Alexithymia in adolescents with autism spectrum disorder: Its relationship to internalising difficulties, sensory modulation and social cognition

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Abstract

Alexithymia is a personality trait frequently found in adults with Autism Spectrum Disorder (ASD), and has been linked to impairments in emotion recognition and empathy. The presentation of alexithymia within ASD at younger ages remains unexplored, and was examined in the present study. Alexithymia rates were significantly elevated in ASD (55%; 31/56 scoring above cut-off) versus non-ASD adolescents (16%; 5/32 scoring above cut-off). Within individuals with ASD, alexithymia was associated with increased self-reported anxiety, parent-reported emotional difficulties, self-reported sensory processing atypicalities, and poorer emotion recognition, but was not associated with theory of mind ability. Overall, our results suggest that alexithymia is highly prevalent, and has selective cognitive correlates in young people with ASD.

Keywords: Alexithymia, Autism Spectrum Disorder, Emotion Recognition, Theory of Mind, Anxiety, Sensory Processing

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Individuals with autism spectrum disorder (ASD) have difficulties in social communication and social relating, show restrictive and repetitive patterns of behaviour, and hyper- and hypo-sensitivity to sensory input (American Psychological Association 2013). They frequently experience co-occurring mental health problems, notably anxiety disorders (Simonoff et al. 2008). The reasons behind the elevated rates of mental health problems in individuals with ASD remain under exploration. Recent research suggests that individuals with ASD also have elevated rates of the personality trait alexithymia, with a prevalence of 40-65% reported in adults with ASD (Berthoz and Hill 2005; Hill et al. 2004), versus 10% in typically developing populations (Salminen et al. 1999). Alexithymia (Sifneos 1973) is defined by difficulties in identifying and describing feelings, difficulties distinguishing feelings from the bodily sensations of emotional arousal, and a tendency to focus on external events rather than inner experiences (Taylor et al. 1991). It is conceptualised as a difficulty in cognitively mapping feeling states onto internal bodily responses (Taylor 2000).

Given the high rate of co-occurrence, it is possible that certain aspects of the cognitive profile reported in ASD may be related to the presence of alexithymia. Bird and Cook (2013) have suggested that emotion recognition and empathy atypicalities seen in individuals with ASD may result from (co-occurring) alexithymia rather than ASD itself. Furthermore, given that alexithymia is associated with higher rates of anxiety and depression (Bankier et al. 2001; Berthoz et al. 1999; Honkalampi et al. 2000) and atypical responses to sensory input (Herbert et al. 2011; Kano et al. 2007; Katz et al. 2009; Lyvers et al. 2014; Nyklicek and Vingerhoets 2000) in non-ASD populations, individual differences in alexithymia may also be associated with the increased rates of internalising disorders and sensory sensitivities in ASD.

Alexithymia and internalising disorders

Taylor et al. (1999) propose that alexithymia is primarily a disorder of affect regulation, leading to difficulties in modulating the autonomic nervous system, thus resulting in hyper-arousal in response to stress. In line with this view, there are consistent reports of increased anxiety, particularly panic disorder, among non-ASD individuals with elevated alexithymia (Bankier et al. 2001; Berthoz et al. 1999; Marchesi et al. 2005). Additionally, one prospective longitudinal study found that higher alexithymia in early adolescence was associated with the development of an anxiety disorder four years later (Karukivi et al. 2014). The relationship between alexithymia and depression is potentially more complex. While some studies report higher rates of depression in individuals with high alexithymia (Honkalampi et al. 2000), others suggest that this association is mediated by anxiety (Karukivi et al. 2010; Marchesi et al. 2000).

The association between alexithymia and emotional problems, particularly anxiety, is highly relevant to ASD as studies find between 42% and 84% of individuals with ASD have co-occurring anxiety disorders (Simonoff et al. 2008; White et al. 2009). Furthermore, up to 24% of young people with ASD experience depressive symptoms (Leyfer et al. 2006). While depression does not co-occur as frequently as anxiety in young people with ASD, its prevalence is higher than in the general population and can be highly functionally impairing (Kim et al. 2000; Mattila et al. 2010). Since alexithymia occurs more frequently in individuals with ASD, it may be related to the elevated emotional difficulties also observed in this group. However, the relationship between alexithymia and emotional disorders within ASD remains under exploration. Berthoz et al. (2013) found that adults with ASD exhibit increased alexithymia, anxiety and depression, but did not explore the relationship between these factors. The current study therefore sought to investigate the relationship between alexithymia, anxiety and depression in young people with ASD. We chose to use both self

and parent-report measures of internalising symptoms, due to suggestions that young people with ASD have difficulty reporting on their emotional experiences (Mazefsky et al. 2011).

Alexithymia and sensory processing atypicalities

Alexithymia is associated with a heterogeneous pattern of sensory modulation. On the one hand, individuals with elevated alexithymia can exhibit hypersensitivity to sensory input, such as lower tolerance of pain and heat, and over responsiveness to visceral stimulation (Kano et al. 2007; Katz et al. 2009; Nyklicek and Vingerhoets 2000). On the other hand, they also show reduced awareness and registration of internal bodily signals (Ernst et al. 2014). For example, individuals with elevated alexithymia show weaker registration of arousal resulting from chemical intake (e.g. caffeine) and poorer awareness of increases in their own heart rate (Herbert et al. 2011; Lyvers et al. 2014). Additionally, a recent study found evidence of reduced multisensory integration in alexithymia (Grynberg and Pollatos 2015). It is possible that sensory modulation atypicalities within alexithymia mirror the emotional awareness difficulties that occur with this trait, whereby there is a discrepancy between somatic activity and subjective reports of sensory experience (Grynberg and Pollatos 2015).

ASD is characterised by a complex and heterogeneous pattern of sensory modulation, with both increased sensitivity and reduced responsiveness to sensory input often observed within the same individual (Baranek et al. 2006; Crane et al. 2009; Hirstein et al. 2001). Recent studies suggest that up to 90% of children with ASD report some form of sensory sensitivity (Leekam et al. 2007). Although sensory atypicalities are more frequent and pronounced in childhood, they continue to persist through adolescence and into adulthood (Kern et al. 2007). Individuals with ASD often exhibit high levels of distress to low-threshold input, such as ordinary sounds, textures and smells (Tomchek and Dunn 2007; Tomchek et al. 2014). By contrast, they also show reduced responsiveness and registration of input (such as failing to orient to novel stimuli or react when their name is being called) as well as sensory

seeking behaviours (Kern et al. 2007). While the causes of atypical sensory processing in ASD are unclear, the pattern of concurrent increased and reduced responding to sensory stimulation is indicative of a difficulty managing one's response to sensory input, rather than having a specific style of atypical processing (Dunn et al. 2002). There appears to be overlap between the patterns of sensory modulation atypicalities that occur within each condition, whereby sometimes individuals exhibit heightened responses to sensory events and at other times fail to attend to them. However, the relationship between sensory sensitivities and alexithymia within ASD has not yet been explored.

Alexithymia and Social Cognition

Alexithymia has been associated with a difficulty in identifying the emotions of others in both ASD and non-ASD populations. Within non-ASD populations, individuals with elevated alexithymia exhibit reduced accuracy in emotion recognition, particularly for negative emotions such as anger (e.g. Pandey and Mandal 1997; Prkachin et al. 2009; Reker et al. 2010). Additionally, Berthoz et al. (2002) reported that individuals with high alexithymia exhibit weaker brain activation when viewing emotional faces and this is specific to negative emotions (particularly anger). Emotion recognition difficulties are also found in individuals with ASD (Uljarevic and Hamilton 2013), although there is a high rate of variability in performance (Bird and Cook 2013; Jones et al. 2011). Bird and Cook (2013) have suggested that the presence of alexithymia may account for this variability, and found that alexithymia, not autism severity, predicts difficulties in identifying emotions from facial or vocal expressions (Cook et al. 2013; Heaton et al. 2012), as well as with the strength of neural responses to watching people in pain (Bird et al. 2010). The explanatory role of co-occurring alexithymia in ASD is proposed to be specific to particular facets of social cognition, namely emotion processing. Conversely, theory of mind impairments are hypothesised to be intrinsic to ASD rather than due to alexithymia, although this has not been

formally tested in individuals with ASD. Emotion recognition and theory of mind are thought to be distinct systems, representing different types of information (e.g., affective representation vs. cognitive computation) and associated with independent neuroanatomical regions (Shamay-Tsoory et al. 2009), which dynamically interact to support typical empathic functioning (Bird and Viding 2014; de Waal 2008). Hence differential relationships with alexithymia might be expected. Several studies have explored the relationship between alexithymia and theory of mind, with equivocal results (e.g. Moriguchi et al. 2006; Wastell and Taylor 2002). Only one study to date has explored the differential relationship between emotional resonance and theory of mind with alexithymia and sub-clinical ASD traits (Lockwood et al. 2013). In this study, high levels of alexithymia were related to poorer emotional resonance but not theory of mind. Sub-clinical ASD traits, on the other hand, were associated with reduced theory of mind but not emotional resonance.

Using a well-characterised sample (the Special Needs and Autism Project; Baird et al. 2006), the present study aimed to extend current knowledge by exploring the correlates of alexithymia in adolescents with ASD. The presence of alexithymia may be one contributor to the wide heterogeneity in the behavioural phenotype and cognitive profile found among individuals with ASD. Furthermore, as previous research on alexithymia in ASD has been limited to adult populations, the prevalence and correlates of alexithymia in younger age groups with ASD remain unknown. Given the present literature, the current study tested the following hypotheses:

1. Adolescents with ASD will have elevated alexithymia compared to adolescents without ASD.
2. For those with ASD, higher levels of alexithymia will be associated with increased self-reported anxiety and depression, parent-reported emotional difficulties and self-reported sensory modulation atypicalities.

3. For those with ASD, higher levels of alexithymia will be associated with impaired emotion recognition, but not theory of mind ability.

Method

Sample

The current sample was drawn from the Special Needs and Autism Project (SNAP) cohort. This cohort was drawn from 56,946 children living in the South Thames area of England and born between July 1990 and December 1991, initially as part of an autism prevalence study (see (Baird et al. 2006) for further details). All participants with a diagnosis of ASD received a consensus clinical ICD-10 ASD diagnosis made by 3 expert clinicians (GB, ES, TC) following a comprehensive diagnostic assessment that included the Autism Diagnostic Interview-Revised [ADI-R; (Le Couteur et al. 1989)] and Autism Diagnostic Observation Schedule-Generic [ADOS-G; (Lord et al. 2000)], as well as assessment of language, IQ, adaptive behaviour, psychiatric comorbidities and a medical examination (see Baird et al. 2006; for details). Twenty-six participants who did not meet clinical criteria for an ASD formed part of the non-ASD group (Baird et al. 2006). They had a range of primary ICD-10 diagnoses (16 mild intellectual disability; 3 moderate intellectual disability; 3 specific reading/ spelling disorder; 2 AD/HD; 1 expressive/receptive language disorder; 1 no diagnosis). The remaining non-ASD participants (n=31) were drawn from local mainstream schools, giving a total of 57 non-ASD participants. Parent and teacher report confirmed that none had a psychiatric or developmental diagnosis, a statement of special education needs, or were receiving medication. The Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003) was collected from parents of 25 of the 31 adolescents; no individual scored 15 or above, which is the cut-off for ASD.

The SNAP cohort was assessed at ages 12 and 16 years. Assessment at 16 years focussed on the cognitive phenotype of ASD and only those who had estimated IQ > 50 at 12 years and could communicate verbally were included (Charman et al. 2011). All questionnaires and cognitive tasks within the current study were administered at age 16 years. From the total SNAP cohort assessed at age 16 (N=157; 100 participants with ASD and 57 non-ASD participants), only participants who had completed the TAS-20 at age 16 years were included in current analyses (N=88); giving 56 adolescents with a diagnosis of ASD and 32 adolescents without a diagnosis (non-ASD group).

The study was approved by the South East Multicentre Research Ethics Committee (REC) (05/MRE01/67). Written informed consent was obtained from all parents.

Self-Rated Questionnaire Measures

Alexithymia: Alexithymia was measured using the self-rated 20-item Toronto Alexithymia Scale [TAS-20; (Bagby et al. 1994a; Bagby et al. 1994b)]. The TAS-20 is comprised of three subscales; difficulty identifying feelings (e.g., 'I am often confused about what emotion I am feeling'), difficulty describing feelings (e.g., 'It is difficult for me to find the right words for my feelings') and a tendency for externally orientated thinking (e.g., 'Looking for hidden meaning in movies or plays distracts from their enjoyment'). Each statement is rated from 'strongly disagree' to 'strongly agree' on a 5 point Likert scale. It yields scores ranging from 20-100, and authors suggest that a score of >51 indicates the presence of alexithymia while a score of >61 indicates severe alexithymia (Taylor et al. 1999). In the current analyses, a binary cut-off was used to designate participants with (TAS-20 total >51), and participants without (TAS-20 total <51) co-occurring alexithymia. The TAS-20 has high internal reliability and validity (Parker et al. 2003). It had good internal consistency within our total sample (α=.84) and within the subsample of participants with ASD who were the focus of our main analyses (α=.82).

Anxiety: The self-rated State Trait Anxiety Inventory for Children [STAIC; Spielberger 1973)] was used to measure anxiety symptoms. The current study used the trait scale of the STAIC, which focusses on relatively stable feelings of apprehension, arousal and tension. The scale comprises of 20 statements, 10 are negatively framed (e.g., 'I feel nervous and restless') and 10 are positively framed (e.g., 'I feel satisfied with myself'). Each statement is rated from 'not at all' to 'very much so' on a 4-point Likert scale and positive statements are reverse-scored. The total scores range from 20-80, with higher scores indicating higher levels of anxiety. The trait scale had good internal consistency in our sample of participants with ASD (α=.89), comparable to that found in general populations (α=.87) (Knight et al. 1983).

Depression: The 18-item Depression Self-Rated Scale for children was used to assess depressive symptoms [DSRS; (Birleson 1981)]. The scale comprises of 18 statements, 9 negatively framed (e.g., 'I think life isn't worth living') and 9 positively framed (e.g., 'I look forward to things as much as I used to'). Respondents are asked to indicate how often they have experienced the feelings depicted in each statement over the past week by selecting 'never', 'sometimes' or 'most of the time'. The responses to each statement are rated on a scale of 0-2 and the positive items are reverse scored. The total scores range from 0-36, with higher scores indicating greater levels of depression. This questionnaire has good test-retest reliability (r=.80) and internal consistency (α=.86) (Birleson 1981), and discriminates well between clinician-rated depressed and non-depressed children (Birleson et al. 1987). In our sample of participants with ASD internal consistency was near acceptable (α=.69).

Sensory profile: Sensory sensitivities were measured using the self-report 60-item Adult/Adolescent Sensory Profile [AASP; (Brown et al. 2001)]. The subscales of the AASP are based on a four factor model indexing low registration (behaviours that indicate a high threshold to sensory stimulation, such as disregard or slow response to sensation), sensation

seeking (behaviours that seek to increase sensory input, for example making noises or exploring objects using ones skin), sensory sensitivity (behaviours that indicate a low threshold to sensory stimulation such as distractibility and difficulty screening stimuli) and sensation avoiding (behaviours that seek to control or limit the amount of sensory input, for example reliance on rigid rituals) (Dunn 1997). A higher score on any of the AASP subscales indicates the individual experiences or exhibits more of the sensory behaviour. The AASP had excellent internal consistency within our sample of participants with ASD (α=.91), which compares well with that reported in non-ASD samples (α=.73 in Brown et al. (2001)).

Parent-rated Questionnaire Measures

Emotional and behavioural symptoms: The parent-rated Strengths and Difficulties Questionnaire [SDQ; (Goodman et al. 2000)] was used to measure emotional and behavioural mental health symptoms. The SDQ has 25 items scored on a three-point scale (not true - somewhat true - certainly true), and comprises three psychiatric subscales of hyperactivity (ADHD symptoms), conduct problems, and emotional problems, along with two further subscales of peer relationship problems and prosocial behaviour. Current analyses focussed on the parent-report conduct, hyperactivity and emotional subscales only as these were deemed to be more directly relevant to the hypotheses. Internal consistency was acceptable in our sample of participants with ASD for the hyperactivity subscale (α=.74), and near acceptable for the emotional subscale (α=.68). Internal consistency for the conduct subscale was unacceptable (α=.45).

Autism severity: The parent-rated Social Responsiveness Scale [SRS; (Constantino et al. 2003)] was used as a measure of the severity of social difficulties associated with ASD. The SRS comprises 65 items providing a total score of autistic traits. The SRS had excellent internal consistency within our sample of participants with ASD (α=.94).

Cognitive measures

Cognitive ability: IQ was measured with the Wechsler Abbreviated Scales of Intelligence [WASI; (Wechsler 1999)] generating full-scale (FSIQ), verbal (VIQ) and performance, or nonverbal, (PIQ) IQ measures.

Emotion recognition: The Ekman-Friesen test of affect recognition was used to assess emotion recognition ability (Ekman and Friesen 1976). Participants were shown 60 black and white photographs of male and female faces depicting each of the six basic emotions (happy, sad, fear, surprise, anger, and disgust) on a PC screen. There were 10 pictures of each emotion category. Participants were told that they would be shown a series of faces and that they should 'decide how the person is feeling' and choose a word to 'best describe how the person is feeling'. The response sheet was a piece of laminated paper with grid squares containing the 6 response options: 'Happiness', 'Sadness', 'Anger', 'Fear', 'Surprise' and 'Disgust'. Both verbal responses and pointing to the emotion label were considered valid responses; the experimenter inputted the responses using the keypad. The total number of correct responses for each of the six emotions (happy, sad, fear, surprise, anger, disgust) was analysed, alongside the total overall score.

Theory of mind: The Strange Stories task (Happé 1994) was used as a general measure of mental state understanding. The participants were read a series of six stories, which were also available in front of them and accompanied by an appropriate 'picture book' illustration. At the end of each story, which included at least one character, they were asked a question about the text. Four of the stories necessitated understanding of the protagonist's mental state to correctly answer the question. The other two stories were control items, where the answer could be correctly inferred without mental state understanding. The outcome variable was the average score across these four theory of mind items (score range 0-2, with 0 representing an incorrect or "don't know" response, 1 a partial or implicitly correct response, and 2 representing a full and explicitly correct answer).

The Frith-Happé animations (Abell et al. 2000) consist of a series of silent video animations of a pair of interacting cartoon triangles. Participants were asked to describe the interactions of the triangles. Four animations depicted theory of mind interactions, with the triangles coaxing, mocking, seducing or surprising each other, and two animations depicted goal-directed interactions (fighting, chasing). The outcome variable was the average intentionality score across the four theory of mind interactions (score range 0-5, with scores calculated based on the degree of mental state attribution given in the participants' description of the interactions).

The Combined False Belief task (designed by Rhonda Booth, Institute of Psychiatry) is a combination of first and second order false belief tasks based on previous tasks used to measure false belief understanding (Baron-Cohen 1989; Bowler 1992). Participants were read a story about two characters; Mary and John, whilst viewing cartoon depictions of the story. They were told that Mary and John hide some chocolate in the kitchen fridge but, whilst Mary is outside, John removes the chocolate and places it in his bag. The first order false belief question asks: "Where does Mary think the chocolate is?". The participant was also asked a justification question ("Why does Mary think the chocolate is in the _____?").

For the second order part of the story, the participant is told that when John was hiding the chocolate, Mary saw him from the kitchen window, but that John did not see Mary looking. The second order false belief question asks: "Where does John think Mary will look for the chocolate?". The participant is again asked a justification question ("Why does John think Mary will look for the chocolate in the _____?").

The two outcome variables were performance on the first and second order parts of the story. If the participant failed the false belief question, then the overall score was automatically set to zero (score range 0-2 for answers given from the first order false belief

task, 0-3 for answers given from the second order false belief task, with a higher score reflecting better performance).

Statistical Analysis

All data reduction and statistical analysis were undertaken in Stata version 11 (StataCorp 2009). Chi-squared was used to compare the percentage of participants scoring above threshold for the presence of alexithymia between the ASD and the non-ASD group. Due to small numbers in our non-ASD group giving us insufficient power, associations between mental health symptoms, sensory sensitivities and cognitive task performance and alexithymia focussed upon the ASD group, comparing those with and without co-occurring alexithymia. Bivariate comparisons of demographic characteristics, mental health symptoms and sensory sensitivities were explored between the ASD with co-occurring alexithymia group, and the ASD without co-occurring alexithymia group using ANOVA. Significant associations between the presence of alexithymia, mental health problems and sensory sensitivities were subsequently co-varied for VIQ (which differed between the ASD participants with and without co-occurring alexithymia; see below). Both the emotion recognition task, in which six different emotions were assessed, and the theory of mind tasks were analysed using multivariate regression to increase efficiency and reduce type 1 errors from multiple testing. For both analyses, the overall combined emotion recognition/theory of mind score was first entered into the regression and subsequently each emotion/theory of mind task was entered as a separate predictor in the regression model. Significance of associations between alexithymia and performance on the cognitive tasks were determined from Wald tests using the robust form of the parameter covariance matrix. Significant associations were subsequently co-varied for both VIQ and anxiety, because of previously reported relations between anxiety and task performance in other samples (e.g. Reker et al. 2010). Co-varying for VIQ and anxiety in our analyses allowed us to determine whether any

significant associations found were solely due to the presence alexithymia. All confidence intervals are for the 95% significance level. Cohen's d is reported to indicate the effect size of significant findings (Cohen 1973).

Results

Prevalence of alexithymia

Participants in the ASD group exhibited significantly higher rates of alexithymia than those in the non-ASD group, with 31 out of 56 (55%) scoring above the recommended cut-off (>51) on the TAS-20 as compared to 5 out of 32 (16%) in the non-ASD group ($X^2 = 13.30$, df = 1, $p < .01$). Furthermore, 16 participants from the ASD group (29%) versus 5 from the non-ASD group (16%) scored above the "severe" alexithymia cut-off (>61); however due to the small numbers, analyses focussed on those with and without alexithymia using the >51 cut-off.

ASD +/- alexithymia

Table 1 gives descriptive characteristics for participants with ASD with versus without co-occurring alexithymia (ASD+/-ALX). There were no significant differences in age, gender ratio, or SRS scores between the ASD-ALX and the ASD+ALX groups. The ASD+ALX group had a marginally significantly lower VIQ than the ASD-ALX group [$F(1,54) = 4.02$, $p = .05$, d=0.54], but performance and full scale IQ did not differ.

Emotional and Behavioural Symptoms

Self- and parent-reported emotional and behavioural problems in the participants with ASD with and without alexithymia are shown in Table 2. The ASD + ALX group had greater self-reported anxiety on the STAIC than the ASD-ALX group [$F(1,52) = 7.87$, $p = .007$, d = 0.77]. This difference remained significant when VIQ was controlled for [$F(1,51) = 11.00$, $p < .01$]. Additionally, this difference still remained significant when both depression and VIQ were controlled for [$F(1,48) = 5.84$, $p = .02$]. The ASD +ALX group also showed a trend

toward increased self-reported depression on the DSRS, scoring higher than the ASD-ALX group [$F(1,51) = 3.28$, $p = .076$, d = .50], and this difference became significant when VIQ was controlled [$F(1,50) = 4.52$, $p = .04$]. However, when anxiety and VIQ were controlled for, the group differences in depression became non-significant, although still of moderate effect size [$F(1,48) = 0.174$, $p = .68$, d = .50]

With regard to parent-rated questionnaires, the ASD+ALX group had marginally greater levels of emotional symptoms (as rated by the SDQ) than the ASD-ALX group [$F(1,53) = 3.73$, $p = .058$, d = .52]. This group difference became significant when VIQ was accounted for [$F(1,52) = 4.25$, $p = .04$]. No group differences were found for hyperactivity or conduct problems.

Sensory Sensitivities

Rates of self-reported sensory sensitivities (as rated by the AASP) between groups are shown in Table 3. The ASD+ALX group had a trend towards higher scores on the low sensory registration subscale [($F(1,49) = 3.74$, $p = .059$, d = .54]. This difference became significant when the effect of VIQ was controlled [$F(1,48) = 4.28$, $p = .04$]. No group differences were found for the sensory seeking, sensory sensitivity or sensory avoidance subscales.

Cognitive Correlates

Total emotion recognition and theory of mind task scores are shown by group in Table 4. Multivariate regression testing for each emotion individually found that the ASD+ALX group showed a specific decrease in recognition accuracy for anger (β=-1.03, p=.04), but did not significantly differ in recognition of other emotions. When VIQ and anxiety were controlled for, the association with anger recognition dropped to a trend (β= -.10, p= .08). Multivariate regression found no differences in performance between the

ASD+ALX and the ASD-ALX groups in any of the theory of mind tasks. Accounting for VIQ and anxiety did not alter the pattern of results.

Since VIQ was lower in the ASD+ALX group, we sought to determine whether individuals with very low VIQ might have had difficulty completing the cognitive tasks, as these are reliant upon understanding verbal information. To further explore the role of VIQ, we ran a correlation between TAS-20 and VIQ scores, which revealed a trend level association between the two (r^2= -.25, p=.05). Subsequently, four participants with significantly low VIQ (IQ<70 being considered as "extremely low" score on the WASI and consistent with intellectual disability) were removed from the analysis. Within the sub-set of participants with VIQ >70, the decrease in emotion recognition accuracy in the ASD+ALX group remained at trend level for anger (β= -.11, p= .07) when both anxiety and VIQ were controlled for. There were no differences in performance on the theory of mind tasks.

Discussion

The present study is the first to explore the prevalence of alexithymia in adolescents with ASD, and its association with emotional and behavioural symptoms, sensory sensitivities, and cognitive performance. Fifty-five percent of the ASD sample scored above the TAS-20 threshold for alexithymia, as compared to 16% in the non-ASD group. Co-occurring alexithymia was associated with increased self-reported anxiety, parent-reported emotional difficulties, and self-reported sensory processing atypicalities. Alexithymia was also related to reduced emotion recognition accuracy, singly for anger, but not with theory of mind ability. Results suggest alexithymia is highly prevalent in young people with ASD, and has specific and selective associations to emotional difficulties, reduced sensory awareness, and emotion recognition performance.

Prevalence of alexithymia and associated demographic characteristics

Fifty-five percent of the ASD sample scored above the TAS-20 threshold for alexithymia. This is in line with previously reported rates of 40-65% in ASD adult populations, and supports the proposal that alexithymia is more prevalent in individuals with ASD than in the general population (Berthoz and Hill 2005; Hill et al. 2004). Alexithymia was not associated with autism severity, suggesting this is not merely a 'by-product' of having severe autism, but a specific and independent trait, which is seen in some, but not all, individuals with ASD – as well as many clinical groups outside ASD.

Participants with ASD and co-occurring alexithymia had lower verbal IQ (VIQ) but did not differ on performance or full scale IQ. There was a significant negative relationship between VIQ and TAS-20 scores, with participants scoring the lowest on VIQ reporting high levels of alexithymia.

The association of co-occurring alexithymia with emotional difficulties

In line with findings in non-ASD samples (Bankier et al. 2001; Berthoz et al. 1999; Marchesi et al. 2005), our study found that young people with ASD and co-occurring alexithymia reported significantly higher trait anxiety than those with ASD but without alexithymia. The high prevalence of anxiety in individuals with ASD is consistently reported (Simonoff et al. 2008; White et al. 2009), but the shared cognitive correlates between the two disorders remain under exploration (e.g. Hollocks et al. 2014).The results of the current study suggest that alexithymia is associated with higher rates of anxiety in individuals with ASD, similar to non-ASD populations.

The current study also sought to investigate whether alexithymia is associated with depressive symptoms in young people with ASD. Initially, co-occurring alexithymia did appear to be associated with increased depressive symptoms, when controlling for VIQ. However, once anxiety was controlled for, group differences in depression became non-significant. By contrast, when depression was controlled for in the analysis of anxiety levels,

group differences remained highly significant. This further supports previous findings suggesting that the relationship between depression and alexithymia is mediated by anxiety (Karukivi et al. 2010; Marchesi et al. 2000). Results also showed increased emotional difficulties, as reported by parents on the SDQ, in the group with co-occurring alexithymia. Furthermore, there were no group differences on the hyperactivity and conduct problem subscales of the SDQ, supporting the idea that that the relationship between alexithymia and mental health difficulties in ASD is specific to emotional problems. The SDQ emotional subscale measures anxious and depressive symptoms, but is predominated by items relevant to anxiety (Muris 2007). Thus, both parent and self-report of emotional symptoms not only suggest that adolescents with ASD and co-occurring alexithymia had more difficulties within this domain, but that they had elevated anxiety in particular.

Co-occurring alexithymia could relate to emotional difficulties, and particularly anxiety, in a number of ways. Alexithymia is associated with difficulty regulating responses to both physical and emotional arousal, which may result in hyper-responsivity and panic in response to stressors in the environment (Cox et al. 1995). Individuals with high alexithymia may also receive less social support because of their difficulty in communicating feelings effectively and interpreting the emotional responses of others (Taylor et al. 1999). For young people with ASD, who already have communication and social difficulties, the presence of an additional personality trait that makes it more difficult to manage and communicate emotional states may put them at increased risk for developing emotional difficulties.

The association between alexithymia and sensory sensitivities

Our study is the first to explore the association between co-occurring alexithymia and sensory sensitivities within individuals with ASD. Both alexithymia and ASD are marked by a complex and heterogeneous profile of both sensory hyper sensitivity and reduced responsiveness. Current analyses found that co-occurring alexithymia was associated with

increased scores on the "low registration" quadrant of sensory processing, as rated by the AASP (Brown et al. 2001). Examples of items on the AASP low registration quadrant include "I seem slower than others when trying to follow an activity or task" or "I don't notice when my name is called". This quadrant describes individuals that have a high neurological threshold and passive behavioural responses to sensory stimulation; they have reduced awareness of sensory events that others readily notice and require high intensity input to become involved in a task or activity (Crane et al. 2009; Dunn 2001; Miller et al. 2007). More generally, this sensory processing style has been associated with a behavioural profile of withdrawal, inattention and difficulty engaging (Miller et al. 2007).

This profile is consistent with accounts of reduced sensory awareness in non-ASD individuals with high alexithymia (Neumann et al. 2004). Similar to the accounts of reduced registration of emotional arousal, there appears to be a disconnect between general physiological/somatic activity and conscious awareness of sensation in individuals with high alexithymia (Grynberg and Pollatos 2015). This is reflected in findings of poorer body-perception, such as reduced registration of the effects of chemical intake or poorer perception of own heart beat (Ernst et al. 2014; Herbert et al. 2011; Lyvers et al. 2014). Furthermore, individuals with alexithymia experience less pleasure during relaxation and report more boredom, with suggestions they may find it difficult to engage with and derive pleasure from the stimulation in their environment (Eastwood et al. 2007; Eastwood et al. 2012; Friedlander et al. 1997). Low sensory registration has also been reported in individuals with ASD (Crane et al. 2009; De la Marche et al. 2012); therefore our findings suggest that there is an overlap in sensory modulation difficulties between the two conditions.

While hypersensitivity to sensory stimulation is also prevalent in both alexithymia and in ASD, no group differences for the high and low alexithymics with ASD were found on this quadrant. This may be because the types of sensory stimulation that cause

hypersensitivity in those with alexithymia are not best captured by the AASP. Individuals with alexithymia exhibit hyper-responsiveness to specific types of stimulation, namely unpleasant stimuli such as heat or pain (Katz et al. 2009; Nyklicek and Vingerhoets 2000). By contrast, young people with ASD show increased sensitivity more generally to stimuli such as loud noises, the feel of certain textures, smells, tastes, among numerous other things (Tomchek et al. 2014). The items on the AASP sensitivity quadrant are more oriented towards general types of stimulation (such as hearing loud noises) than unpleasant or painful sensations.

Therefore, we postulate that, within individuals with ASD as in other populations, alexithymia is related to increased difficulty managing one's response to sensory information. In particular, it is associated with decreased responsiveness and engagement with sensory events. However, the heightened responses to ordinary stimuli often noted in individuals with ASD did not appear to be related to alexithymia.

The role of alexithymia in social processing

One of the aims of the present study was to explore the impact of alexithymia on social cognition in young people with ASD. Specifically, the current study sought to examine whether alexithymia was solely associated with difficulties in emotion recognition or if its role extended to other facets of social processing, namely theory of mind. Results showed that co-occurring alexithymia was related to a selective difficulty in recognising emotions, only for anger, but it was not associated with theory of mind performance.

Social cognition is a broad construct and a growing literature suggests that emotion recognition and theory of mind are underpinned by two distinct systems (Bird and Viding 2014). Emotion recognition is part of an emotional contagion system, which involves identifying emotions in others and representing them within ourselves. Theory of mind is a cognitively focussed, perspective taking system that requires more complex processes and

computations (de Waal 2008; Preston and de Waal 2002). These two systems are thought to be neuroanatomically distinct (Shamay-Tsoory et al. 2009). Difficulties with theory of mind in individuals with ASD are consistently reported; however, evidence of emotion recognition deficits is more equivocal (Bird and Cook 2013; Tager-Flusberg 2010). Our findings suggest that alexithymia is associated solely with the emotion recognition facet of social cognition and not theory of mind ability, in individuals with ASD. This is in line with recent research on empathy in non-ASD populations, which examined the role of different facets of personality (alexithymia, sub-clinical ASD traits, and psychopathy) on affective resonance and theory of mind. Results showed alexithymia was specifically related to reduced affective resonance but did not contribute to individual differences in theory of mind. Sub-clinical ASD traits, on the other hand, were related to poorer theory of mind but not to emotional resonance (Lockwood et al. 2013).

Due to the negative correlation between alexithymia and VIQ, we controlled for VIQ in our analysis of cognitive task performance. When VIQ was controlled for, group differences in emotion recognition dropped to trend level. Only one other study has explored the role of VIQ in the relationship between emotion recognition and alexithymia in a non-ASD population. In line with current results, previous work finds differences in emotion recognition become non-significant once the effect of VIQ is controlled for (Montebarocci et al. 2011). To test for the effects of outliers, we removed the individuals with the lowest VIQ scores (VIQ<70) from the analysis and found that the relationship with TAS-20 and VIQ became non-significant and the decrease in accuracy for anger recognition remained at trend level. We propose that participants with the lowest VIQ scores (and high rates of alexithymia) may have had difficulty understanding the cognitive task demands, as instructions were mainly presented verbally.

Strengths, limitations and implications for future research

The present study is the first to explore the prevalence of co-occurring alexithymia in adolescents with ASD. Our findings mirror rates previously shown in adults with ASD (Berthoz and Hill 2005; Hill et al. 2004). We extend previous findings by highlighting that co-occurring alexithymia is associated with specific and selective behavioural and cognitive components within individuals with ASD. Furthermore, the association between co-occurring alexithymia, and increased anxiety and emotion recognition difficulties suggests that the presentation of this personality trait is similar in ASD compared to non-ASD populations. Our results have important implications for both researchers and clinicians. Future research should take VIQ into account when administering self-report questionnaires and emotion recognition tasks in individuals with alexithymia and develop tasks that have less reliance on verbal cues. In terms of clinical implications, results suggest clinicians need to be aware of the variability among individuals with ASD with respect to additional traits such as alexithymia. Assessment at an individual level for the presence of co-occurring traits could help clinicians to decide whether they need to modify existing interventions, for example, with cognitive behavioural therapy, as individuals with both ASD and alexithymia may require additional work to aid recognition of emotions within themselves.

The present study is the first to find that alexithymia has a selective impact on emotion recognition but does not appear to contribute to individual differences in theory of mind within individuals with ASD. As findings on emotion recognition in individuals with ASD have been equivocal, these results may help to parse out some of the heterogeneity within the literature, and they suggest future studies of emotional processing in individuals with ASD should take account of the presence of alexithymia.

One limitation of the present study is the lack of statistical power to include a typically developing group of individuals with alexithymia to make comparisons. Furthermore, very few of the ASD sample scored in the range considered to be “severely

impaired" on the TAS (>61). Future studies should determine whether the current pattern of findings is replicated in individuals with ASD and severe co-occurring alexithymia. Finally there is a need for longitudinal studies to explore the development and trajectories of co-occurring alexithymia in ASD. Such studies would help address the mechanisms that lead to such high prevalence of this trait within ASD and potential pathways that lead to its association with increased anxiety and sensory modulation atypicalities.

In conclusion, the present study found increased prevalence of alexithymia among adolescents with ASD, as compared to adolescents without ASD. Among those with ASD, elevated alexithymia was associated with reduced accuracy in emotion recognition, only for anger, but not with individual differences in theory of mind ability. Furthermore, individuals with elevated alexithymia reported increased anxiety, depression and sensory processing atypicalities, and their parents rated them as having greater emotional difficulties. Overall, this is the first study to explore the prevalence and cognitive correlates of alexithymia in young people with ASD and the findings have implications for both research and clinical practice.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Table 1 Demographic characteristics of individuals without ASD, and individuals with ASD, with and without co-occurring alexithymia, as rated by the Toronto Alexithymia Scale (TAS-20)

Measure (*SD*, range) unless otherwise indicated	Non-ASD (n=32)	ASD-ALX (n=25)	ASD+ALX (n=31)
Age	15.50 (*.57*, 14.17-16.92)	15.41 (*.45*, 14.75-16.75)	15.49 (*.50*, 14.67-16.75)
Sex (Male: Female)	32:0	24:1	30:1
TAS-20 difficulty identifying feelings	12.03 (*5.45*, 7-25)	11.40 (*3.5*, 7-17)**	20.32 (*5.07*, 10-34)**
TAS-20 difficulty describing feelings	10.97 (*4.53*, 5-23)	10.52 (*3.77*, 5-17)**	16.13 (*2.92*, 11-22)**
TAS-20 externally orientated thinking	22.63 (*3.51*, 10-29)	20.88 (*3.73*, 14-29)**	24.97 (*3.74*, 16-34)**
TAS-20 total (28-78)	45.63 (*11.64*, 30-74)	42.80 (*6.72*, 28-51)**	61.42 (*7.22*, 52-78)**
SRS total score	51.4 (*18.35*, 34-79) (n=5)	85.20 (*29.56*, 21-137)	84.59 (*26.33*, 32-131)
WASI full-scale IQ	98.59 (*15.10*, 66-124)	95.52 (*10.60*, 77-113)	92.77 (*12.45*, 70-119)
WASI verbal IQ	94.81 (*13.70*, 63-119)	93.60 (*11.57*, 77-112)*	86.77 (*13.47*, 61-120)*
WASI performance IQ	102.69 (*4.97*, 73-125)	98.20 (*12.17*, 77-120)	100.87 (*13.60*, 67-126)

ALX indicates alexithymia; ASD autism spectrum disorder; SD standard deviation; SRS Social Responsiveness Scale; WASI Wechsler Abbreviated Scale of Intelligence

* indicates significance at $p<0.05$, ** indicates significance at $p<0.01$

Table 2 Mental health symptoms in individuals with ASD with and without co-occurring alexithymia, as rated by the Toronto Alexithymia Scale (TAS-20)

Measure (*SD*, range)	ASD-ALX (n=25)	ASD+ALX (n=30)
STAIC-Trait	32.58 (*6.39*, 22-47)**	37.90 (*7.32*, 23-54)**
DSRS	8.41 (*4.10*, 1-17) (n=24)	10.31 (*3.52*, 3-17) (n=29)
SDQ conduct subscale	1.28 (*0.94*, 0-3)	1.52 (*1.62*, 0-6) (n=29)
SDQ emotional subscale	2.76 (*2.33*, 0-8)*	4.07 (*2.63*, 0-9)*
SDQ hyperactivity subscale	5.52 (*2.08*, 2-10)	5.07 (*2.75*, 0-10)

ALX indicates alexithymia; ASD autism spectrum disorder; DSRS depression self-rated scale; SDQ Strengths and Difficulties Questionnaire; STAIC state and trait anxiety inventory for children

* indicates significance at $p<0.05$, ** indicates significance at $p<0.01$

Table 3 Sensory sensitivities as rated by the Adult/Adolescent Sensory Profile (AASP) in individuals with ASD with and without co-occurring alexithymia, as rated by the Toronto Alexithymia Scale (TAS-20)

Mean (*SD*, range)	ASD-ALX (n=24)	ASD+ALX (n=27)
Sensory registration	34.63 (*9.47*, 18-55)*	38.81 (*5.76*, 24-48)*
Sensory seeking	38.87 (*6.76*, 28-52) (n=23)	39.85 (*7.26*, 30-57)
Sensory sensitivity	34.19 (*12.40*, 18-60) (n=21)	38.89 (*6.70*, 27-54)
Sensory avoidance	36.30 (*11.55*, 18-66) (n=23)	38.26 (*8.87*, 21-60) (n=23)

ALX alexithymia; ASD autism spectrum disorder

* indicates significance at $p<0.05$

Table 4 Performance on emotional recognition and theory of mind tasks in individuals with ASD with and without co-occurring alexithymia, as rated by the Toronto Alexithymia Scale (TAS-20)

Mean (*SD*, range)	ASD-ALX (n=25)	ASD+ALX (n=31)
Emotion		
Happiness	9.88 (*0.33*, 9-10)	9.97 (*0.18*, 9-10)
Sadness	7.80 (*1.89*, 3-10)	7.03 (*2.12*, 2-10)
Fear	6.76 (*2.38*, 0-9)	6.45 (*2.49*, 1-10)
Anger	7.80 (*1.63*, 2-10)*	6.77 (*1.94*, 3-10)*
Surprise	9.00 (*1.38*, 4-10)	8.48 (*2.05*, 3-10)
Disgust	5.64 (*2.56*, 1-10)	5.10 (*2.56*,0-9)
Theory of mind		
Strange Stories	0.98 (*0.48*, .25-2)	0.91 (*0.52,* 0-2)
Frith-Happé Animations	3.16 *(.68*, 1.5-4.25) (n=24)	3.14 (*0.90*, 1.25-4.75)
Combined 1st order False Belief	1.96 (*0.20*, 1-2)	1.94 (*0.36*, 0-2)
Combined 2nd order False Belief	1.96 (*0.73*, 0-3)	2.13 (*1.09*, 0-3)

ALX indicates alexithymia; ASD autism spectrum disorder

* indicates significance at $p<0.05$

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