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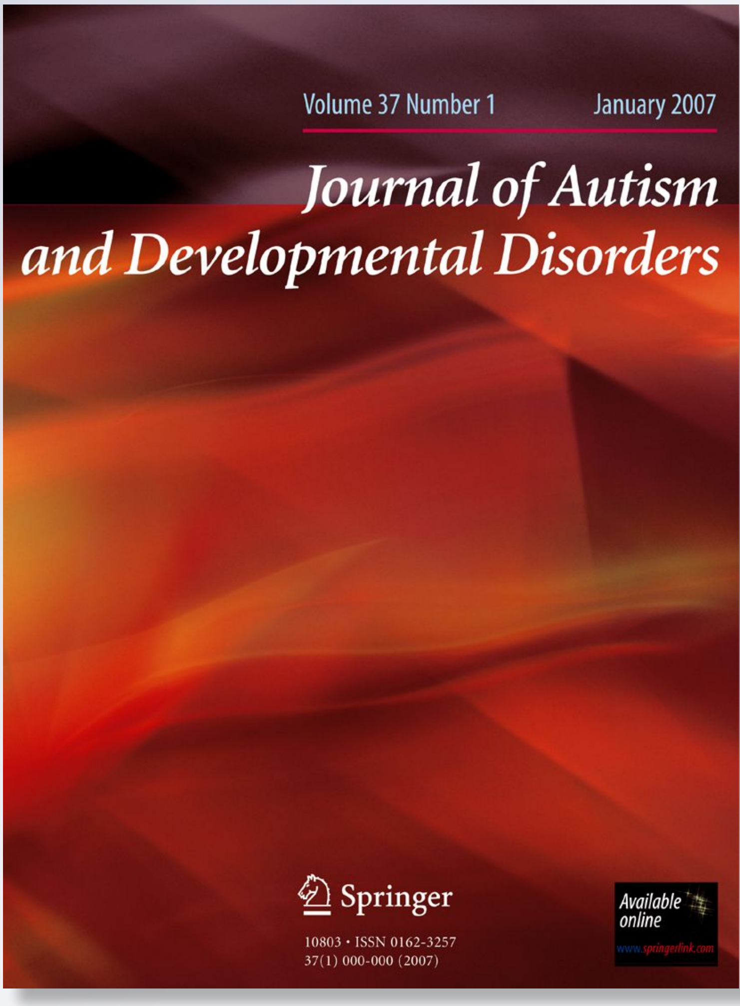

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ORIGINAL PAPER

The Role of Alexithymia in Reduced Eye-Fixation in Autism Spectrum Conditions

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Abstract Eye-tracking studies have demonstrated mixed support for reduced eye fixation when looking at social scenes in individuals with Autism Spectrum Conditions (ASC). We present evidence that these mixed findings are due to a separate condition—alexithymia—that is frequently comorbid with ASC. We find that in adults with ASC, autism symptom severity correlated negatively with attention to faces when watching video clips. However, only the degree of alexithymia, and not autism symptom severity, predicted eye fixation. As well as potentially resolving the contradictory evidence in this area, these findings suggest that individuals with ASC and alexithymia may form a sub-group of individuals with ASC, with emotional impairments in addition to the social impairments characteristic of ASC.

Keywords Autism · Alexithymia · Eye-tracking · Eye · Mouth · Face

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People tend to immediately look at each others' faces, (e.g. Birmingham et al. 2008; van der Geest et al. 2002; Yarbus 1967), and in particular, their eyes (e.g. Pelphrey et al. 2002; Walkersmith et al. 1977). This preference is present from birth (Haith et al. 1979; Johnson et al. 1991; Maurer and Salapatek 1976), and may aid in the development of more advanced social cognitive ability (see Morton and Johnson 1991; Senju and Johnson 2009b). The eye-region plays a key role in interpersonal interaction. For example, the eyes are used to modulate social interactions by indicating turn-taking during conversations and to communicate social dominance and appeasement (Exline 1971; Kendon 1967). The eyes also provide rich information about the emotional state of another (Baron-Cohen et al. 1997).

A key social determinant of eye fixation in typical individuals, particularly of the ratio of eye:mouth fixations, is the emotional expression of the fixated face. Dimberg and Petterson (2000) have shown that emotions are expressed differentially across the face. Thus, recognising different emotional expression will require different facial fixation behaviour. Adolphs et al. (2005) describe a patient with damage to her amygdalae who had a deficit in recognising the facial expression of fear as a result of making significantly fewer eye-fixations than typical individuals. When explicitly instructed to fixate the eye-region of emotional face stimuli, the patient's ability to recognise fear recovered to normal levels. Impaired fear recognition with reduced eye-fixations has also been found in adolescent males with high psychopathic traits and males with autism (Corden et al. 2008; Dadds et al. 2008).

Validating the importance of the ratio of eye:mouth fixations when discriminating facial emotional expressions, Adolphs et al. (2005) showed that eye and mouth information was most useful in discriminating emotions using the 'bubbles' technique, where small regions of the face are revealed randomly on a trial by trial basis. More generally, many studies show that in order to accurately categorize observed emotional expressions one must appropriately scan eye and mouth features, as different emotional expressions are most reliably signalled by different parts of the face (Aviezer et al. 2008; Calder et al. 2000; Smith et al. 2005; Wong et al. 2005).

The hypothesized importance of face/eye fixation in developing intact social cognition has prompted many researchers to investigate the fixation patterns of individuals with impaired social cognition. There are reports of atypical attention to faces in schizophrenia (e.g. Loughland et al. 2002; Phillips and David 1997; Sasson et al. 2007), Turners Syndrome, (e.g. Mazzola et al. 2006), Fragile X Syndrome (Dalton et al. 2008), social anxiety (Horley et al. 2003, 2004) and Williams Syndrome (Riby and Hancock 2009). The population that has been investigated most extensively however, are those with an Autism Spectrum Condition. Autism Spectrum Conditions (henceforth "autism" for brevity) are developmental disorders characterised by abnormalities of social interaction, impaired verbal and non-verbal communication, and a restricted repertoire of interests and activities (American Psychiatric Association 2000).

Several researchers have claimed that impaired attention to the eye region may be a causal factor in the social impairments seen in autism (Baron-Cohen 1994; Dalton et al. 2005; Klin et al. 2002). These claims are based on the large number of studies documenting reduced attention to faces (Hutt and Ounsted 1966; Trepagnier et al. 2002; Riby and Hancock 2008; Sasson et al. 2007; Bal et al. 2010; Baranek 1999; Chawarska and Shic 2009; Osterling and Dawson 1994; Osterling et al. 2002; Hernandez et al. 2009) and/or atypical eye fixation in autism (as initially detailed in Kanner's first descriptions of autism, Kanner 1943, 1944; see also Joseph and Tanaka 2003; Riby and Hancock 2008; Boraston et al. 2008; Sterling et al. 2008; Jones et al. 2008; for a review see Senju and Johnson 2009a). Klin et al. (2002) assessed fixation patterns while participants observed emotional movie clips containing social interaction. Individuals with autism showed reduced attention to faces, and in addition, greater attention to the mouth region of faces at the expense of attention to the eye-region. Furthermore, the degree to which participants fixated the mouth region of the face was positively correlated with their social competence as measured by the Autism Diagnostic Observation Schedule (ADOS, Lord et al. 2000). Similarly, Spezio et al. (2007) demonstrated, using the bubbles technique, that when judging emotion, an autism group relied to a greater degree on mouth information (with an accompanying increase in mouth fixations), and less on eye information, than a typically developing group. Furthermore, Dalton et al. (2006) showed that even seemingly unaffected siblings of those with autism demonstrated fewer fixations to the eye-region than control participants with no family history of autism.

Despite the abundance of studies demonstrating atypical face and eye fixation in autism, an equally large number of studies have found contradictory results; showing no evidence for reduced fixations on the face and/or altered eye or mouth fixations in children or adults with autism (O'Connor and Hermelin 1967; Dapretto et al. 2006; Neumann et al. 2006; Rutherford and Towns 2008; Lahaie et al. 2006; Falck-Ytter et al. 2010; Freeth et al. 2010; Fletcher-Watson et al. 2009; see Senju and Johnson 2009a for an overview). Young et al. (2009) studied the gaze behaviour of 6 month-old infants, some of which were considered at-risk for autism due to having affected siblings. A subset of this group showed decreased gaze to the eyes, and increased gaze to the mouth during mother-infant interaction. However, none of this subset later was diagnosed with autism, while three that were diagnosed with autism demonstrated typical eye-gaze at 6 months (see also Cassel et al. 2007; Yirmiya et al. 2006; Elsabbagh et al. 2009). In a review of 11 studies published between 1966 and 1994, Buitelaar (1995) concluded that evidence was inconsistent in relation to gaze-avoidance (i.e. reduced eye-fixation) in autism, and that autism did not involve "a universal and predominant pattern of gaze avoidance." Buitelaar argued that "gaze avoidance" was a secondary phenomenon and not a primary characteristic of autism.

One candidate for a primary characteristic that may be driving the inconsistent results with respect to eye-fixation in autism is alexithymia. Alexithymia has been described as a subclinical phenomenon marked by difficulties in identifying and describing feelings and difficulties in distinguishing feelings from the bodily sensations of emotional arousal (Nemiah et al. 1976). Alexithymia is thought to characterize 10% of the general population (Linden et al. 1995; Salminen et al. 1999). However, although neither a necessary nor sufficient feature of autism, studies have revealed severe degrees of alexithymia in approximately 50% of individuals with autism, with the majority showing slight or severe impairments (Berthoz and Hill 2005; Hill et al. 2004; Lombardo et al. 2007; Silani et al. 2008). It has recently been shown that emotional deficits thought to be characteristic of autism have, in fact, been caused by the high prevalence of alexithymia within this group (Bird et al. 2010; Silani et al. 2008). For example, Bird et al. (2010) demonstrated that the empathy deficits previously reported in autism were likely related to alexithymia. Participants with autism who were not alexithymic demonstrated typical empathy, but individuals with autism **and** alexithymia showed an empathy deficit.

So-called 'shared-network' models of empathy (e.g. Preston and de Waal 2002) raise the possibility that alexithymia may lead to impaired emotion recognition. These models suggest that the same neural networks represent the emotional state of both the self and the other. Thus, impaired representation of the emotional state of the self in alexithymia would lead to impaired representation of the other's emotion, which may be manifested as impaired recognition of emotion. Several studies support this conjecture, reporting impaired recognition of facial emotion in alexithymia (Mann et al. 1994; Parker et al. 1993; Jessimer and Markham 1997; Lane et al. 1996, 2000; Prkachin et al. 2009). The reliance of accurate emotion recognition on typical visual scan paths to emotional face stimuli (Aviezer et al. 2008; Calder et al. 2000; Smith et al. 2005; Wong et al. 2005), makes it possible that the impaired emotion recognition in individuals with alexithymia is due to atypical attention to the eye and mouth regions of emotional face stimuli. As far as we are aware, no previous study has examined visual scan paths in individuals with alexithymia (irrespective of autism diagnosis).

Findings of impaired emotion recognition in individuals with alexithymia but without autism raise the possibility that levels of co-morbid alexithymia in individuals with autism determine the appropriateness of visual scan paths to emotional faces, particularly eye:mouth ratios which have been shown to be important for recognising emotion (Aviezer et al. 2008; Calder et al. 2000; Smith et al. 2005; Wong et al. 2005). Varying degrees of co-morbid alexithymia across studies may therefore explain the heterogeneity of findings in relation to atypical eye:mouth fixation behaviour in autism. Accordingly, the aim of this exploratory study was to examine the eye-gaze behaviour of a group of high-functioning adults with autism in response to dynamic video stimuli depicting social interaction. We aimed to investigate the impact of autistic symptom severity and alexithymia on eye-gaze behaviour in a sample of 13 high-functioning adults with autism.

Method

Participants

Thirteen individuals (mean age 40.5 years, SD 14.5 with an independent clinical diagnosis of an Autism Spectrum Condition participated in this study (see Table 1). 10 participants were male, the group's mean IQ, measured using the Wechsler Adult Intelligence Scale-3rd UK Edition (Wechsler 1999) was 115 (SD 14). The mean alexithymia score, as measured by the 20-item Toronto Alexithymia Scale (TAS, Bagby et al. 1994) was 60 (SD = 11). Although a continuous measure, research on individuals without a diagnosis of ASC suggests that scores under 51 on the TAS indicate a lack of alexithymia, while scores over 61 indicate alexithymia (Bagby et al. 1994). The ADOS (conducted by a trained and certified administrator) was used to characterise the participants' current level of functioning—on this measure seven participants met criteria for autism and six participants met criteria for an autism spectrum condition (total ADOS score of 7 or more). This group was compared to a Control group of 13 individuals without an Autism Spectrum Condition diagnosis matched on age (mean 32.8 years, SD = 10.8; $F_{(1,24)} = 2.5$, $p = 0.13$, $\eta^2 = 0.094$), and IQ ($F_{(1,24)} < 1$, $p = 0.8$, $\eta^2 = 0.003$). Neither age, nor IQ, correlated with the gaze data reported below.

Table 1 Clinical Diagnoses, Autism Diagnostic Observational Schedule (ADOS), Toronto Alexithymia Scale (TAS) and full-scale IQ scores for the ASC group

Participant	Clinical diagnosis	ADOS total score	TAS	Full-scale IQ
1	AS	7	51	124
2	ASD	10	54	102
3	AS	8	59	103
4	ASD	7	80	116
5	AS	10	55	112
6	AS	7	61	132
7	Atypical A	11	62	140
8	AS	15	41	118
9	AS	17	73	91
10	AS	9	45	128
11	AS	9	72	103
12	AS	12	59	107
13	A	14	65	116

Clinical diagnosis refers to the original clinical assessment provided by a psychologist or psychiatrist (*A* Autism, *AS* Asperger's Syndrome, *ASD* Autism Spectrum Disorder)

Apparatus

Participants sat in a reclining chair looking up at an arm-mounted 19" LCD screen approximately 60 cm away. A Bobax3000 remote eye tracker was mounted at the base of the display, consisting of a camera focused on the participant's eye and a set of LED illuminators. The participant wore a headset, through which they could hear the stimuli and speak to the experimenter. Gaze position and regions of interest that were fixated were calculated approximately 100 times a second. In addition, an audio–video record of what the participant saw, heard and said during the experiment was recorded, superimposed with their gaze position.

Stimuli

Participants viewed four video clips. Two were taken from a popular TV drama series ("Damages") and were selected to show two individuals engaged in a significant emotional, social interaction. They lasted 61 and 98 s. The other two clips were of a newsreader delivering news items straight to camera, and lasted 20 s each. These clips were selected as they simulate direct eye-gaze, that is, the gaze of the newsreader is towards the camera. Video clips were presented with their original soundtracks to which participants listened via headphones. Statistical analyses demonstrated that eye-gaze behaviour did not vary as a function of video type and therefore average measures were taken across all four video stimuli. Regions of interest were defined across the entire scene, and around the faces of the one or two people onscreen, and these face regions were further subdivided into eye and mouth regions. Regions were redrawn for each scene cut, and so changed in size and position. The smallest regions were approximately $4^\circ \times 2^\circ$ of visual angle.

Procedure

The eye-tracking experiment was carried out as part of a larger battery of tests that required 4 h of testing in total. The order of the tests completed by participants was determined randomly across participants. A 9-point calibration routine was performed that took under a minute. Participants were told that they would be shown clips from TV and at random intervals they would be given a short visual attention test. On these trials they were required to fixate a central cross until it disappeared, and then move their eyes as quickly as possible to a target stimulus that appeared in a random location. The participants then watched the video stimuli in a randomized order, interspersed with 'visual attention tests'. They were instructed that the purpose of the study was to look at the effects of watching the videos on their ability to move their eyes to the target in the attention tests. This cover story was intended to make the eye tracking during the video stimuli less salient; suggesting instead that the eye tracker was calibrated for the visual attention test. In total, the study took no more than 12 min.

Data Analysis

Two measures were derived per participant across all clips. The first served as an index of social attention and was the ratio of the total time spent fixating the face compared to non-face areas of the screen (face:non-face ratio). The second was the ratio of eye to mouth fixations when a face was fixated (eye:mouth ratio). Thus, a ratio of 0.5 on the face:non-face or eye:mouth measure indicates equal attention to face and non-face, and eye and mouth stimuli, respectively. Face:non-face ratios greater than 0.5 indicate an attentional preference towards face stimuli in comparison with non-face stimuli, while ratios less than 0.5 indicate a preference towards non-face stimuli in comparison with face stimuli. Eye:mouth ratios greater than 0.5 indicate an attentional preference towards eye stimuli in comparison with mouth stimuli, while ratios less than 0.5 indicate a preference towards mouth stimuli in comparison with eye stimuli.

Results

Group Comparison

In order to characterise the attention profile of the ASC Group they were compared to the matched Control group (see Fig. 1). Analyses revealed that the ASC group (face:non-face ratio $M = 0.45$, $SD = 0.13$) were significantly less likely than the Control group (face:non-face ratio $M = 0.55$, $SD = 0.07$) to attend to face stimuli than non-face stimuli ($F_{(1,24)} = 5.8$, $p = .02$, $\eta^2 = 0.194$). The use of ratio measures allows one to test whether either group show a significant bias towards face or non-face stimuli by comparing each group's mean score against a value of 0.5 which would indicate no preference for either stimuli. The Control group show a preference for faces ($t_{(12)} = 2.56$, $p = .03$, Cohen's $d = 1.48$), however, the ASC group showed no such preference ($t_{(12)} = -1.35$, $p = .20$, $d = 0.78$).

Analysis of the eye:mouth ratios for each group provides an index of where on the face each group attended when they were looking at the face stimuli. Despite the ASC group spending less time overall looking at the eye stimuli, the ratio of eye:mouth fixations when they were fixating the

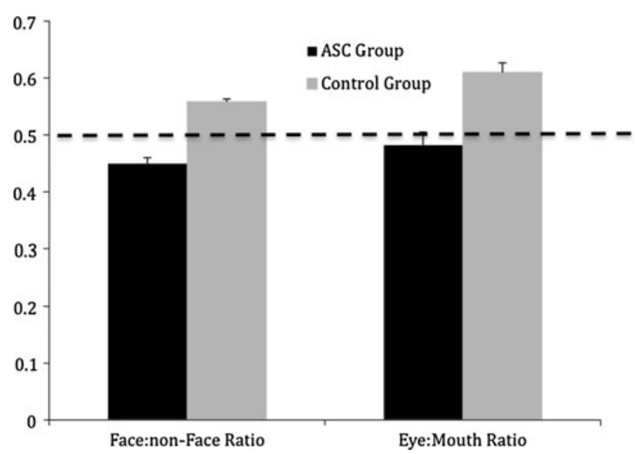

Fig. 1 The ratio of face:non-face and eye:mouth fixations for both the group of individuals with an Autism Spectrum Condition (ASC Group) and the Control Group. A ratio of 0.5 (*dashed line*) indicates equal attention to both stimulus classes. Ratios greater than 0.5 indicate an attentional preference towards the first stimulus class (face or eye stimuli), while ratios less than 0.5 indicate a preference towards the second stimulus class (non-face or mouth stimuli)

face did not differ significantly as a function of group (ASC Group $M = 0.48$, SD = 0.30, Control Group $M = 0.64$, SD = 0.21, $F_{(1,24)} = 2.49$ $p = .13$, $\eta^2 = 0.094$). The mean ratio from each group was tested against 0.5 to identify any preferences for eye or mouth stimuli. These analyses showed a preference for eye fixation in the Control group ($t_{(12)} = 2.42$, $p = .03$, $d = 1.40$) but no preference for the ASC group ($t_{(12)} = -0.22$, $p = .83$, $d = -0.13$).

ASC Group

Correlation coefficients were computed separately for TAS and ADOS scores with face:non-face, and eye:mouth ratios within the ASC group. TAS scores were significantly correlated with eye:mouth ratios ($r = -0.681$, $p = .01$) but not face:non-face ratios ($r = -0.302$, $p = .32$), while ADOS scores were significantly correlated with face:non-face ratios ($r = -0.743$, $p = .004$) but not eye:mouth ratios ($r = -0.211$, $p = .49$) (see Fig. 2).

In order to formally assess the contribution of TAS and ADOS scores in relation to each other, two stepwise regression analyses were performed on data from the 13 participants in the ASC group: the first included TAS as an initial predictor of face:non-face ratio with ADOS scores as a subsequent predictor; the second regression model included ADOS scores as an initial predictor of eye:mouth ratios with TAS scores entered as a subsequent predictor. Results of the first regression showed, as expected, that TAS did not predict face:non-face ratio (F 1,11 = 1.1, $p = .32$, $r^2 = 0.09$), but when ADOS was added to the model, the change in variance accounted for (change in r^2) was significant (F 1,10 = 16.5, $p = .002$, r^2 change = 0.57, full model F 2,10 = 9.6, $p = .005$, $r^2 = 0.66$). The second regression indicated that eye:mouth ratio was not predicted by ADOS scores (F 1,11 < 1, $r^2 = 0.04$) but when TAS scores were added to the model the change in variance accounted for was significant (F 1,10 = 9.8, $p = .011$, r^2 change = 0.47, full model F 2,10 = 5.4, $p = .026$, $r^2 = 0.52$).

Discussion

Results indicated that, in comparison to the typically-developing Control group, the ASC group spent less time fixating face than non-face stimuli when watching the video stimuli. When fixating the face, the two groups did not differ in terms of eye:mouth fixations. However, the Control group demonstrated a preference to attend to eyes over mouth areas of the face that was not shown by the ASC group. Within the ASC group, results showed that the degree of social attention, as indexed by fixations to the face compared to all non-face areas, was significantly predicted by autism symptom severity but was not predicted by levels of alexithymia. In contrast, attention to the eyes and mouth was predicted by levels of alexithymia but not autism symptom severity.

These results may provide a basis for resolving two inconsistent findings in autism. First, as previously discussed, studies using eye-tracking in autism have reported inconsistent visual scan path findings with regard to eye and mouth fixation in autism. The present results suggest that the degree to which atypical scan paths are observed in autism is unrelated to symptom severity, indeed atypical

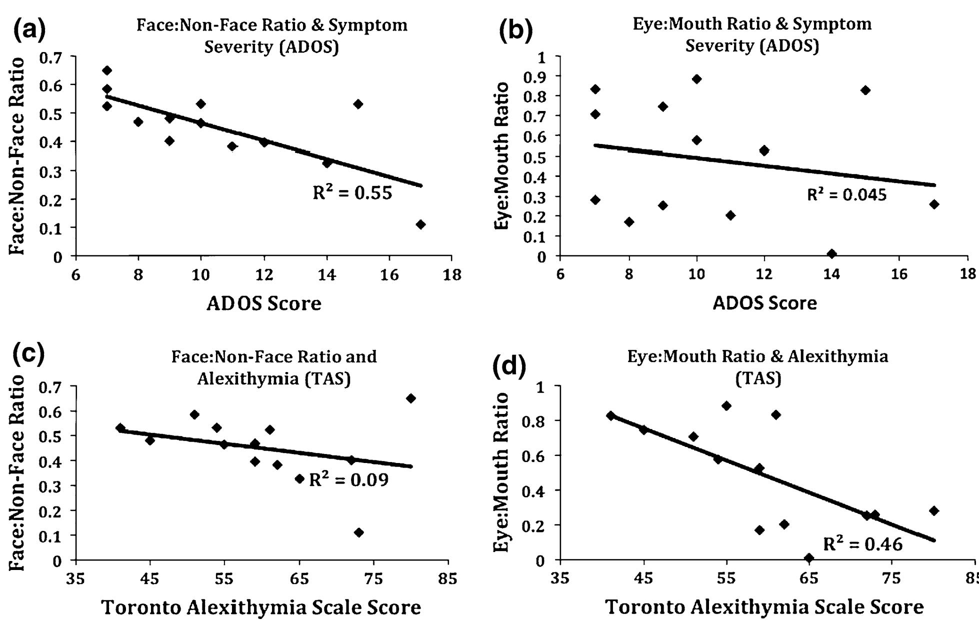

Fig. 2 The relationship between symptom severity as measured by the Autism Diagnostic Observational Schedule (ADOS) and (**a**) the ratio of face and non-face fixations, and (**b**) the ratio of eye and mouth fixations. In addition, the relationship between levels of alexithymia as measured by the Toronto Alexithymia Scale and (**c**) the ratio of Face and Non-Face fixations, and (**d**) the ratio of eye and mouth fixations. R^2 values indicated on each graph

scan paths of the eyes and mouth may be unrelated to autism diagnosis, but instead are determined (in part) by the degree of co-morbid alexithymia in the sample of individuals with autism. Second, many studies have demonstrated the importance of typical scan paths in recognising facial emotion (Aviezer et al. 2008; Calder et al. 2000; Smith et al. 2005; Wong et al. 2005), therefore if alexithymia is associated with atypical scan paths to eyes and mouth, then the inconsistent findings with respect to recognition of emotional facial expression in autism (see Bal et al. 2010; Jemel et al. 2006) may also be explained by varying degrees of co-morbid alexithymia in the sample of individuals with autism across studies. We suggest therefore, that future studies of emotion processing in individuals with autism obtain measures of alexithymia in order to determine whether any impairments seen are due to autism, alexithymia, or the combination of these two factors.

These results may also explain the previous finding of impaired emotion recognition in alexithymia. As emotion recognition relies on appropriate fixation of the inner features of the face (Aviezer et al. 2008; Calder et al. 2000; Smith et al. 2005; Wong et al. 2005), the atypical visual scan paths exhibited by alexithymic individuals may therefore result in impaired recognition of emotion from facial expressions. These results support 'shared network' (Preston and de Waal 2002) accounts of social cognition. Alexithymia is defined (and measured by) problems identifying and describing emotions in the self, yet these data show that alexithymia results in atypical scan paths necessary to accurately 'decode' emotion in the other (Adolphs et al. 2005). In combination with the results of Bird et al. (2010), who showed impaired empathy in alexithymic individuals, evidence is accumulating for the idea that impaired representation of emotion in the self is associated with impaired representation of emotion in the other. With respect to the current question however, future research must establish whether it is atypical scan paths that cause poor emotion recognition, or emotion recognition deficits that lead to atypical scanning.

In line with previous research, autism was associated with atypical gaze behaviour: symptom severity was associated with the amount of time spent fixating the face in comparison with non-face stimuli. We would argue that this measure relates to social attention and is commensurate with previous claims of reduced social attention in autism (Klin et al. 2002). In a break with previous research, however, we claim that there is a second distinct influence within these data: an inability to attend to emotional facial features in an optimal manner that is associated with alexithymia. Such a distinction supports the independence of autism and alexithymia reported elsewhere (Bird et al. 2010; Hill et al. 2004; Silani et al. 2008), although the reason for the increased prevalence of alexithymia in individuals with autism is still unknown.

It should be noted that (to our knowledge), this is the only study to investigate the influence of alexithymia on eye-gaze behaviour in ASC. It is also clear that differing levels of alexithymia across study samples cannot be the only explanation of inconsistencies in the literature on eye-gaze in ASC. For example, Speer et al. (2007) found reduced eye-fixation by individuals with ASC only when dynamic stimuli involving social interaction were used. Static stimuli, and dynamic stimuli involving no social interaction did not result in a reduction in eye-fixation in the ASC group. The current results therefore require further investigation, both with a larger sample size and a greater range of stimuli. One stimulus factor of interest is the presence of an accompanying soundtrack. The video stimuli used in the current experiment included sound; it would be useful to systematically investigate the interaction between sound and motion due to reports of preferences for audio visual synchrony in ASC (Klin et al. 2009). It should also be noted that five volunteers with ASC were tested in both the current study, and that reported in Bird et al. (2010). The reported relationships between alexithymia and eye:mouth ratio and social attention and face:non-face ratio were still significant when these individuals were excluded however, and neither their ADOS, nor their TAS-20 scores were extreme. We therefore suggest that the current results and those reported in Bird et al. (2010) are not due to this particular subset of participants. It is clear however, that these results require replication in other individuals with ASC.

It is an open question whether the relationship between alexithymia and eye:mouth fixation behaviour holds in typically-developing individuals, or just in individuals with ASC. Data from Bird et al. (2010) shows that the pattern of reduced empathic brain activity in alexithymic individuals is identical whether those individuals have ASC or not. However, more research is needed on the important question of whether alexithymia in individuals with ASC is due to the same cause, and is manifested similarly, as in individuals without ASC. Notwithstanding these limitations, these results and others (Bird et al. 2010; Silani et al. 2008) suggest that the presence of alexithymia defines a subgroup of individuals with an autism spectrum disorder who exhibit emotional impairments related both to the self and the other in addition to the characteristic social impairments.

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