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Exploring the cognitive, emotional and sensory correlates of social anxiety in autistic and neurotypical adolescents

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Abstract

Background—Social anxiety is common in autistic adolescents. While emerging evidence indicates the importance of several mechanisms (including intolerance of uncertainty (IU), alexithymia and sensory processing) for maintaining anxiety, limited research has explored how these factors are associated with social anxiety in autistic adolescents.

Methods—We investigated whether IU, emotional and sensory processing are related to social anxiety in autistic and neurotypical adolescents, gathering experimental and questionnaire data from 61 autistic and 62 neurotypical 11- to 17-year-olds recruited to have similarly high levels of anxiety.

Results—In autistic and neurotypical adolescents matched for social anxiety, similar significant associations were observed between social anxiety and IU, alexithymia, maladaptive emotion regulation, sensory hypersensitivity and interoceptive sensibility. Taking a dimensional approach, we found that child- and parent-reported IU, alexithymia and sensory hypersensitivity mediated the relationship between autistic traits and social anxiety symptoms in the combined group of adolescents.

Conclusions—Our findings indicate that similar correlates of social anxiety are evident in autistic and neurotypical youths experiencing social anxiety, and further our understanding of mechanisms that may contribute towards social anxiety in both groups.

Keywords

autism; social anxiety; cognition; emotion; adolescence

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[1]Identity-first language (e.g. autistic people) is preferred for many people on the autism spectrum (Kenny et al., 2016) and is used throughout.

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Autistic individuals [1] often experience co-occurring mental health problems, with approximately 40% experiencing anxiety disorders (Simonoff et al., 2008). Social anxiety, characterised as an intense fear of social situations often accompanied by a fear of being scrutinised by others, is common in autistic people, with estimates ranging from 15.1% to 50% (Maddox & White, 2015; Salazar et al., 2015). The onset of social anxiety typically occurs in early adolescence (Grant et al., 2005), and the experience of these symptoms in adolescence is a significant predictor of social anxiety in adulthood (Pine et al. 1998), signifying the importance of exploring factors associated with social anxiety in the teenage years. To date, little is known about the specific factors that underlie social anxiety, as opposed to overall anxiety symptomatology, yet such research might elucidate prevention or treatment approaches.

Alexithymia and interoception

Several constructs are thought to play a role in the development/maintenance of anxiety. Alexithymia, which is characterised by difficulties identifying and describing one's own emotions (Taylor, Bagby, & Parker, 1991), is associated with increased anxiety in autistic and neurotypical adults (Berthoz, Lalanne, Crane, & Hill, 2013; Karukivi et al., 2010). Elevated rates of anxiety have been reported in autistic adolescents with high versus low alexithymic traits (Milosavljevic et al., 2016), and in adults alexithymia mediates the relationship between autistic traits and anxiety symptoms (Maisel et al., 2016). Difficulties understanding emotional experiences may contribute towards social anxiety, but this has not been explored in adolescence.

Evidence suggests that alexithymia is underpinned, at least in some cases, by impaired interoceptive processing – the ability to identify one's own internal bodily states (Herbert, Herbert, & Pollatos, 2011). Mixed findings about the relationship between interoceptive accuracy and anxiety have been reported (Antony et al., 1995; Paulus & Stein, 2010). In autistic adults, heightened anxiety is associated with reduced interoceptive accuracy and heightened interoceptive sensibility - greater awareness (but not accurate judgement) of internal states (Garfinkel et al., 2016). Similarly, associations between interoceptive sensibility and anxiety have been reported in autistic and neurotypical children (Palser, Fotopoulou, Pellicano, & Kilner, 2018). As social anxiety is often characterised by a fear of appearing anxious, increased awareness of one's bodily sensations (e.g. blushing) may trigger a perpetuating cycle of anxiety. Disentangling this relationship in autistic adolescents is important.

Emotion regulation

Problems with regulating emotions are a prominent feature of anxiety disorders in neurotypical (Cisler, Olatunji, Feldner, & Forsyth, 2010) and autistic people (White et al., 2014). Emotion regulation (ER) is the process of modifying emotional responses to meet situational demands, classified into adaptive and maladaptive strategies. Research has shown that autistic people with high anxiety use more maladaptive ER strategies (Bruggink, Huisman, Vuijk, Kraaij, & Garnefski, 2016; Cai, Richdale, Dissanayake, & Uljarević, 2018). In autistic adults, greater emotion dysregulation is associated with heightened social anxiety

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(Swain, Scarpa, White, & Laugeson, 2015), suggesting that difficulties regulating emotional experiences may exacerbate socially anxious feelings, an avenue that requires greater attention in adolescence.

Sensory processing

Sensory processing atypicalities, including *hyper-* and *hypo-sensitivity,* are common in autistic people (Baranek, David, Poe, Stone, & Watson, 2006). Several studies have shown that greater parent-reported sensory hypersensitivity is associated with heightened anxiety in autistic and neurotypical youths (Neil, Olsson, & Pellicano, 2016; Wigham, Rodgers, South, McConachie, & Freeston, 2015). Sensory hypersensitivity may increase anxiety around situations linked to sensory overload (e.g. crowds) or specific sensory aversions (e.g. laughter). While one study using parent-reported sensory hypersensitivity and social anxiety in autistic children suggests no link (Black et al., 2017), research investigating this relationship using self-report is needed.

Intolerance of uncertainty

Intolerance of uncertainty (IU), the experience of uncertainty as very negative, is implicated in the development/maintenance of anxiety (Carleton, 2012). As many social situations are ambiguous (e.g. laughter could be friendly or ridiculing), IU could fuel social-evaluative concerns. Supporting this view, IU is associated with increased social anxiety severity in neurotypical adolescents (Boelen, Vrinssen, & van Tulder, 2010) and elevated anxiety in autism (Neil et al., 2016; Wigham et al., 2015). IU also mediates the relationship between autism diagnosis and anxiety symptoms in autistic children (Boulter, Freeston, South, & Rodgers, 2014). Whether IU is associated with increased social anxiety in autistic adolescents has not been tested but is important as IU is increasingly seen as a treatment target for anxiety in autism (Rodgers et al., 2017).

Together, the aforementioned cross-sectional research illustrates the associations between anxiety and several factors. A recent theoretical framework in autism proposes that emotional, sensory and cognitive difficulties contribute towards anxiety (South & Rodgers, 2017; Supplementary Material 1). Little empirical evidence exists, however, about how these factors relate to social anxiety in autistic, and in some cases neurotypical, adolescents, and whether associations differ by group. Furthermore, our current understanding is largely based on research investigating group comparisons and relationships in samples that differ on self-reported mental health symptoms. Therefore, we aimed to recruit autistic and neurotypical adolescents with comparable levels of social anxiety, to ensure that group differences were not driven solely by higher anxiety in the autism sample. This approach may help clarify factors associated with social anxiety, and any differences in these between autistic and neurotypical adolescents, with possible implications for prevention and intervention.

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Study aims

The present study aimed: (1) to investigate group differences in mental health symptoms and cognitive, emotional and sensory correlates; (2) to investigate which correlates are associated with social anxiety in autistic and neurotypical adolescents, and whether any group differences exist in the pattern of associations (including potential mediators).

First, we predicted that autistic adolescents would report greater IU, emotional (i.e. alexithymia and ER) and sensory difficulties. Second, we expected that increased autistic traits would be associated with greater IU, emotional and sensory difficulties. Third, we hypothesised that greater IU, more emotional and sensory difficulties (specifically sensory hypersensitivity) and interoceptive sensibility would be associated with heightened social anxiety. Extending previous research (Boulter et al. 2014; Maisel et al. 2016; Bitsika et al. 2019), we took a dimensional approach to investigate whether IU, alexithymia and sensory hypersensitivity mediate the relationship between autistic traits and social anxiety symptoms across all adolescents. The dimensionality of both social anxiety and autistic traits have been widely documented (Fehm et al. 2008; Kamp-Becker et al. 2010), and therefore we employed dimensional measures to better capture within- and across-group relationships between autistic traits, social anxiety and correlates of interest.

Method

Participants

Participants included 61 autistic (42 male) and 62 neurotypical (26 male) adolescents, recruited through secondary schools in South East England. Inclusion criteria were as follows: aged between 11 and 18 years, fluent in English, with a full-scale IQ (FSIQ) ≥70, a word reading age ≥10 years, and no diagnosis of epilepsy, any genetic or psychotic conditions. In the present study, we oversampled anxious neurotypical adolescents to ensure that our groups were comparable on levels of social anxiety symptoms. As such, all recruitment information and school discussions focused on anxiety (Supplementary Material 2). All parents consented and all children gave their assent. This research was approved by the Psychiatry, Nursing and Midwifery Research Ethics Committee, King's College London.

Autism diagnosis was confirmed using documentation from schools and parents. All autistic adolescents had received an autism diagnosis, including 46 (75%) diagnosed with autism and 15 (25%) diagnosed with Asperger's Syndrome. Parent and school reports confirmed that none of the neurotypical adolescents had a diagnosis of autism. Parents completed the Social Communication Questionnaire-Lifetime (SCQ-L; Rutter, Bailey, & Lord, 2003) and the Social Responsiveness Scale-2nd edition (SRS-2; Constantino & Gruber, 2012), which provide a reliable measure of autistic traits. Four autistic adolescents fell below the cut-off criteria suggestive of autism on both the SCQ-L (<15) and SRS-2 (<66), while three neurotypical adolescents scored above the cut-off criteria. In addition, three adolescents did not have complete data on either the SRS-2 and SCQ-L. Excluding these individuals (n=10; seven autistic males, two neurotypical males and one neurotypical female, mean age=13.80) made little difference to the pattern of results (Supplementary Material 3). All analyses are

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therefore reported on the full sample, with allocation to group based on reports of formal diagnosis.

FSIQ was measured using the Wechsler Abbreviated Scale of Intelligence-II four-subtests (Wechsler, 1999) and word reading ability was measured using the Schonell Reading Test (Schonell, 1942) or child's educational reports. Autistic and neurotypical adolescents did not differ significantly on age, FSIQ, verbal IQ, performance IQ or word reading (effect sizes <0.29). Autistic and neurotypical adolescents differed significantly on sex, SRS total, SCQ-L and SCQ-Current (Table 1).

Questionnaires

Child- and parent-reported questionnaires are outlined in Table 2 (for questionnaire details see Supplementary Material 4).

Tasks

The Heartbeat Tracking (HBT) Task (Schandry, 1981) was used to quantify interoceptive accuracy, and the Time Estimation (TE) Task was a control task (Murphy et al., 2018). During the HBT Task, participants were asked to silently count their heartbeats, while objective heartbeat was measured using a pulse oximeter attached to their finger. After each trial, adolescents reported the number of heartbeats and then rated their confidence in their answer. The TE Task was completed using the same procedure, however, participants counted seconds (see Supplementary Material 6). Interoceptive accuracy and time estimation were calculated as a proportion, with higher scores indicating better performance (Murphy et al., 2018). This scoring method is not appropriate for participants who overestimate double their actual heartbeats or time intervals. Where > double over-estimation occurred (n trials=7; two autistic males and one autistic female) responses were capped at double their actual heartbeat, giving a performance score of 0%. For the HBT Task, average accuracy-confidence discrepancies were calculated as a measure of interoceptive insight (Supplementary Material 7).

Procedure

All adolescents completed the activities one to one with the experimenter. First, adolescents completed the WASI-II and word reading assessment to confirm eligibility. If eligible, adolescents completed the tasks and questionnaires in a pseudo-randomised order.

Statistical analysis

All data analyses were conducted using R. All variables were checked for missingness: no child questionnaire data were missing; one autistic child didn't complete the HBT/TE tasks; one autistic child did not complete the word reading assessment. Questionnaire data were gathered from 119 parents, with missing data for three autistic males and one neurotypical female (mean age=14.00). Missing data were handled according to measure guidelines where available, otherwise item-level data were mean imputed. Cases with more than 10% missing data on a questionnaire were excluded from further analyses (Bennett, 2001); one autistic male and two neurotypical females (mean age=15.33) did not have SCQ-L data. Where assumptions of normality were violated, equivalent non-parametric or robust tests

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were used. Between-group analyses were conducted using t-tests and Wilcoxon rank-sum tests. Because of different sex ratios in the diagnostic groups, two-way ANOVAs were conducted to control for sex and explore sex by diagnostic group effects on descriptive data, mental health problems and factors. Within-group correlation analyses were conducted to investigate the relationship between autistic traits (SRS-2) and social anxiety (LSAS-CA-SR and BFNE-S) and cognitive, emotional and sensory factors. Correlation analyses were conducted split by sex and Fisher's r-to-z tests examined any differences in the strength of the associations. All sex difference analyses are outlined in Supplementary Material 8. For clarity, key sex effects are highlighted briefly in the text.

Mediation analyses were performed to assess whether IU, alexithymia and sensory hypersensitivity mediate the relationship between autistic traits and social anxiety (LSAS-CA-SR) in the full sample (i.e. combining the autistic and neurotypical groups). Mediation analyses were conducted using Lavaan (Rosseel, 2012). Models were fit to raw data using a robust Maximum Likelihood estimator and full information maximum likelihood to account for non-normal data missing at random. The mediation analyses included factors with a strong theoretical underpinning (South & Rodgers, 2017). IU (parent and child separately), alexithymia and sensory hypersensitivity were included as mediators of the relationship between parent-reported autistic traits and social anxiety (Figure 1). Additionally, we investigated the relative contribution of each mediator (e.g. IU as a mediator controlling for alexithymia and sensory hypersensitivity). Child sex was regressed out of the outcome and mediators.

Results

Between-group differences

Autistic and neurotypical adolescents reported similar levels of mental health problems, including social anxiety (Table 1). Using the cut-off for the LSAS, 54.8% of neurotypical adolescents and 52.4% of autistic adolescents reached the threshold for generalised social anxiety. Parents reported significantly greater child emotional and behavioural problems for autistic adolescents compared to neurotypical adolescents. After controlling for sex, the group difference between parent-reported SDQ conduct problems fell below significance (p=.233).

Neurotypical adolescents self-reported significantly greater sensory hyposensitivity, compared to autistic adolescents (Table 3). However, this difference fell below significance after controlling for child sex (p=.158, f=0.13). Furthermore, parent-reported IU was higher for autistic adolescents compared to neurotypical adolescents. No other significant group differences were observed. No significant group difference was observed for time accuracy or interoceptive accuracy, but autistic adolescents showed significantly poorer interoceptive insight into their performance, compared to neurotypical adolescents. Additionally, neurotypical adolescents reported significantly greater interoceptive sensibility (awareness of own bodily states) than autistic adolescents.

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Association between social anxiety questionnaires

Strong significant associations were observed between the LSAS-CA-SR and the BFNE-S in the full sample (r=.69, p<.001), autistic group (r=.72, p<.001) and neurotypical group (r=.66, p<.001). We explored these associations split by sex and observed no differences.

Association between social anxiety and autistic traits

Parent-reported autistic traits were weakly-to-moderately associated with social anxiety symptoms, using the LSAS-CA-SR, in the full sample (r=.26, p=.004) and within the autistic (r=.31, p=.016) and neurotypical (r=.38, p=.002) groups separately. No significant association between autistic traits and the BFNE-S were observed in the full sample (r=.11, p=.228) or autistic group (r=.18, p=.172), however, a significant moderate association was observed in the neurotypical sample (r=.31, p=.017).

We explored the association between autistic traits and social anxiety, using the LSAS-CA-SR and BFNE-S, split by sex (see Supplementary Material 8). The association between autistic traits and BFNE was significantly stronger in autistic girls, compared to autistic boys (Z=2.30, p=.021). No other associations differed by sex in either group. Given the significant association between autistic traits and social anxiety symptoms using the LSAS-CA-SR but not BFNE-S in the full sample, we decided to use the LSAS-CA-SR as our primary measure of social anxiety symptoms in further analyses. To provide transparency, we note where differences in the relationship between factors and the LSAS-CA-SR and BFNE-S are observed.

Furthermore, partialling out SDQ behavioural problems (Hyperactivity and Conduct Problems), significant associations between autistic traits and social anxiety (LSAS-CA-SR) remained in the full sample (r=.23, p=.012), autistic group (r=.37, p=.004) and neurotypical group (r=.34, p=.008; Supplementary Material 9).

Associations between social anxiety, age and sex

We assessed sex by diagnostic group effects on child's age and social anxiety (LSAS-CA-SR). No significant main or interaction effects were observed (see Supplementary Material 8). Furthermore, no significant associations between age, social anxiety and the mediators (e.g. IU, alexithymia and sensory hypersensitivity) were observed in either the autistic group, neurotypical group or the full sample (rs=-.11-.13, ps>.329).

Associations between autistic traits and cognitive, emotional and sensory factors

In both the autistic and neurotypical adolescents, autistic traits were associated with higher alexithymia, sensory hypersensitivity and parent-reported IU (Table 4). In neurotypical adolescents only, autistic traits were associated with greater child-reported IU. In autistic and neurotypical adolescents, we observed no association between autistic traits and interoceptive accuracy, sensibility or insight (rs=-.15-.25 ps>.05). These associations were of similar magnitude across groups (Zs=-1.59-1.20, ps>.112), however, a stronger association with parent-report IU was observed in the neurotypical group compared to the autistic group (Z=-2.53, p=.011).

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We explored sex differences in the associations between autistic traits and factors within diagnostic group. In neurotypical adolescents, we observed a significantly stronger association between sensory hypersensitivity (Z=2.34, p=.019), child-reported IU (Z=2.20, p=.029) and autistic traits in the girls, compared to the boys.

Associations between social anxiety and cognitive, emotional and sensory factors

Within the autistic and neurotypical groups separately, self-reported social anxiety (LSAS-CA-SR) was significantly associated with elevated alexithymia, more maladaptive ER strategies, heightened sensory hypersensitivity, and greater child and parent-reported IU. In autistic adolescents only, self-reported social anxiety was significantly associated with greater sensory hyposensitivity. In the autistic and neurotypical groups, no significant associations were observed between social anxiety and interoceptive accuracy or insight (autistic rs=-.13-.05, ps>.339; neurotypical rs=-.17--.06, ps>.178). A significant moderate association between interoceptive sensibility and social anxiety was observed in the autistic (r=.46, p<.001) and neurotypical (r=.33, p=.009) groups, with higher social anxiety related to greater self-reported subjective awareness of internal states. The magnitude of correlations did not differ between groups (Zs=-0.38-1.64, ps>.101). For the BFNE-S, a significant difference in the strength of the association with child-reported IU was observed (Z=2.20, p=.028). Overall, we observed a similar pattern of associations between social anxiety symptoms and factors in both groups. Furthermore, no within diagnostic group sex differences in the strength of associations were observed.

Exploring whether IU, sensory hypersensitivity and alexithymia mediate the relationship between autistic traits and social anxiety

Given the similar levels and associations between variables in the two groups, mediation analyses were conducted in the combined sample (see Figure 1). Our analysis showed weak-to-moderate mediation effects via child-reported IU (β=.16, p=.002), parent-reported IU (β=.31, p=.002), alexithymia (β=.15, p=.009) and sensory hypersensitivity (β=.16, p=.002), while the direct effects from autistic traits to social anxiety were not significant (β=.12-.13, ps>.063). Applying Bonferroni correction (p≤.006), the indirect effect of alexithymia fell below significance.

Subsequent analyses investigating the relative contributions found significant indirect effects via child-reported IU (β=.10, p=.004) and sensory hypersensitivity (β=.09, p=.019), while the indirect effects via parent-reported IU (β=.14, p=.088) and alexithymia (β=.07, p=.056) were no longer significant. The direct effects were also not significant (βs=-.06-.06, ps>.361). Applying Bonferroni correction (p≤.006), the indirect effect via sensory hypersensitivity fell below significance.

Taking a dimensional approach risks creating a Simpsons paradox problem, whereby interpretations are altered by combining two distinct groups. To address this possibility, we performed exploratory mediation analysis for autistic and neurotypical adolescents separately (Supplementary Material 10). Two distinct group differences emerged. First, in autistic adolescents, child-reported IU was not a significant mediator (β=.00, p=.982), and in neurotypical adolescents' parent-reported IU was not a significant mediator (β=.22, p=.074).

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Second, the indirect effect via alexithymia fell below significance in autistic adolescents (β=.14, *p*=.069). In the autistic group, significant indirect effects via parent-reported IU and sensory hypersensitivity were observed. In the neurotypical sample, significant indirect effects via child-reported IU, alexithymia and sensory hypersensitivity were observed. We also conducted exploratory analyses to investigate the mediation pathways in the full sample split by sex (see Supplementary Material 11).

Discussion

This study explored the correlates of social anxiety in autistic and neurotypical adolescents. First, elevated social anxiety was associated with increased IU, alexithymia, maladaptive ER and sensory hypersensitivity in autistic and neurotypical adolescents separately. Our mediation analysis, taking a dimensional approach combining groups, showed that child- and parent-reported IU, alexithymia and sensory hypersensitivity mediated the relationship between autistic traits and social anxiety. However, in the adjusted analyses, parent-reported IU and alexithymia no longer mediated this relationship, suggesting that child-reported IU and sensory hypersensitivity play an important role in mediating the relationship between autistic traits and social anxiety explored dimensionally.

First, we observed similar levels of self-reported social anxiety across both adolescent groups. In both groups, self-reported social anxiety symptoms, using the LSAS-CA-SR, were observed across the trait distribution and mean levels were similar to neurotypical adolescents with anxiety disorders (Mean=69.66; Schneider et al., 2018). These findings reflect our study's anxiety-focused recruitment approach and intention to match the groups on social anxiety. Importantly, relatively few studies obtain independent self-reports, however, all youths in our study completed measures without their parents, possibly reflecting a purer measure of self-reported emotional difficulties. Consistent with previous research (Keith, Jamieson, & Bennetto, 2019), parents of neurotypical adolescents under-reported their children's symptomatology, compared to self-report, signifying perhaps a lack of awareness of their child's internal experiences, and highlighting the importance of multi informant approaches. This observation did not hold in the autistic group. Parents reported greater child emotional and behavioural difficulties for autistic than neurotypical adolescents. Furthermore, similar self-reported levels of IU, alexithymia, sensory hypersensitivity and maladaptive ER strategies in autistic and neurotypical adolescents were observed.

Consistent with research examining IU and anxiety in autism (Neil et al., 2016), our findings show that IU is related to social anxiety severity in autistic adolescents. Child- and parent-reported IU mediated the relationship between autistic traits and social anxiety in all adolescents, but the latter fell below significance when adjusting for other mediators. Similar findings have been reported in adults using self-reported IU and a dimensional mediation approach (Maisel et al., 2016). In addition, differential mediation effects for IU were observed for autistic and neurotypical adolescents based on the reporter, highlighting the importance of adopting multi-informant approaches. Our study is the first to provide evidence for the role of IU in social anxiety for autistic adolescents. Social situations may be anxiety provoking for adolescents with social differences and/or a preference for sameness.

Together, these findings suggest that some adolescents may benefit from social anxiety treatments that target IU.

Across the whole sample, alexithymia mediated the relationship between autistic traits and social anxiety, although this fell below significance when adjusting for other mediators. These findings support the notion that difficulties understanding emotional states are associated with heightened social anxiety, which may lead to a possible avoidance of social situations, where emotional responses may be generated. Our data also lend support to the hypothesis that some socio-emotional difficulties may be explained by co-occurring alexithymia (Bird & Cook, 2013), as opposed to autism. However, in autistic adolescents, alexithymia seems to explain less variance in social anxiety, while in neurotypical adolescents, alexithymia seems to have a mediating effect. Building on previous research (Swain et al., 2015), our findings show that using more maladaptive ER strategies is associated with social anxiety in autistic adolescents.

Like others (Palser et al., 2018), we found that increased interoceptive sensibility - but not interoceptive accuracy - is associated with greater social anxiety in autistic and neurotypical adolescents. A greater subjective, self-reported awareness of one’s own bodily states may exacerbate social anxiety, particularly when experienced with an enhanced self-focused attention (Blöte et al., 2014). Future work disentangling interoception, alexithymia and self-focused attention will aid in understanding the causal/maintaining factors of social anxiety.

Sensory difficulties, in particular sensory hypersensitivity, was associated with greater social anxiety in autistic and neurotypical adolescents, as reported elsewhere (e.g. Neil et al., 2016). In autistic adolescents only, greater hyposensitivity (e.g. registration difficulties and sensory seeking) was associated with higher social anxiety. Importantly, individuals can often experience both sensory hypersensitivity and hyposensitivity in different contexts. Thus, a greater understanding of how different sensory difficulties contribute towards anxiety across multiple settings is needed. Across all adolescents, sensory hypersensitivity mediated the relationship between autistic traits and social anxiety. Notably, our data suggests that avoidance of anxiety-provoking situations could be driven by particular sensory environments (e.g. sensory enriched environments). Further research investigating sensory environments and social anxiety is required to understand the impact of sensory hypersensitivity across adolescence.

Models of anxiety in autism have emphasised the role of alexithymia, IU and sensory processing (South & Rodgers, 2017). To our knowledge, this study is the first to use a combination of dimensional measures to provide evidence that these constructs mediate the relationship between autistic traits and social anxiety across all adolescents. Our findings suggest that for some adolescents, targeting specific mechanisms (e.g. IU) may be beneficial for alleviating social anxiety, as seen for anxiety in autistic people (Rodgers et al., 2017). In particular, few differences emerged in the associations and mediation pathways for autistic and neurotypical adolescents. Therefore, adapting existing effective interventions may be fruitful for autistic adolescents, whilst keeping in mind that approaches may need to be tailored to suit autistic people's needs. Building on our cross-sectional findings, future longitudinal research disentangling the causal mechanisms that contribute towards social

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anxiety in adolescence will be important for understanding aetiology and fostering the identification/prevention of anxiety.

The present study was strengthened by the matching of autistic and neurotypical groups on social anxiety, and by a dimensional approach that allowed us to capture the range of symptoms and examine relationships beyond diagnostic categories. Nevertheless, limitations warrant discussion. First, data were derived using self- and parent-report questionnaires. Future research would benefit from using both multi-informant and experimental methods to build a better picture of social anxiety and associated factors. Second, all adolescents involved in this project had cognitive abilities within the average range and as such these findings may not generalise to wider populations. Third, this study may have been inadequately powered to detect mediation effects in our within-group (versus combined) analyses, indicating the need for larger samples to replicate all effects. Furthermore, sex differences were not a key focus and hence we were under-powered to detect these effects. However, we have noted and discussed the intriguing pattern of results in the supplementary material and emphasise that replication in larger samples collected for this purpose is needed. In addition, it is important to acknowledge that many of the standard measures used were not designed for, and have yet to be validated with, autistic individuals. Although previous research suggests that self-report measures of social anxiety (e.g. LSAS, BFNE-S) are not simply tapping autism symptomatology (Spain et al., 2016), validation of standardised measures in autistic populations are needed. Lastly, the specificity of these relationships to social anxiety remains unclear, given that individuals can experience many co-occurring symptoms of anxiety at any one time. Future research clarifying the purity of these relationships is warranted.

Conclusion

In conclusion, our study shows that child and parent-reported IU, alexithymia and sensory hypersensitivity mediate the relationship between autistic traits and social anxiety. However, when controlling for other mediators, parent-reported IU and alexithymia no longer mediated this relationship. Although these data cannot speak to causality, our findings suggest that similar factors are associated with social anxiety in autistic and neurotypical adolescents. While these only represent some possible pathways to social anxiety, longitudinal research replicating our findings and clarifying these pathways in youths will help build a better profile of likely aetiology. This research and future investigations will have important clinical implications for prevention, early identification and informing the adaptation of interventions to improve treatments that target social anxiety in adolescence.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

HBT	Heartbeat Tracking
TE	Time Estimation

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Key points and Relevance

- Social anxiety is commonly experienced by autistic young people, yet we know very little about the underlying mechanisms or risk factors.
- In groups of autistic and neurotypical adolescents with similarly high social anxiety, elevated social anxiety was associated with increased intolerance of uncertainty (IU), alexithymia, maladaptive emotion regulation strategies and sensory hypersensitivity.
- Across all the adolescents, child- and parent-reported IU, alexithymia and sensory hypersensitivity mediated the relationship between autistic traits and social anxiety.
- These results may have implications for the aetiology and treatment of social anxiety in autistic adolescents.

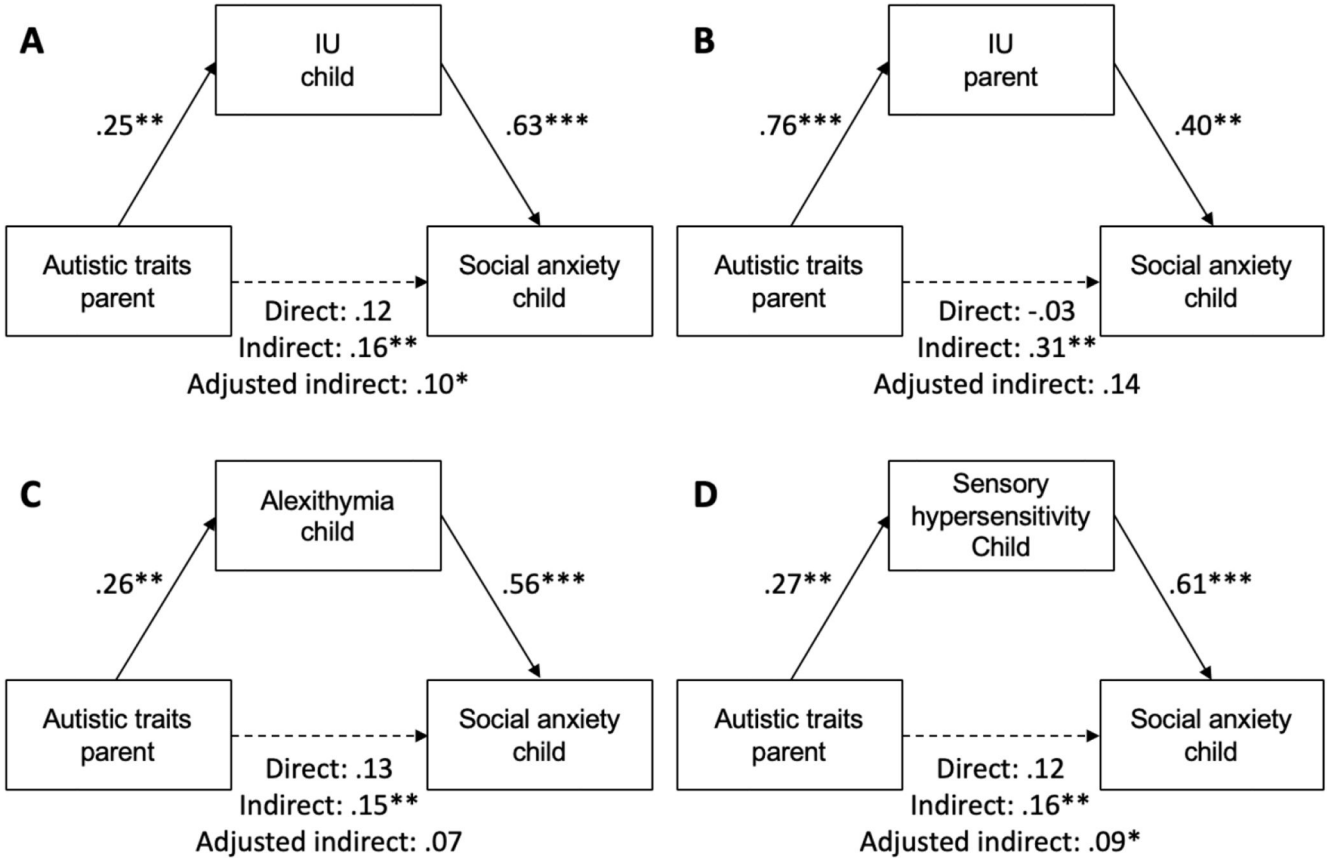

Figure 1.

Mediation analysis examining factors in the relationship between autistic traits and social anxiety, using the LSAS-CA-SR, controlling for child sex. *Notes:* Standardised β coefficients are reported. In the adjusted analyses, social anxiety was regressed on additional mediators (e.g. IU mediation controlling for alexithymia and sensory hypersensitivity). IU=intolerance of uncertainty. $p<.05$*, .01**, .001***.

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Table 1

Demographics and mental health symptoms in autistic and neurotypical adolescents; mean (s.d.), range, group effect statistic and effect size

Variables	Autistic adolescents (n=61)		Neurotypical adolescents (n=62)		χ^2	
Sex (male:female)	**42:19**		**26:36**		**7.96****	
	Mean(SD)	**Range**	**Mean(SD)**	**Range**	***t-test/W*** [a]	***d/r*** [a]
Age (years)	13.46(1.77)	11-17	13.52(1.57)	11-17	1863[a]	.01[a]
WASI full scale IQ	98.16(13.99)	75-130	100.76(11.55)	79-128	-1.12	0.20
WASI verbal IQ	97.23(13.77)	67-132	100.68(10.16)	79-128	-1.58	0.29
WASI performance IQ	99.59(15.58)	68-133	100.31(12.88)	71-131	-0.28	0.05
Word reading[b] (0-100)	78(12.35)	49-98	81.35(11.07)	48-98	-1.58	0.29
Autistic traits						
SRS-2 total[c]	77.47(10.65)	49-90	54.26(12.58)	38-90	3213[a] ***	.70[a]
SCQ Lifetime[d]	20.94(6.98)	6-36	4.73(5.24)	0-26	3338[a] ***	.79[a]
SCQ Current[c]	17.58(5.82)	5-29	7.11(5.03)	1-26	3233[a] ***	.71[a]
Child-reported mental health						
Social anxiety	65.85(33.61)	3-134	65.35(31.36)	8-125	0.08	0.02
BFNE-S	24.2(9.52)	9-40	16.15(8.49)	9-40	-1.20	0.22
Trait anxiety	50.75(10.77)	28-75	50.54(13.1)	23-75	0.10	0.02
Depression	10.38(6.98)	0-23	9.84(7.34)	0-26	1983[a]	.04[a]
SDQ-Conduct	3.02(1.94)	0-9	2.90(2.22)	0-9	1981[a]	.04[a]
SDQ-Hyperactivity	5.87(2.28)	2-10	5.81(2.60)	0-10	1844[a]	.02[a]
SDQ-Emotional	4.97(2.68)	0-10	5.44(2.62)	0-10	-0.98	0.18
Parent-reported mental health						
SDQ-Conduct[c]	2.55(2.31)	0-9	1.57(1.87)	0-7	2232[a] *	.23[a]
SDQ-Hyperactivity[c]	5.97(2.76)	0-10	3.75(3.02)	0-10	2520[a] ***	.37[a]
SDQ-Emotional[c]	5.59(2.80)	1-10	3.87(3.15)	0-10	2340[a] **	.28[a]

Notes:WASI=Wechsler Abbreviated Scale of Intelligence, SRS-2=Social Responsiveness Scale, SCQ=Social Communication Questionnaire. BFNE-S=Brief Fear of Negative Evaluation-Straightforward, SDQ=Strengths and Difficulties Questionnaire, *t*=t-test statistic, *d*=Cohen's d, *a*=Wilcoxon test statistic and correlation coefficient effect size. b: n=122, c: n=119, d: n=118. *p*<.05*, .01**, .001***

Table 2

Child and parent reported questionnaires, key variables and alpha of scale by group

Questionnaires	Child/parent	Outcome	α (autistic, neurotypical)
Autistic traits			
SRS-2	Parent	Autistic traits total score	.94, .97
SCQ-L/C	Parent	Autistic traits lifetime and current scores	-
Mental health			
LSAS	Child	Social anxiety total score based on reports of fear and avoidance in social situations	.97, .97
BFNE-S	Child	Straightforward (8 items) total score based on fear of negative evaluation	.94, .94
SMFQ	Child	Depression total	.93, .93
STAI	Child	Trait anxiety total based on how a person generally feels day to day	.90, .93
SDQ	Child/Parent	Conduct total and hyperactivity total (behavioural problems) and emotional total (anxiety and depression)	Child:.57-.76, .65-.80 Parent:.78-.82, .76-.86
Factors			
TAS-20	Child	Alexithymia total based on difficulties identifying and describing own emotions	.76, .82
AASP	Child	Hyposensitivity total (low registration, seeking), Hypersensitivity total (sensitivity and avoidance)	.86-.93, .69-.90
IUS	Child/Parent	IU total based on uncertain situations viewed as negative	Child:.87, .89 Parent:.96, .85
CERQ	Child	Adaptive ER (e.g. acceptance), Maladaptive ER (e.g. self-blame)	.84-.89, .86-.87
BPQ-Awareness[a]	Child	Interoceptive sensibility total based on subjective awareness of one's own internal states	.96, .96

Notes: [a]Through piloting the Body Perception Questionnaire with neurotypical children (n=3), it became apparent that some items were difficult to interpret. For these items, an easier alternative was made available (Supplementary Material 5).

Table 3

Emotional, cognitive and sensory variables in autistic and neurotypical adolescents; mean (s.d.), range, group effect statistic and effect size

Variables	Autistic adolescents (n=61)		Neurotypical adolescents (n=62)			
	Mean(SD)	Range	Mean(SD)	Range	*t-test/W* [a]	*d/r* [a]
Alexithymia	60.65(11.24)	38-80	60.55(12.66)	34-91	0.05	0.01
Adaptive ER	54.53(14.24)	32-96	54.95(12.38)	35-90	1816[a]	.03[a]
Maladaptive ER	41.39(10.94)	22-70	40.79(11.49)	19-67	0.30	0.05
Hypersensitivity	81.69(22.74)	31-127	82.68(21.10)	43-134	-0.25	0.05
Hyposensitivity	75.20(16.45)	35-111	81.15(12.27)	55-105	-2.27*	0.41
IU-Child	37.51(11.01)	12-60	36.97(10.36)	13-59	0.28	0.05
IU-Parent[b]	42.54(9.92)	20-57	25.18(17.96)	0-60	2769[a] ***	.49[a]
Interoception						
Interoceptive accuracy[e]	30.95(28.63)	0-97.95	38.95(31.12)	0-95.92	1565[a]	.14[a]
Confidence[d]	49.96(30.48)	0-100	41.86(27.48)	0-100	1.54	0.28
Interoceptive sensibility	107.48(34.11)	51-189	127.82(35.53)	59-207	-3.24**	0.58
Interoceptive insight[d]	33.36(27.75)	0-100	22.23(20.10)	0-93	2279[a] *	.21[a]
Time accuracy[d]	77.26(13.91)	5.5-93.89	77.08(14.57)	38.5-96.19	1794[a]	.03[a]
Time confidence[c]	68.16(19.6)	27.5-100	66.82(15.64)	32.5-100	0.58	0.11

Notes:ER=Emotion Regulation, IU=Intolerance of Uncertainty. *t*=t-test statistic, *d*=Cohen's d, *a*=Wilcoxon test statistic and correlation coefficient effect size. b: n=119, c: n=120, d: n=121, e: n=122. *p*<.05*, .01**, .001***

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Table 4

Associations between social anxiety symptoms, autistic traits and correlates of interest for autistic and neurotypical adolescents

Variables	Autistic adolescents (n=61)		Neurotypical adolescents (n=62)	
	Autistic traits	Social anxiety	Autistic traits	Social anxiety
BFNE	.18	.72***	.31*	.66***
Alexithymia	.36**	.63***	.31*	.57***
Adaptive ER	-.09	-.12	-.05	-.06
Maladaptive ER	.22	.54***	.16	.58***
Hypersensitivity	.33*	.62***	.36**	.67***
Hyposensitivity	.13	.29*	-.09	.09
IU-Child	.14	.71***	.41***	.62***
IU-Parent[b]	.46***	.53***	.75***	.40**

Notes:ER=Emotion Regulation, IU=Intolerance of Uncertainty, b: n=119. p<.05*, .01**, .001***