Dysfunctional perceptual antecedent can justify the social orienting deficit in autism spectrum disorder: an eye-tracking study

Cristina Carrozza and Rosa Angela Fabio

Abstract
Purpose – Children with Autism Spectrum Disorder (ASD) show reduced attention to social stimuli. The reasons for these impairments are still being debated by researchers. The aim of this study is to analyse if reduced attention towards social stimuli is determined by initial underlying difficulties in the control of visual attention. Among the variables that could produce these difficulties, the authors considered geometric complexity and typology of geometric figures.
Design/methodology/approach – To test this hypothesis, in this paper, an eye-tracker paradigm was used for assessing visual exploration and recognition memory towards geometric figures (curved vs rectilinear) with two levels of geometric complexity (low and high) in 17 children with ASD matched with 17 children with typical development (TD).
Findings – The results showed that the ASD group seemed indifferent to both the geometric complexity and the typology of figures (curved and rectilinear), whereas the TD group showed higher performances with highly complex and curved geometric figures than with low complex and rectilinear geometric figures.
Research limitations/implications – Because of the chosen research approach, the research results may lack generalizability. Therefore, researchers are encouraged to test the proposed hypotheses further.
Practical implications – This paper includes implications upon the presence of an unspecified visual attention deficit that is present from the early stages of the processing of stimuli.
Social implications – The understanding of this deficit from the early stages of the processing of stimuli can help educators to intervene at an early stage when disturbances in social relationships are starting.
Originality/value – This study contributes to understanding the presence of dysfunctional perceptual antecedents that could determine general difficulties in paying attention to social stimuli in ASD subjects.
Keywords Visual attention deficit, Shape stimuli, Autism, Complex stimuli, Deficit to social stimuli
Paper type Research paper

Introduction
The ability to select information with sense organs is the basis of human knowledge. Through inputs from the surrounding environment, the individual acquires information regarding reality that is indispensable to interact with it and build more elaborate forms of knowledge, such as thoughts and memories (Parker and Gibson, 1979). As attention is a key component for complex cognitive operations, a deficit in this function could hinder the development of higher order cognitive and social skills. This difficulty of paying attention to stimuli, especially social stimuli (faces), is present, for example, in subjects with Autism Spectrum Disorder (ASD) (American Psychiatric Association [APA], 2013; Mukherjee et al., 2018). ASD is a complex neurodevelopmental condition characterized by socio-communicative impairments and restricted and repetitive patterns of behaviors and interests (APA, 2013).
Researchers are still debating the reasons for this reduced attention. It is possible that subjects with ASD pay less attention to social stimuli because these are not “interesting and motivating” (Chevallier et al., 2015; Martin et al., 2019) or because these are not a priority in their attention system (Chawarska et al., 2010). Moreover, the difficulty of focusing on social stimuli (Chawarska et al., 2012, 2013; Fabio et al., 2018a, 2018b; Fabio, 2017; Fabio et al., 2011; Lim, 2019; Shic et al., 2011) is likely to be the direct result of greater emphasis on non-social stimuli, including objects related to circumscribed interests and geometric (Sasson and Touchstone, 2014; Pierce et al., 2011; Pierce et al., 2015; Shi et al., 2015; Shaffer et al., 2017). Despite these results, other studies have also shown that basic deficits in ASD can be attributed to general difficulties in the control of visual attention (Bryson et al., 2004; Landry and Bryson, 2004; Elsabbagh and Johnson, 2007; Elsabbagh et al., 2013; Mohammadhasani et al., 2018, 2019; Sacrey et al., 2013).

In this study, the theory explaining the difficulties of visual exploration in ASD is related to the presence of an attention visual impairment that is present from the early stages of visual input processing (Bryson et al., 2004; Landry and Bryson, 2004; Elsabbagh and Johnson, 2007; Elsabbagh et al., 2013; Sacrey et al., 2013). According to this theory, attention difficulties in subjects with ASD and in other pathologies as the subject with attention deficit hyperactivity disorder are not caused by differences in visual exploration of social stimuli but by initial general difficulties in the control of visual attention (Bryson et al., 2004; Castelli et al., 2013; Elsabbagh et al., 2013; Landry and Bryson, 2004; Fabio and Caprì, 2015, 2017; Fabio et al., 2015; Gangemi et al., 2018; Sacrey et al., 2013). More precisely, some specific, dysfunctional perceptual antecedents might determine these difficulties (Carrozza et al., 2019).

Furthermore, as social stimuli (face – facial configurations) are similar in shape to curved figures (e.g. circle, oval), we considered geometric complexity and typology of geometric figures (curved vs rectilinear) among the variables that could cause these difficulties, in this study.

Several studies have found that children with ASD, compared to children with typical development (TD), display early difference in the perception of geometric stimuli (Pierce et al., 2011; Pierce et al., 2015; Shi et al., 2015; Shaffer et al., 2017). Studies have also found that ASD children, compared to TD children, show the following:

- longer fixation time (FT) for geometric stimuli rather than social stimuli (Pierce et al., 2011; Pierce et al., 2015);
- a preference for geometric stimuli that is present at an early age (starting from the first year) (Chien et al., 2015; Fabio and Urso, 2014; Pierce et al., 2011; Pierce et al., 2015; Shaffer et al., 2017); and

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Demographic and clinical characteristics of the sample</th>
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<tbody>
<tr>
<td></td>
<td>ASD (N = 17)</td>
</tr>
<tr>
<td>Age (months)</td>
<td>63.35 (11.45)</td>
</tr>
<tr>
<td>Gender (M:F)</td>
<td>12:5</td>
</tr>
<tr>
<td>DQ (GDMS)</td>
<td>52.88 (10.70)</td>
</tr>
<tr>
<td>Language DQ</td>
<td>57.47 (11.23)</td>
</tr>
<tr>
<td>Manual eyepiece DQ</td>
<td>56.76 (13.82)</td>
</tr>
<tr>
<td>Performance DQ</td>
<td>60.64 (15.34)</td>
</tr>
<tr>
<td>Practical reasoning DQ</td>
<td>37.05 (14.86)</td>
</tr>
<tr>
<td>ADOS – 2 Total</td>
<td>14.6 (5.0)</td>
</tr>
</tbody>
</table>

PAGE 290 ADVANCES IN AUTISM VOL. 6 NO. 4 2020
difficulty in memory of complex geometric stimuli compared to simple stimuli (Minshew and Goldstein, 2001; Pallett and MacLeod, 2011).

In contrast to these results, Shi et al. (2015) have shown that the stimuli used by Pierce et al. (Pierce et al., 2011; Pierce et al., 2015) with subjects of 2–3 years were not adequate with subjects at a later age (4–6 years). To confirm this hypothesis, they presented the stimuli used by Pierce et al. (2011, 2015) to a sample of preschool children. From this study, no statistically significant differences were found between the ASD group and the TD group. Instead, when the same group of subjects (preschool children) were exposed to more complex social stimuli (children engaged in interacting and playing with each other), they showed reduced attention to more complex social stimuli and greater attention to non-social dynamic stimuli (geometric patterns and letters) (Shi et al., 2015).

Regarding the typology of geometric stimuli (curved or rectilinear), few studies have investigated the impact of type of geometric stimuli on subjects with ASD and their effects on some processes such as judgments, decisions and preferences. For example, McPartland et al. (2011) investigated patterns of visual attention to different types of stimuli (faces, three-dimensional objects and geometric figures) in an ASD group of adolescents. The results showed that ASD subjects, compared to TD subjects, looked more closely at the top region of the stimuli irrespective of the category of belonging (social vs non-social) (McPartland et al., 2011). Recently, Chien et al. (2015) have found that ASD subjects, compared to TD subjects, showed attention and mnemonic difficulties with complex geometric stimuli (Chien et al., 2015). A year later, Belin et al. (2017) investigated the effects of simple geometric stimuli (curved and rectilinear) on attention responses of school-aged children with ASD and with TD (Belin et al., 2017). The results showed that TD children, as widely demonstrated in literature, explored curved geometric shapes more, also by attributing positive emotional connotations to these shapes (Salgado-Montejo et al., 2015; Bertamini et al., 2016; Velasco et al., 2016). Instead, subjects with ASD observed rectilinear geometric shapes longer and perceived them “positively”. In addition, it was found that when group participants with ASD looked at curved stimuli, they attributed a social value to them (probably because they are similar in shape to facial configurations; face = oval) (Belin et al., 2017; Cotter et al., 2017).

Summarizing the above, there are several differences between the ASD and TD groups. In effect, from the first months of life, children with TD show a preference for curved and rounded lines and figures rather than straight or rectilinear ones (Westerman et al., 2012; Van Oel and Van Den Berkhof, 2013; Vartanian et al., 2013; Palumbo et al., 2015; Salgado-Montejo et al., 2015; Bertamini et al., 2016; Gómez-Puerto et al., 2016; Palumbo and Bertamini, 2016; Velasco et al., 2016; Cotter et al., 2017). Preference for curved features in children with TD is because of a sort of natural coupling between perceptual features and sensorimotor processes that are attuned to curved configurations.

In a current review, Gómez-Puerto et al. (2016) defined a general framework that explained the preference for curvature considering four explanatory mechanisms: eye movement, specific neural activity, gestalt principles and an appraisal approach (Gallese, 2016; Gómez-Puerto et al., 2016; Belin et al., 2017; Cotter et al., 2017).

With reference to the first mechanism, children preferred curved lines because they allow them to preserve cognitive load, and also because curved lines are related to the ease of eye motion (Gómez-Puerto et al., 2016). Also, some movements are preferred, as they generated fluency and comfort (Gómez-Puerto et al., 2016).

In terms of neurophysiology of the visual system, Fantz and Miranda (1975) showed that, in the early days of life, neonates focused longer on curved stimuli than on rectilinear stimuli (Fantz and Miranda, 1975; cit in Gómez-Puerto et al., 2016). They hypothesized that this early preference is because of cortical cell activity which increases on seeing curved lines (Hubel and Wiesel, 1968; cited in Gómez-Puerto et al., 2016).
Regarding Gestalt principles, a curve can be considered a set of strongly grouped points (Tonder and Spehar, 2013). Some studies reported that preference for curvature is likely caused by intrinsic characteristics of the lines, which can be described as cases of good continuation or good gestalt (Gómez-Puerto et al., 2016). According to Belin et al. (2017) and Cotter et al. (2017) individuals associate curved lines in positive terms, such as quiet, lazy, graceful and playful, whereas rectilinear lines/shapes are considered agitating, hard or furious.

However, pleasure and interest are distinct responses and many pleasant things are not always interesting to individuals (Graf and Landwehr, 2015). Some studies show that people respond differently to certain low-level stimulus features such as familiarity and complexity. As to the complexity of geometric stimuli, this feature has long been discussed in literature (Nadal et al., 2010; Bertamini et al., 2016). Nadal et al. (2010) suggest that there are three different forms of complexity that contribute to people’s perception of visual complexity:

1. the amount and variety of elements;
2. the way those elements are organized; and
3. asymmetry (Nadal et al., 2010).

In a recent study, Bertamini et al. (2016) calculated the complexity of some geometric shapes with regard to two parameters: articulation (considered as a set of points in a plan, so that the product of the distances is constant) and shape (curved vs rectilinear). From the results of the study, it emerged that in general people preferred geometric curved shapes to rectilinear ones. With reference to complexity, rectilinear geometric shapes were considered more complex than curved ones. According to researchers, these results are due to different articulation and an “ambiguous” orientation of rectilinear lines. The lack of clear orientation influenced the perception of the complexity of the forms (Bertamini et al., 2016).

According to other research, the complexity of stimuli also affects the memory of these stimuli (Huhmann, 2003; Pallett and MacLeod, 2011; Hyde et al., 2016). Specifically, some studies have found that school-aged children are able to remember more simple stimuli than complex ones (Huhmann, 2003). This result is not in agreement with evidence that has emerged in other studies, where it was found that undergraduates tend to remember more complex stimuli (Pallett and MacLeod, 2011). These controversial results depend on the different age of subjects in the studies and on the different stimuli (Huhmann, 2003; Pallett and MacLeod, 2011; Hyde et al., 2016).

Based on literature, the main aim of this study was to understand if visual impairments regarding social stimuli in ASD subjects derive from an attention deficit that is present in the early stages of stimuli processing. Among the variables that could lead to the attention deficit towards social stimuli, this study considered geometric complexity (high vs low) and typology of geometric figures (curved vs rectilinear). Thus, the specific goal of this paper was to assess whether geometric complexity associated with typology of geometric figures influenced the attention deficit towards social stimuli. In addition, considering the influence that this visual attention deficit may have on the development of some cognitive processes (for example learning and memory), this study also investigated the recognition memory of this specific category of stimuli.

The underlying logic of this work is as follows:

- If the time of visual exploration and number of recognitions of children with ASD were affected both in figures with low geometric complexity and with high geometric complexity, this may be due to the presence of a non-specific attention visual deficit from the early stages of processing of stimuli (pre-attention phase).
If children with ASD looked at and memorized figures with a low geometric complexity (irrespective of typology) better than those of high geometric complexity, then the contributing factor may be the level of complexity (geometric).

Finally, if there was a difference in visual exploration and in memory of recognition between curved and rectangular figures, irrespective of complexity (high vs low), this would mean that the underlying factor is not the complexity, but the specific deficiency of visual exploration towards curved figures (similar in form to facial configurations).

Methods

Participants

The ASD group was comprised of 17 children (12 males and 5 females) between 36 to 72 months (M = 63.35, SD = 11.45). They were enrolled through the Institute of Applied Sciences and Intelligent Systems (ISASI) – National Research Council of Italy (CNR) – Messina and Provincial Health Service (ASP), Catania, Italy.

ASD diagnosis was made according to DSM-V criteria (APA, 2013) by an experienced multidisciplinary team including two child psychiatrists and two developmental psychologists.

The Autism Diagnostic Observation Schedule - 2 edition (ADOS-2; Lord et al., 2012) was used as part of the diagnostic process.

Developmental quotient was assessed using the Griffiths Mental Development Scales (GMDS) (Griffith et al., 2006). The ASD group (M = 63.35, SD = 11.45) was individually matched for gender and verbal developmental quotients (DQ) with a control group of 17 infants (M = 12, F = 5; M = 53.41; SD = 12.44) with TD. These children were recruited from private schools in Messina and Catania. The same team of experts observed also TD children and found that none of them presented any neurological or psychiatric disorders nor had a first-degree family member with a developmental, learning or neurological disorder. None of these children were on medication. Participant characteristics are summarized in Table 1.

The study protocol was approved by the Ethics Committee of the Department of the University. All participants’ parents gave written informed consent.

Apparatus

Infrared eye-tracking recording was performed using SMI Eye Tracking device provided by SensoMotoric Instruments (Teltow, Germany). The SMI system measures the gaze direction of each eye and from these measurements it can be evaluated where on the screen the subject is looking. This system recorded the data of both eyes from the reflection of an infrared light source on the cornea and pupil (Billeci et al., 2016).

During the task, children were seated in a chair, approximately 50–55 cm from a 22-inch flat screen monitor with a remote camera. Distance from the screen and inclination angle of the system were adjusted for each child to obtain good tracking of the eyes. Before starting the experimental task, a five-point calibration sequence run, with recording only, started when at least four points were marked as properly calibrated for each eye. To obtain calibration information, children were first shown a coloured ball that appeared in one of five locations on the screen. If calibration quality was poor or fair for any of these points, the process was repeated three times for each subject. Gaze date were recorded with a sample rate of 120 Hz and accuracy better than 1 degree of visual angle. After the calibration sequence, four arrays were presented on the monitor (Figures 1 and 2). Only during the presentation of the first array, did the experimenter gave the subject the following instruction: “Please, carefully observe the figures on the screen: circle, triangle, oval, and rhombus. Then I’ll ask you what you’ve seen before”. After each slide, a black cross was presented in the centre.
of the screen to ensure that the children’s gaze was directed to the centre. Each array presentation lasted 10,000 ms. Subsequently, the four recognition memory tasks were presented in sequence. Only during the presentation of the first task did the experimenter ask the subject: “Which of these images have you already seen?” (The child could use two types of response: pointing to the stimulus or labelling it.) The correct answer was scored 1; the wrong one, 0. The duration of these tasks depended on the time taken by the subject to provide the answer. When children did not respond, the task timed out after 10 seconds.

**Eye tracking measures**

For the geometric figures of arrays, Fixation Time (FT) was evaluated, that is the sum of the fixation durations inside the area of interest (AOI). On the other hand, for the stimuli of recognition memory tasks, the sum of the correct recognized items (for each: 0 = wrong, 1 = correct) was considered.

**Stimuli**

In this study, a task was created with reference to the studies by Bertamini et al. (2016) and Belin et al. (2017). Specifically, with regard to the variable typology of stimuli, in particular...
the category of curved stimuli, we used curved stimuli presented in the study by Bertamini et al. (2016). Unlike in that study, the eye-tracker paradigm was used (Falck-Ytter et al., 2013; Guillon et al., 2014; Chita-Tegmark, 2016) to locate and characterize the subtle variations in visual attention of subjects with ASD to the stimuli presented. In addition, to evaluate the different responses of the two groups (ASD vs. TD) compared to the two typologies of stimuli (curved vs. rectilinear), rectilinear stimuli were also included in this study (Belin et al., 2017). In relation to the geometric complexity parameter (high vs. low), all the studies that conceptualized geometric complexity in terms of quantity of intrinsic elements, orientation, position, articulation and size of geometric (curved and rectilinear) figure were considered (Zhao and Stough, 2005; Wang et al., 2008; Plemenos and Miaoulis, 2009; Nadal et al., 2010; Bertamini et al., 2016). According to these researchers, the level of geometric complexity (high vs. low) depends on the number of visible elements, the area of each element, and the distance and orientation of each element (Zhao and Stough, 2005; Wang et al., 2008; Plemenos and Miaoulis, 2009; Nadal et al., 2010; Bertamini et al., 2016).

In accordance with these studies, in a first phase, eight geometric figures with low complexity (4 rectilinear figures: square, triangle, rhombus and rectangle; 4 curved figures: circle, oval, infinite and cornet) were produced. Subsequently, to create the same figures with high complexity, denseness/area were added to the eight geometric shapes (Anobile et al., 2015; Anobile et al., 2016; Cicchini et al., 2016), each of them having the same small size (Tables 2 and 3). The geometric figures ($n = 16$) were inserted into randomly assigned arrays ($n = 4$) (Figure 1). The array submission order was randomized and counterbalanced for all participants in the study.

Additionally, for the recognition memory, four recognition memory tasks were entered after each array. Each task contained a target stimulus and a distracting stimulus.

The task (calibration, arrays, fixing points and recognition memory tasks) had an average duration of approximately 4 minutes.

In order to extrapolate gaze data of each subject, rectangular AOIs were defined in the array (5 AOIs: 4 for the figures and 1 for background), in the fixing point (1 AOI) and in the recognition memory tasks (2 AOIs: 1 for the figure and 1 for distractor). The AOIs were the same size.

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>ASD Means (SD)</th>
<th>TD Means (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low complexity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Square</td>
<td>1.52 (2.09)</td>
<td>2.23 (1.67)</td>
</tr>
<tr>
<td>Triangle</td>
<td>1.23 (1.82)</td>
<td>3.29 (2.88)</td>
</tr>
<tr>
<td>Rectangle</td>
<td>0.76 (1.09)</td>
<td>2.35 (1.90)</td>
</tr>
<tr>
<td>Rhombus</td>
<td>2.17 (2.48)</td>
<td>3.52 (3.16)</td>
</tr>
<tr>
<td>Circle</td>
<td>1.11 (1.21)</td>
<td>2.17 (1.77)</td>
</tr>
<tr>
<td>Oval</td>
<td>0.76 (1.09)</td>
<td>2.76 (2.38)</td>
</tr>
<tr>
<td>Cornet</td>
<td>1.64 (2.05)</td>
<td>2.94 (2.46)</td>
</tr>
<tr>
<td>Infinity</td>
<td>1.00 (1.62)</td>
<td>2.82 (2.57)</td>
</tr>
<tr>
<td><strong>High complexity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Square</td>
<td>1.29 (1.49)</td>
<td>1.76 (2.27)</td>
</tr>
<tr>
<td>Triangle</td>
<td>1.70 (2.02)</td>
<td>2.94 (2.01)</td>
</tr>
<tr>
<td>Rectangle</td>
<td>1.29 (1.57)</td>
<td>3.29 (2.61)</td>
</tr>
<tr>
<td>Rhombus</td>
<td>1.82 (2.62)</td>
<td>2.88 (2.91)</td>
</tr>
<tr>
<td>Circle</td>
<td>2.29 (3.31)</td>
<td>4.17 (3.02)</td>
</tr>
<tr>
<td>Oval</td>
<td>2.17 (2.50)</td>
<td>2.00 (1.45)</td>
</tr>
<tr>
<td>Cornet</td>
<td>1.88 (1.83)</td>
<td>6.11 (3.31)</td>
</tr>
<tr>
<td>Infinity</td>
<td>1.88 (1.83)</td>
<td>6.11 (3.31)</td>
</tr>
</tbody>
</table>
Statistical analyses

Data were analysed using SPSS Version 24.0 for MacOS. Descriptive statistics on the characteristics of the experimental sample were presented separately for subjects with ASD and subjects with TD. Comparisons between the two groups were performed using independent samples t-tests. The descriptive statistics of the two groups show that there are significant differences only with respect to chronological age, $t(33) = 2.37, p < .02$, while for the quartile spread (QS) no statistically significant effects occur.

Regarding the analysis of parameters extracted from the eye-tracking, the following tests were used: repeated measures analysis of variance and t-tests for paired samples. The data were analysed considering two parameters: visual exploration (FT) and recognition memory (sum of correct response) of both groups (ASD and TD). Alpha level was set to 0.05 for all statistical tests. For all statistical tests, in cases of significant effects, the effect size of the test was reported.

Results

The results are presented firstly in relation to visual exploration parameters and after in relation to recognition memory. Before analyzing these two parameters, the FT of the four matrices of both groups was evaluated. An analysis of variance was performed: 2 (Groups: ASD vs TD) $\times$ 2 (Geometric Complexity: High vs Low) $\times$ 2 (Typology of Figures: Curved vs Rectilinear). Based on the results, it was found that the order of the arrays factor has no significant effects. These data indicated that each of the four matrices was explored for the same time by both groups.

Visual exploration

With respect to the first parameter (FT), repeated measures analysis of variance with a between subject factor and two within subject factors was performed: 2 (Groups: ASD vs TD) $\times$ 2 (Geometric Complexity: High vs Low) $\times$ 2 (Typology of Figures: Curved vs Rectilinear). The Group factor showed significant effects, $F(1, 32) = 12.93, p < 0.001$, $\eta^2_p = 0.92$. This indicated that subjects with ASD, compared to subjects with TD, fixated figures within the arrays for less time. The variable Geometric Complexity also had significant effects, $F(1, 32) = 12.92, p < 0.001$, $\eta^2_p = 0.91$. This indicated that when geometric complexity was high, both groups tended to fixate the stimuli for longer time than when geometric complexity was low (Table 2).

Regarding Typology of Figure (curved and rectilinear), statistically significant differences were found, $F(1, 32) = 9.92, p < 0.001$, $\eta^2_p = 0.91$. The interaction Group $\times$ Typology of Figures also showed significant effects, $F(1, 32) = 3.71, p < 0.005$, $\eta^2_p = 0.92$. This indicated that subjects with ASD fixed both types of shapes for the same time; instead, subjects with TD looked at curved forms for a longer time than rectilinear ones. The interaction Groups $\times$ Complexity $\times$ Typology of Figures showed significant effect, $F(1, 32) = 2.27, p < 0.05$, $\eta^2_p = 0.68$. When geometric complexity increased, subjects with
ASD, compared to subjects with TD, reduced fixations towards curved stimuli (see Figure 3).

**Recognition memory**

Regarding recognition memory, a repeated measures analysis of variance was performed: 2 (Groups: ASD vs TD) × 2 (Geometric Complexity: High vs Low) × 2 (Typology of Figures: Curved vs Rectilinear). The parameters considered were: FT towards the target stimulus and the distracting stimulus and Correctness of responses.

With reference to the first parameter (FT), no statistically significant differences were observed in either group.

Instead, in relation to the second parameter (Correctness of the answers), the variable ‘Group’ showed significant effects, $F(1, 32) = 3.08$, $p < 0.005$, $\eta^2_p = 0.83$. This indicated that subjects with ASD, compared to subjects with TD, generally tended to remember the forms seen earlier to a lesser extent. This result was consistent with that of visual exploration. Specifically, subjects with ASD explored and recalled less rectilinear and curved shapes than the TD group (Table 3). Finally, recognition did not seem to be influenced by the other variables considered.

**Discussion**

The aim of this paper is to understand whether the visual impairment of visual exploration towards social stimuli (faces) in the development of ASD symptoms derives from an attention deficit present from the early stages of processing of stimuli. Among the variables that could cause the attention deficit to social and non-social stimuli, geometric complexity and typology of geometric shapes (curved vs. rectilinear) were evaluated in this study. The basic idea is to investigate whether the perception of geometric complexity linked to curved and rectilinear (simple and complex) figures influences the deficit towards social stimuli in subjects with ASD.

The data were analysed considering two parameters: visual exploration and recognition memory.

Visual exploration results indicate that both variables considered (geometric complexity and typology of geometric figures) were statistically significant. Specifically, as far as the...
typology of figures are concerned, the data confirm what emerged in literature, namely that subjects with TD compared to subjects with ASD look more at curved than at rectilinear lines and figures (Westerman et al., 2012; Van Oel and Van Den Berkhof, 2013; Vartanian et al., 2013; Palumbo, Ruta and Bertamini, 2015; Salgado-Montejo et al., 2015; Bertamini et al., 2016; Gómez-Puerto et al., 2016; Palumbo and Bertamini, 2016; Velasco et al., 2016; Cotter et al., 2017). In relation to the complexity variable, the results showed that subjects with ASD seem indifferent to the complexity or to the typology of figures (curved or rectilinear) (Chien et al., 2015; Belin et al., 2017).

Regarding recognition memory, the results show that subjects with ASD, compared to subjects with TD, generally tend to recall previously seen rectilinear and curved shapes to a lesser extent. These data were consistent with visual exploration results. Thus, subjects with ASD did not explore or remember rectilinear and curved shapes as well as the TD group.

With reference to the hypotheses expressed in the introduction, results confirmed the three points analysed (a, b, c). Subjects with ASD a) generally had low indexes of visual exploration on all stimuli; b) they seem indifferent to both geometric complexity c) and to type of figures (curved and rectilinear). Since all the variables considered reflect an inclusive, rather than exclusive, model of deficit, it is possible to hypothesize the presence of an unspecified visual attention deficit from the early stages of processing of stimuli (c).

Following from the above, these results could be interpreted as perceptual functional antecedents that can explain the visual exploration deficit to social stimuli. Specifically, if subjects with ASD do not pay attention to curve and complex figures, this could explain their difficulty in paying attention to faces that are in themselves curved and complex stimuli.

Despite the fact that functional perceptions of the lack of orientation towards social stimuli in subjects with ASD have been investigated, the limit of the present work is the use of “abstract stimuli” (geometric figures). Therefore, future research should focus on the following aspects: a) evaluation of visual exploration and recognition memory of more ecological and naturalistic simple and complex stimuli; b) the study of simple and complex stimuli from other sensory domains (e.g. auditory) and finally c) analysis of complexity in wider samples and with subjects from different age groups (toddler, school-aged children, adolescent and adult). Because of the chosen research approach, another limitation of this research is the lack generalizability of the results. Therefore, researchers are encouraged to further test the proposed hypotheses in the future.

Conclusion

This study contributes to understanding the presence of dysfunctional perceptual antecedents that could determine general difficulties in paying attention to social stimuli in ASD subjects. Understanding this deficit from the early stages of the processing of stimuli in children with ASD has important implications for clinical and therapeutic aspects. With regard to the clinical aspect, this knowledge on how children with ASD in early stages explore some stimuli (social stimuli) allows to investigate and study specific difficulties in the control of visual attention and the consequences that these difficulties might have on important cognitive development (such as learning and memory). Moreover, from a therapeutic point of view, this knowledge could have important consequences for the timeliness of the intervention (early, intensive intervention allows to exploit the brain plasticity which is typical of the first three years of life) and for the setting of therapeutic work (such as typology of intervention, areas to be strengthened and which methodology to use based on the difficulties and the functioning capacity of the subject).

The manuscript received ethics approval and consent to participate. The datasets during and/or analysed during the current study available from the corresponding author on
reasonable request. The authors declare that they have no competing interests. The author received no funding.

CC was a major contributor in writing the manuscript, RAF analysed, interpreted and wrote all the results. Both authors read and approved the final manuscript.

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Further reading


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