsocial emotions. Adolphs et al. (2001) reported that individuals with autism could recognize basic emotions, but failed to recognize more complex stimuli, as when required to judge trustworthiness and approachability of people from their faces.

Taken together, all the above results suggest that people diagnosed with ASD show intact responses to non-social information (South et al. 2008), recognition of basic emotions (Adolphs et al. 2002), or recognition of emotional expressions that have evolved with adaptive functions (Castelli 2005). However, they have deficits in recognition of social emotions, when emotional information conveys social connotations, or in linking the perceptual level of emotional recognition with the higher level of understanding the social meaning of different expressions (Castelli 2005). Thus, ASD is better characterized by an emotion-processing profile, resulting from heterogeneous vulnerabilities in different components of the emotional communication system. A specific pattern of emotion processing weakness unique to ASD involves difficulties with processing social versus non-social stimuli and complex versus simple emotional information, with impairments more consistently reported on implicit than explicit emotion processing tasks (Nuske et al. 2013).

Our results with RTs did not show any interaction between emotional valence of the scenes and group of participants. This suggests a rather preserved ability to process visual emotional stimuli in children with ASD when RTs are considered. It might be due to the fact that we used nonsocial stimuli (note that only a few scenes contained faces). However, when accuracy is considered, we observed that negative pictures produced interference in the performance of children with ASD, leading them to make more errors. This is consistent with previous studies that have reported a difficulty of ASD individuals in processing negative emotions (Ashwin et al. 2006; Bacon et al. 1998; Sigman et al. 1992). This finding is further supported by some neuroanatomical studies that have showed amygdala abnormalities in autism (Nacewicz et al. 2006; Pelphrey et al. 2004; Schultz 2005; Shumann and Amaral 2006; Schumann et al. 2009). Such amygdala abnormalities might contribute to an impaired ability to link socially relevant visual information with the related social knowledge and behavior (Adolphs et al. 2001), and might also account for the poorer performance of children with ASD in the current visual search task when trying to detect changes in emotionally negative scenes.

Limitations and Future Directions

A limitation of the present study concerns the grouping of participants diagnosed with Asperger syndrome (AS) and those diagnosed with high functional autism (HFA). Although our preliminary analyses support the notion of an undifferentiated cognitive profile (Noterdaeme et al. 2010), AS and HFA individuals may differ in both visual search abilities and emotion perception. Some studies have found important differences in dimensions such as language development, social functioning, and symptom presentation, suggesting that these disorders may have distinct neurobiological underpinnings (e.g., Ghaziuddin and Gerstein 1996; Tonge et al. 1999; Ziatas et al. 1998). Comparisons in visual search performance should include other disorders that occur co-morbidly with ASD, such as social anxiety disorder and attention-deficit/hyperactivity disorder (Simonoff et al. 2008). Finally, future research should include both social and non-social emotional stimuli in the flicker task, which will be help to further clarify and strengthen the current findings.

Conclusions

By assessing how children with ASD explore emotional scenes, we aimed to study the relationships between visual search and emotion in such individuals. We found that ASD children are faster than TD children, specifically when detecting changes in MI objects, the most difficult condition. This result is in line with other related studies that showed better performance of ASD people in conjunctive visual search tasks, confirming their superior visual discrimination abilities and a detailed-focused processing style. Emotion laden pictures equally interfered with performance of both ASD and TDC groups when RTs were analysed. However children with ASD were less accurate than children from the control group just when they explored negative pictures to detect changes. These results suggest that the well-known emotional–social impairment of ASD could be specific to negative emotional processing. Further studies will be needed in order to further clarify the role of socio-emotional information in the visual search deficits associated with ASDs.

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