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Nagy, Emese; Paton, Stacey C.; Primrose, Fiona E. A.; Farkas, Tibor; Pow, Coreen F.

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Authors:

Emese Nagy*, Stacey C. Paton, Fiona E.A. Primrose, Tibor N. Farkas, Coreen F. Pow

Affiliation:

Psychology, The University of Dundee

*Corresponding Author:

Emese Nagy, M.D., Ph.D.

Psychology, The University of Dundee

E-mail: E.Nagy@dundee.ac.uk

Phone: 00-44-1382384613

FAX: 00-44-1382-229993

Running head: Speeded, intact recognition of emotions in autism

Abstract

Autism Spectrum Disorders (ASD) involve difficulties with socio-emotional functioning; however, research on emotion recognition remains inconclusive. Children with ASD have been reported to show less susceptibility to spatial inversion. The aim of this study is to examine whether children with ASD utilize atypical abilities in socio-emotional processing.

The present study tested 13 children with ASD (1 female, M: 15.10 yrs, SD: 1.60 yrs), 13 children without ASD (4 females, M: 15.92 yrs, SD: 1.03 yrs) and 20 control adults (11 females, M: 24.77 yrs, SD: 8.30 yrs) to investigate the speed and accuracy of their responses to images of neutral faces and faces expressing 'easy' (happiness, anger) and 'difficult' emotions (surprise, fear) in non-rotated (0°) and rotated (30°, 90°, 150°, 180°, 210°, 270° and 330°) positions.

The results showed that children with ASD recognized both easy and difficult emotions as accurately as did children and adults without ASD. Children with ASD, however, responded significantly faster to difficult emotions when the images were rotated.

These results offer less support for a deficiency model than for an atypical, rapid featural type of processing used by children with ASD to encode and understand complex socio-emotional stimuli.

Keywords: emotion perception, emotion recognition, autism, mental rotation, emotional facial expressions

Introduction

Autism Spectrum Disorders (ASD) are neurodevelopmental disorders, and the diagnostic criteria include difficulties with social communication and interaction, including difficulties with social-emotional reciprocity, nonverbal communication and the development and maintenance of interpersonal relationships. The second symptom group required for the diagnosis comprises restricted, repetitive patterns of behaviour, interests or activities, such as stereotyped or repetitive motor movements; inflexible adherence to routines; highly restricted, fixated interests that are abnormal in intensity or focus; and hyper- or hyporeactivity to sensory input.

The core importance of socio-emotional symptoms is reflected in recent changes to the diagnostic systems. While the DSM-IV-TR (American Psychiatric Association, 2000) required the presence of a minimum of two symptoms related to social interaction and one symptom related to social communication (thus, three of the possible eight symptoms from these formerly separate symptom groups) for the diagnosis, the DSM-5 (American Psychiatric Association, 2013) requires the presence of all four difficulties listed in the social communication and social interaction symptom group.

A variable but persistent difficulties with in recognizing and interpreting emotional expressions is one of the core ASD symptoms that has long been studied. Although impaired processing and recognition of facial emotions have often been reported in people with autism (Capps, Yirmiya, & Sigman, 1992; Hobson, 1986; Weeks & Hobson, 1987), not all studies have found difficulties with these skills (Ozonoff, Pennington, & Rogers, 1991; Ponnet, Roeyers, Buysse, De Clercq, & Van

Der Heyden, 2004; Rump, Giovannelli, Minshew, & Strauss, 2009; Tracy, Robins, Schriber, & Solomon, 2011), especially regarding basic emotions.

Several studies have suggested that, among people with ASD, difficulties in the recognition of specific emotions may be more apparent than a general difficulty with of all emotions. In particular, the recognition of fear and anger has been found to be the most affected in both children (Howard et al., 2000; Rump et al., 2009; Teunisse & de Gelder, 2001; Williams & Gray, 2013) and adults with ASD (Ashwin, Chapman, Colle, & Baron-Cohen, 2006; Corden, Chilvers, & Skuse, 2008; Humphreys, Minshew, Leonard, & Behrmann, 2007).

Nevertheless, ASD has been found to affect the recognition of emotions other than fear and anger. Law et al. (Law et al., 2010) have found disgust to be the most impaired, but anger and surprise to be affected also when presented with subtle intensity. Gross (Gross, 2004) has found the recognition of sadness and surprise to be affected by ASD, while Humphreys et al. (Humphreys et al., 2007) have found difficulty in recognition of fear and disgust only at lower intensities, with no difficulty in fear, disgust, happiness, anger, sadness and surprise when these emotions are presented with full intensity.

It has been generally suggested that people with ASD have difficulties recognizing cognitive emotions, such as surprise, that are related to the beliefs of others (Baron-Cohen, Spitz, & Cross, 1993; Law et al., 2010). Moreover, on the basis of the amygdala impairment model, Ashwin et al. (Ashwin et al., 2006) and Loveland, Bachevalier, Pearson and Lane (Loveland, Bachevalier, Pearson, & Lane, 2008) have suggested a general processing difficulty with ASD for negative emotions, such as anger, disgust, fear and sadness.

In contrast to the above evidence of emotion recognition difficulties with ASD, several studies have found no support for difficulty (Castelli, 2005; Evers, Kerkhof, Steyaert, Noens, & Wagemans, 2014; Jones et al., 2011; Kätsyri, Saalasti, Tiippana, von Wendt, & Sams, 2008; Leung, Ordqvist, Falkmer, Parsons, & Falkmer, 2013; Loveland et al., 2008; Prior, Dahlstrom, & Squires, 1990; Tracy et al., 2011). Loveland et al. (Loveland et al., 1997) have found that when groups with and without ASD are carefully matched by age and IQ, group differences disappear in the recognition of anger, happiness, sadness and surprise. In a recent meta-analysis, Uljarevic and Hamilton (Uljarevic & Hamilton, 2013) reviewed 48 studies, and when happiness was used as a baseline, only the recognition of fear was impaired with ASD, and even that difference disappeared after Bonferroni correction. In conclusion, the previous literature is inconclusive regarding the nature, extent or even the presence of emotion perception difficulty with ASD.

Previous research has found that faces, including emotional facial expressions, are processed holistically (Behrmann et al., 2006; Jemel, Mottron, & Dawson, 2006; Sasson, 2006), although in children without ASD a shift takes place from featural to holistic processing during development (Mondloch, Dobson, Parsons, & Maurer, 2004; Passarotti, Smith, DeLano, & Huang, 2007; Schwarzer, 2000). Children with ASD, however, show a possible advantage in featural processing compared with children without ASD: they are better at sorting spatially inverted stimuli (Hobson, Ouston, & Lee, 1988; Langdell, 1978), and this superior performance is most apparent when the stimuli are faces, as faces are particularly affected by the inversion effect (Dallett, Wilcox, & D'andrea, 1968). Face processing normally relies on configural information (Diamond & Carey, 1986), and the inversion effect greatly disturbs configural processing (Mondloch, Le Grand, & Maurer, 2002). Since configural face

processing develops later than featural processing (Mondloch et al., 2002), this disruption may prove to be helpful for people with ASD.

Indeed, when Tantam, Monaghan, Nicholson and Stirling (Tantam, Monaghan, Nicholson, & Stirling, 1989) asked children with and without ASD to label pictures of facial emotion expressions, children with ASD performed significantly poorer when the pictures were presented upright, but this group difference disappeared when the pictures were shown upside down. Jemel et al. (Jemel et al., 2006) have suggested that these results may reflect a floor effect rather than a relative lack of difficulty with inverted stimuli in children with ASD, as Tantam et al. (Tantam et al., 1989) noted that none of the children without ASD achieved a maximum score on the tasks.

However, Teunisse and de Gelder (Teunisse & de Gelder, 2001, 2003) have found no evidence of an atypical processing of inverted stimuli in adolescents without Intellectual Disability but with ASD showing the inversion effect – that is, a slower and less accurate processing of inverted compared with upright faces. Lahaie et al. (Lahaie et al., 2006) have also found no evidence of an inversion effect, adolescents and adults with and without ASD were faster and more accurate with upright than inverted neutral faces. Additionally, unlike with upside-down rotation, stimuli rotated to the right (between 0° ad 180°) and the left (beyond 180° to 360°/0°) have not been reported to have a side-related inversion effect (Lewis, 2001). In conclusion, the literature does not unanimously support either an inversion effect or a lack thereof with ASD.

The aim of the present study was to examine whether children with ASD show an inversion effect and whether they have a relative advantage in the recognition of

inverted pictures of facial emotions such as fear and surprise, compared with their ability to recognize these emotions in non-rotated, upright presentations, as well as to recognize happiness and anger or a neutral, non-emotional facial condition.

A further aim was to examine whether children with ASD show a side-related inversion effect for the emotions fear and surprise, compared with their ability to recognize these emotions in non-rotated, upright presentations and compared with their ability to recognize happiness and anger or a neutral, non-emotional facial condition.

A final aim, based on the controversial results of the literature outlined above, is to re-examine whether children with ASD have difficulties with recognizing the emotions of happiness, anger, fear and surprise.

It is hypothesized that, while children with ASD will underperform compared with those without ASD in the recognition of fear and surprise, their emotion recognition performance will be less affected when stimuli are rotated. Nevertheless, it is expected that, when the stimuli are rotated to the left or the right, children with ASD will underperform those without ASD.

The performances of children with ASD will be compared with those of children and adults without ASD to control for not only group differences, but also possible developmental stage effects versus possible atypical processing of stimuli with ASD. Performance will be measured by the accuracy of the responses provided and the speed of these responses measured by reaction times.

Participants and Methods

Forty-six participants – 13 children with autism (ASD, 1 girl and 12 boys), 13 children without ASD (3 girls and 10 boys) and 20 adults (11 women and 9 men) – were recruited and tested. The mean age of children with ASD was 15.10 years (SD = 1.60, range=13-16); the mean age of children without ASD was 15.92 years (SD = 1.03, range=14-16); and the mean age of adults was 24.77 years (SD = 8.30, range=21-50 years). Children were recruited from local schools and mainstream and autism units, and adults were recruited from the university. The Departmental Research Ethics Committee, the Educational Department of Dundee City Council and the participating schools approved the experiment.

Children in the autism group were recruited from a local school in Dundee with a specialized unit for children with ASD. All children in the autism group were clinically diagnosed with autistic disorder, verified by the autism units and the parents, and were eligible to be enrolled in a special autism unit. The head teacher of the unit assisted the researchers by confirming the diagnosis. The researchers, however, had no access to the clinical notes and files for the children; therefore, although group membership was assumed, it was further confirmed for the purpose of the study using the Autism Screening Questionnaire (ASQ) (Ehlers, Gillberg, & Wing, 1999), which recommends a cut-off score of 15 for suspected autism diagnosis (Berument, Rutter, Lord, Pickles, & Bailey, 1999). All participants scored within the group-appropriate range with ASD mean = 21.20 (SD = 10.28), range 15–38; without ASD mean = 2.33 (SD = 1.03, range 1–4). Thus, the group membership was confirmed.

The WISC-III Vocabulary Subtest (Wechsler, 1991) was administered to ensure that the two groups of children were matched in a language subtest. The scaled scores were comparable between the children without and with ASD (with ASD mean

= 10.83, SD = 1.72; without ASD mean = 10.17, SD = 3.76); thus, any group-related differences between the children's groups in the study cannot be directly explained by differences in vocabulary.

Procedures

Three types of stimuli or 'conditions' were presented to the participants: neutral faces (sex condition), faces depicting happiness and anger (easy emotion condition) and faces depicting surprise and fear (difficult emotion condition). The pictures were presented in eight rotations (0°, 30°, 90°, 150°, 180°, 210°, 270°, 330°). Cedrus Superlab Pro^{TM} 2.0.4 for Windows was used to programme and administer the experiment.

Pictures were at 230x45 pixel size, centred on the screen against a white background. A portable Toshiba Satellite 1415-S173 laptop with a screen size of 15 inches and screen resolution of 1024x768 was used to administer the experiment. The children sat approximately 60 cm from the laptop monitor.

Pictures were taken from the PoFA (Ekman & Friesen, 1975) validated picture set, which has pictures of four different actors (two men and two women) displaying neutral (picture IDs: SW3-3, NR1-3, GS1-4 and EM2-4), happy and angry (SW4-9, SW3-9, NR2-7, NR1-6, GS2-8, GS1-8, EM5-14 and EM4-7) and surprise and afraid (SW1-16, SW2-30, NR1-14, NR1-19, GS1-16, GS1-25, EM2-11 and EM5-21) expressions. The 20 unique images above were used in the study. Participants participated in a practice session prior to the testing to familiarize them with the laptop, the response keys and the task. The practice session consisted of four stimuli

from the sex condition with no feedback provided, although any questions regarding the procedure were answered.

The pictures were randomized, and participants were instructed to respond as quickly and as accurately as possible with either a blue key or a red key, which were marked with a sticker on the keys 'v' and 'n'. One picture at a time was presented on the centre of the screen. The picture belonged to one of the relevant categories of the forced-choice condition.

In the sex condition, participants were required to respond to the sex of the face presented on the screen (forced choice, male/female) with a key press. In the easy emotion condition the task was to decide whether the face presented was angry or happy; in the difficult emotion condition, participants had to decide whether the face was surprised or afraid.

For each condition, three sessions were presented with a break in between each. The sessions contained 32 images in the sex condition and four of each of the eight rotations (one from each actor), randomized. For the easy emotion condition, each session contained 64 images – eight pictures (four actors shown with two forced-choice emotions, angry and happy) in each of the eight rotations – with the trials randomized. Each session of the difficult emotion condition contained 64 images – eight pictures (four actors showing both fear and surprise) in each of the eight rotations, randomized. Pictures were presented for 1000 millisecond, followed by a response period that was ended by the participant pressing a key. See Figure 1 for an illustration of the rotations.

The study utilised a 3 (Conditions, sex, easy, difficult) * 8 (Rotations) * 3 (Group, children with ASD, children without ASD, control adults) mixed design. The

dependent variables were the percentage of the accurately recognized pictures and the reaction times. The reaction times were recorded by the experiment presentation software with millisecond accuracy. The reaction times of correctly recognised responses were used in the data analysis. The data were analyzed using IBM SPSS 22 for Windows statistical software, and a $p<.05$ was accepted as significant throughout.

A 3x8x3 ANOVA had been conducted to examine the effect of the Conditions (sex, easy emotions and difficult emotions), Rotations (eight different Rotations) and Groups (three groups: children with ASD, children without ASD, control adults) on the accuracy of recognition measured in per cent and the reaction times for accurate responses, measured to a millisecond of accuracy. When the parametric assumption of sphericity was violated using Mauchly's test of sphericity, Greenhouse–Geisser corrections were used throughout.

The 'Easy' and the 'Difficult' Conditions

The Pictures of Facial Affect (PoFA) (Ekman & Friesen, 1975) validated picture set was used to address the aims of the study. The PoFA provides detailed reports on the validation process, showing that stimuli depicting happiness are the most reliably recognized, with 98.56% correct recognition, while fear had the lowest correct recognition at 87.66%. The emotion most commonly confused in the PoFA with fear was surprise (6.53%), while surprise was most commonly confused with fear (5.14%). Happiness, having the very high correct recognition of 98.56%, was not notably confused with other emotions (0.00% with disgust and sadness, 0.056% with anger, 0.22% with fear and 0.83% with surprise), while anger was confused with happiness the least (0.18%). Additionally, children with ASD are reported to show

difficulties with cognitive emotions like surprise and fear (Baron-Cohen et al., 1993), while happiness is often used as a baseline (Uljarevic & Hamilton, 2013).

Therefore, for the purposes of this study, in this forced-choice task, happiness and anger are expected to be confused with each other the least, while fear and surprise are expected to be the most difficult to distinguish from each other using PoFA. Therefore, in the following experimental design, the happiness–anger pair will be referred to as the 'easy' condition and the fear–surprise pair as the 'difficult' condition.

Results

Reaction Times

The 3x8x3 ANOVA explored the effects of the Conditions (sex, easy, and difficult emotion conditions), the eight Rotations and the three Groups (children with ASD, children without ASD, control adults) on the reaction time (RT) of responses. There was a significant Condition*Group interaction, $F(4,88) = 14.57$, $p < 0.001$, $\eta_p^2 = 0.25$, and a significant Condition*Rotation*Group interaction, $F(28,616) = 1.88$, $p < 0.01$, $\eta_p^2 = 0.08$. The overall main effect of Group, $F(2,44) = 11.44$, $p < 0.001$, $\eta_p^2 = 0.34$, was also significant.

Effect of the Group on the Reaction Times

Post-hoc pairwise comparisons using the Bonferroni correction showed that children with ASD were significantly faster compared with both children without ASD and control adults. See Table 1.

Place Table 1 around here please.

Effect of the Condition and the Group on Reaction Times

A post-hoc pairwise comparison adjusted according to the Bonferroni correction showed that ASD children responded significantly faster to the easy emotions than children without ASD ($p < .05$), but there was no difference between non ASD children and control adults or children with ASD and control adults. Children with ASD were significantly faster than children without ASD ($p < .001$) and control adults ($p < .001$) when responding to difficult emotions, but no difference existed between children without ASD and the control adults. The reaction times of the three groups were comparable during the sex condition. See Table 2 and Figure 2.

Place Table 2 around here please

When comparing the Conditions within each group, pairwise comparisons with Bonferroni corrections found that the reaction times of ASD children the RTs in the difficult emotion condition were significantly faster than in the sex condition ($p < .05$) and had a tendency to be faster than in the easy emotion condition (p=.05). The reaction times in the sex and the easy emotion conditions were comparable.

Children without ASD, however, showed significantly faster reaction times in the sex condition than they did in the easy (p<.001) and in the difficult emotion ($p < .01$).

Control adults showed a step-wise increase in reaction times, with the sex condition being the fastest ($p < .001$ for both easy and difficult emotions comparisons) and the difficult emotion condition being the slowest ($p < .01$ for difficult versus easy emotions comparison).

Effect of the Condition*Rotation*Group Interaction on Reaction Times

When comparing reaction times across the different rotations within each group, pairwise comparisons with Bonferroni corrections showed that children with ASD showed comparable reaction times in all three conditions when the pictures were non-rotated, that is, presented at 0 degrees. For the rotation conditions, reaction times remained comparable in the easy emotion, compared with the sex condition. In the difficult emotion condition, however, children with ASD were faster at 180 and 210 and 330 degrees, compared with the sex condition, but their reaction times were unaffected by the other rotations. When comparing the easy and difficult emotion conditions, however, their reaction times were faster at each of the rotations (except for non-rotated pictures) during the difficult emotion condition.

The children without ASD showed a different pattern. They were consistently faster in the sex condition compared with both the easy and the difficult emotion conditions at every rotation, including non-rotated images. Their reaction times, however, were comparable between the easy and the difficult emotion conditions. The rotation, therefore, did not seem to affect their reaction times.

The reaction times of control adults were also unaffected by rotations. At each

rotation, including non-rotated images, they showed significantly faster reaction times

in the sex condition compared with both the easy and the difficult emotion conditions.

They also showed significantly faster reaction times in the easy compared with the

difficult emotion rotated conditions (all differences were significant, with the

exception of 210° and 270°, with $p = .066$ and $p = .069$, respectively), as well as in

the non-rotated condition. See Tables 3a, b and c and Figures 3a, 3b and 3c.

Place Tables 3a, b, c around here please

Reduction of the Rotation data to 'Rotated' and 'Non-Rotated': Does Rotation Itself Make a Difference?

Further analyses aimed to investigate the overall effect of rotated compared

with non-rotated images; therefore, the seven rotated conditions were collapsed into a

'Rotated' variable. A 3x2x2 mixed-design ANOVA then explored the effect of the

three Conditions, the two Rotations (Non-Rotated, Rotated) and the three Groups on

reaction times. There was a significant Condition *Rotation*Group interaction,

$F(4,88) = 3.30$, $p < .05$, $\eta_p^2 = 0.13$. The Group*Rotation interaction was not

significant, $F(4,88) = 0.95$, n.s.

Further post-hoc pairwise comparisons using Bonferroni corrections showed

that for children with ASD, there was no difference in reaction times among the three

Conditions when the pictures were non-rotated. Only when the pictures were rotated,

were the reaction times faster in the difficult emotion condition compared with

reaction times in the easy emotion condition ($p < .001$). That is, paradoxically, children with ASD only showed speeded reaction times for conditions in the difficult condition when the pictures were rotated.

In the case of children without ASD, however, reaction times in the sex condition were significantly faster than in the difficult emotions condition when the pictures were non-rotated ($p < .05$). Reaction times in the sex and easy emotion conditions were comparably fast with non-rotated pictures. When the pictures were rotated, reaction times in both the easy ($p < .001$) and difficult emotion conditions ($p < .01$) were significantly slower compared with times in the sex condition.

In the case of control adults, there was a stepwise significant increase in reaction times from sex to easy ($p < .001$; $p < .001$) and easy to difficult ($p < .001$; $p < .001$) conditions both for non-rotated and rotated pictures, respectively.

See Table 4 and Figures 4a,b, and c.

When comparing reaction times for rotated and non-rotated pictures directly within the groups, children with ASD had significantly increased reaction times for rotated compared with non-rotated easy emotions ($p < .05$) but significantly decreased reaction times in the difficult emotion condition ($p < .01$). They showed comparable reaction times for rotated and non-rotated images in the sex condition.

For children without ASD, direct comparison led to no significant differences in any of the conditions. Control adults, however increased – not decreased – their reaction times with difficult rotated compared with difficult non-rotated pictures. See Table 4.

Place Table 4 around here please

Are There Reaction Time Differences for Left versus Right Rotations?

To examine possible reaction time differences for stimuli rotated to the left versus right, reaction times for the 30, 90 and 150 degree rotated pictures were collapsed as 'right side', and the 330, 270 and 210 degree rotated pictures were collapsed as 'left side'.

A 3 (Conditions) x 2 (Right and Left Sides) x 3 (Groups) mixed-design ANOVA was conducted to explore the effects of these factors on reaction times. There was a significant Side*Group interaction, $F(2,44) = 3.50$, $p < .05$, $\eta_p^2 = 0.14$, and a tendency for a 3-way Condition*Side*Group interaction, $F(4,88) = 2.32$, $p = .063$, $\eta_p^2 = 0.10$.

Post-hoc pairwise comparisons with Bonferroni corrections found that the reaction times of children with ASD were significantly different on right and left sides when compared with both children without ASD and control adults, while the reaction times of children without ASD and control adults were comparable with each other.

When compared within the groups, children with ASD had a tendency ($p = .095$) to be faster on the left side, while children without ASD showed a tendency toward the opposite pattern, being slower on the left Side ($p = .084$). See Table 5.

Place Table 5 around here please

To explore the significant Condition*Side*Group interaction, post-hoc pairwise comparisons using Bonferroni corrections found that while Adults showed no side-related differences in their reaction times, both children with and without ASD showed significant side-related reaction time differences in the difficult emotion condition. children with ASD were significantly faster for stimuli rotated to the left side in the difficult emotion condition ($p < .05$), while children without ASD were significantly faster for stimuli rotated to the right side($p < .05$). See Table 6 and Figures 5 a, b and c.

Place Table 6 around here please

Correct Responses

A 3x8x3 ANOVA examined the effects of the three Conditions, the eight different rotations and the three groups on the percentage of correct responses. There was no significant main effect of Group, $F(2,44) = 0.70$, n.s. Condition * Group, $F(4,88) = 2.14$, n.s.; Rotation*Group $F(14,308) = 1.46$, n.s.; and Condition*Rotation*Group interaction $F(28,616) = 0.86$, n.s., were also not significant.

Effect of Rotation Overall on the Correct Responses

When collapsing the 7 rotated conditions and comparing the rotated and non-rotated pictures using a 3x2x2 mixed-design ANOVA, there was no significant Condition*Group, $F(4,88) = 1.18$, n.s.; Rotation*Group, $F(2,44) = 1.21$, n.s.; or Condition*Rotation*Group, $F(4,88) = 1.49$, n.s., interaction.

Effect of Side on the Correct Responses

A 3 (Conditions) x 2 (Side) x 3 (Groups) mixed-design ANOVA was conducted to measure these factors' effects on reaction times. The results found no significant Condition*Group, $F(4,88) = 1.99$, n.s.; Side*Group, $F(2,44) = 0.81$, n.s.; or Condition*Side*Group, $F(4,88) = 0.85$, n.s., interaction.

Discussion

In summary, the results of this study showed that children with ASD responded significantly faster to both easy and difficult emotions than to neutral sex conditions, while children without ASD and control adults were comparable to each other. This difference between the groups was not due to being better at the task overall, as the reaction times of the three groups were comparable in the sex condition. When looking at the pattern of responding among the groups, children with ASD were the fastest in the difficult emotion condition, while children and adults without ASD were the fastest in the sex condition and slowest in both emotion conditions. The post-hoc tests indicated that this difference was due to children with ASD's rapid response in the difficult emotion condition.

When testing the hypothesis that rotation would affect the group performance differently in the three conditions, the results showed that children with ASD showed comparable reaction times in all three conditions when the pictures were non-rotated. When the pictures were rotated, the reaction times of children with ASD remained comparable in the easy emotion and the sex condition. In the difficult emotion condition, however, children with ASD were faster at 180, 210 and 330 degrees than they were in the sex condition, as well as faster in each of the rotations (except for non-rotated pictures) during the difficult emotion compared with the easy emotion condition. The reaction times of children without ASD and control adults were unaffected by rotations.

Further analysis collapsing the rotated conditions confirmed the above findings. Children with ASD showed no reaction time differences among the three conditions when the pictures were non-rotated. Only when the pictures were rotated

did their responses in the difficult emotions appear, compared with the sex and easy emotion conditions. Children without ASD were faster in the sex condition compared with the difficult emotion condition when the pictures were non-rotated and faster in the sex condition compared with the easy and difficult emotions when the pictures were rotated. This is the opposite pattern than we saw for children with ASD. Interestingly, children with ASD were also faster on the left visual field for difficult emotions, while children without ASD showed the opposite pattern. Likewise, control adults increased their reaction times from sex to easy emotion conditions while having the slowest responses in the difficult emotion condition. Importantly, these differences in reaction times did not translate to group differences in the percentage of accurate responses. Children with ASD responded faster to difficult emotions, in particular when they were rotated, but they did so without decreasing the accuracy of their responses compared with the accuracy of children without ASD and control adults.

The absolute or relative superior performance of children with ASD when processing inverted stimuli has already been suggested in the literature (Hobson et al., 1988; Langdell, 1978; Tantam et al., 1989), although the results have not been unanimously confirmed (Wallace, Coleman, & Bailey, 2008b). Wallace, Coleman and Bailey (Wallace, Coleman, & Bailey, 2008a) for example, have found that both people with and without ASD recognize emotions in upright and inverted positions, and a face-inversion effect existed for both groups. Likewise, our results do not support the idea that children with ASD in general have a processing speed advantage when stimuli are rotated. They were faster with rotated stimuli for difficult emotions, while children without ASD and control adults showed the opposite pattern, being slower with rotated, difficult emotions but not with the other conditions.

Some of our results may be consistent with the Weak Central Coherence theory of autism (Frith & Happé, 1994; Happé & Frith, 2006). The fact that children with ASD perform better when stimuli are rotated may suggest a processing advantage for local and featural information in line with the Weak Central Coherence model. In the present study, children with ASD indeed seemed to utilize atypical mechanisms, but only when the information processing was particularly challenging. This study found that children with ASD made faster decisions than both children and adults without ASD in the difficult emotion condition when pictures were rotated. They also showed a faster response to rotated versus non-rotated difficult emotional stimuli. This pattern, however, was not found in the case of the easy emotion condition, where the inversion effect – that is, a slower response – was observed; therefore, the Weak Central Coherence theory cannot fully explain the results.

These speed differences cannot be attributed to the poorer accuracy of children with ASD, as there were no differences among the three groups in accurate recognition in the difficult emotion condition or rotation conditions. Given that the speed advantage in children with ASD affected only the rotated pictures, in particular those of difficult emotions, it may be that fast decisions on rotated emotion pictures reflect true differences in the information-processing style of children with ASD.

It is possible that recognizing difficult emotions was challenging for all three groups, but children and adults without ASD predominantly used configural processing, even though this inversion task has been shown to be better performed using featural processing (Diamond & Carey, 1986). Children with ASD probably also found the task challenging, but they used a different strategy. They were either able to switch from configural to featural processing, or they simply continued to employ the contextually more efficient featural information processing style. The fact

that they showed the typical inversion effect for easy emotions but the opposite pattern for difficult emotions might suggest a change in their strategy rather than the consistent use of featural processing throughout. Whether they changed their strategy because difficult emotions are less meaningful to them or simply because of the perceived difficulty of the task should be further investigated. The presence of both the inversion effect and a different strategy in the same experiment, however, suggests atypical processing rather than developmental delay. In the case of developmental delay, children with ASD would use featural processing throughout, so only including more age groups in future studies could show whether their strategy changes over time as it does throughout the development of children without ASD (Mondloch et al., 2002).

It is worthwhile noting that, although the accuracy of all three groups in recognizing difficult emotions was relatively low, given the design of the task, this low level of recognition provides no clear evidence of impaired recognition accuracy. For the purposes of this study using the PoFA validation results, emotions in the easy emotion condition (happiness and anger) were expected to be confused the least with each other, while emotions in the difficult emotion condition (fear and surprise) were expected to be the most difficult to distinguish between. A lower level of recognition, therefore, was expected across all three groups for the difficult emotions.

Although it was hypothesized that no difference would exist between the recognition of stimuli rotated to the left and the right, there was a side-related difference in reaction times. Children without ASD were significantly faster for difficult emotions on right-side rotations, while children with ASD were faster on left-side rotations. Although all stimuli were centred on the monitor, this finding might have parallels to reports of right visual field superiority for face detection among

adults without ASD (Marzi & Berlucchi, 1977), although in our study only children but not adults without ASD showed this right-side rotation advantage. Alternatively, it is possible that it is children without ASD who use featural processing with difficult emotion stimuli. Bombari, Preuss and Mast (Bombari, Preuss, & Mast, 2014) have found a left hemisphere advantage for featural processing and a right hemisphere advantage for configural processing. That might mean that the children with ASD relied more on configural processing for difficult emotions, as indicated by their speed advantage with left-side rotated stimuli. Whether the children turned their heads when looking at the rotated pictures, thus utilizing the two visual fields differently, was not measured.

The results, however, might also show a parallel with experiment 2 in Bombari et al.'s study (Bombari et al., 2014), reporting the advantage of the right hemisphere over the left hemisphere when processing familiar as opposed to novel stimuli. This possibility might highlight a limitation of the current study. The PoFA (Ekman & Friesen, 1975) has been a useful and carefully validated tool for the current experiment and extensively used in the past; however, the pictures were used in their original, unaltered format. This means that the hair, clothing or even picture ID number might have influenced the way participants processed and responded to the pictures across rotations, and perhaps children with ASD quickly became familiar with the stimuli across rotations. It might be advisable for future studies to edit out such non-essential elements when creating the stimulus set for similar experiments.

Several studies, especially when controlling for IQ, have found no group-related differences in ASD individuals' recognition of emotions ((Castelli, 2005; Evers et al., 2014; Jones et al., 2011; Kätsyri et al., 2008; Loveland et al., 2008; Loveland et al., 1997; Prior et al., 1990). Tracy et al. (Tracy et al., 2011) and Dallett

et al. (Dallett et al., 1968) have found that children and adolescents with ASD are not only as accurate as children and adolescents without ASD but also as comparably fast, even with complex emotions. It may be that the task was too easy for children with ASD, resulting in a floor effect (Jemel et al., 2006; Tantam et al., 1989), thus, limiting the ability to derive conclusions from the results. The accuracy results, however, are comparable with results from the literature (Ekman & Friesen, 1975), and the PoFA stimuli were used in 28 of 74 studies reviewed by Uljarevic and Hamilton (Uljarevic & Hamilton, 2013) in their meta-analytic review of emotion recognition in ASD. A further argument against the floor effect is that the reaction times of the ASD group were significantly faster for each of the rotations in the difficult condition compared with the easy condition and two of the sex condition data points, but the group had no reaction time differences with non-rotated pictures among the conditions. For children without ASD, however, reaction times in the difficult condition were significantly slower compared with the sex condition for both non-rotated and rotated pictures, while no reaction time differences existed between the easy and difficult conditions for either the rotated or non-rotated pictures. In case of the adults without ASD, there was a step-wise, significant increase from sex, to easy, to difficult condition for both the rotated and non-rotated pictures.

Overall, the lack of group-related accuracy differences and the differentially faster reaction times in the difficult, rotated emotion condition among children with ASD – but not among the other two groups – may reflect an atypical processing pattern for children with ASD. The presence of the inversion effect in other conditions in children with ASD further argues against the floor effect. It is likely that the lack of differences in accuracy support those studies in which children with ASD and without Intellectual Disability recognized emotions just as well as did children without ASD

(Jones et al., 2011; Loveland et al., 2008), but they do so using different strategies. The socio-emotional difficulties of people with ASD could lie beyond naming, matching and recognizing basic emotional expressions and include difficulties in appropriately utilizing and responding to socio-emotional information in ecologically valid everyday interactions (Loveland, Pearson, Tunali-Kotoski, Ortegon, & Gibbs, 2001).

Not only inversion could cause a possible switch in processing strategies. Kikuchi, Senju, Hasegawa, Tojo and Osanai (Kikuchi, Senju, Hasegawa, Tojo, & Osanai, 2013) have found that children with ASD respond less accurately to emotional stimuli when images are blurred and thus contain less featural information, but their performances become comparable with children without ASD when pictures are unedited and include more featural information. Based on a large body of relevant data, it has been proposed that people with ASD predominantly use featural information processing, affecting face and non-face perception (Davies, Bishop, Manstead, & Tantam, 1994; Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005). Although Mottron, Burack, Iarocci, Belleville and Enns (Mottron, Burack, Iarocci, Belleville, & Enns, 2003) have suggested that global processing is intact in people with ASD, they proposed an enhanced perceptual functioning (EPF) model with more detail-focused featural attention (Mottron, Dawson, Soulieres, Hubert, & Burack, 2006), while Davies et al. (Davies et al., 1994) have proposed a general processing deficit model in ASD. Our current experiment, however, does not support a deficit model or the general use of featural processing with ASD for facial socio-emotional information. Only stimuli in the difficult emotion condition, in particular when they were rotated, were processed differently and more efficiently by children with ASD than by children and adults without ASD. The inversion effect remained when rotated

easy emotions were processed. This difference likely reflects atypical processing, as children with ASD were likely to approach challenging pictures via featural processing. That approach speeded up recognition but did not affect accuracy. Children without ASD and control adults, however, might be less likely to utilize featural processing under such circumstances. They were, therefore, slowed down, even though their speed did not interfere with their accuracy in the current design.

However, the use of still pictures in a forced-choice computerized task in a laboratory environment may have serious limitations for making any conclusions regarding the emotion perception of people with ASD. After finding that people with ASD can perform as well as people without ASD in emotion recognition tasks (Loveland et al., 1997), Loveland (Loveland, 1991) suggested that people with ASD may have an difficulties with perceiving and understanding the significance or 'affordances' of their social environment (Gibson, 1979). This type of difficulty would then secondarily affect their understanding of facial expressions in a social context rather than purely naming and matching stimuli in a laboratory environment. If so, the use of still images on a computer screen would yield inconclusive or negative results when groups are matched for diagnosis and mental age (Loveland et al., 1997). Future studies could use ecologically valid social stimuli to test the impaired social affordances hypothesis.

It is also important to note that only the ASQ (Berument et al., 1999) was used to confirm group membership. While all children with ASD had confirmed diagnoses as a basis of their admission to the special autism unit from which they were recruited, and their teachers confirmed the diagnoses prior to the testing, the experimenters had no direct access to the clinical notes on the diagnoses. Future studies could utilise diagnostic tools, including the Autism Diagnostic Observation Schedule-Generic

(ADOS-G; (Lord et al., 2000) and the Autism Diagnostic Interview-Revised (Lord, Rutter, & Le Couteur, 1994).

It is also worthwhile noting that only the WISC-III (Wechsler, 1991) Vocabulary subtest was used to estimate group-related differences, other than the diagnosis, that might have affected outcome measures. Future studies could include full IQ testing to ensure that no IQ-related differences contribute to outcome measures.

In summary, the results of the current study are not supportive of a deficiency model of autism or a model of delayed development. Rather, they demonstrate the atypical (Baron-Cohen et al., 2000) processing mechanisms that, under some circumstances, people with ASD might utilize to efficiently encode and understand complex social stimuli that are normally processed configurally in people without ASD. Featural processing might be the predominant but not sole way that people with ASD process information, or it is possible that people with autism more efficiently switch off configural to detail-focused processing of more difficult emotional stimuli, in consistent with the weak coherence theory (Happé & Frith, 2006). Understanding these atypical processes and the possible strengths of people with autism could enable future research to develop targeted intervention processes based on the abilities and existing, albeit atypical, skills of this special population.

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Figure legends

Figure 1.

Figure 1. Shows a picture of the four actors from the Pictures of Facial Affect (Ekman and Friesen, 1976), and the orientations for the eight rotations.

Figure 2.

Figure 2. shows Reaction times at the three conditions in children with ASD, children without ASD and control adults.

Figures 3 a,b,c

Reaction times across the eight rotations in the three conditions for children with ASD (Figure 3a), children without ASD (Figure 3b) and control adults (Figure 3c).

Figures 4a,b, c

Reaction times to rotated versus non-rotated images in the three conditions for children with ASD (Figure 4a), children without ASD (Figure 4b) and control adults (Figure 4c).

Figures 5a,b, c

Reaction times to right versus left sided images in the three conditions for children with ASD (Figure 5a), children without ASD (Figure 5b) and control adults (Figure 5c).