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The Relationship Between Sensory Reactivity Differences and Anxiety Subtypes in Autistic Children

Keren MacLennan , Lauren Roach, and Teresa Tavassoli

Autistic children are at greater risk of developing anxiety than their nonautistic peers. Sensory reactivity differences have been implicated as one of the risk factors. Specifically, sensory hyperreactivity has previously been linked to anxiety, including separation anxiety and specific phobia; however, minimal research has explored the influence of sensory hyporeactivity and seeking. Therefore, the present study examined the correlational relationship between sensory reactivity differences and anxiety subtypes in 41 autistic children aged between 3 and 14 years, using parent- and self-reported measures. We found positive correlations between sensory hyperreactivity and total anxiety, separation anxiety and physical injury fears. However, when controlling for autism traits, we found sensory hyperreactivity to be related to physical injury fears and specific phobia, and sensory hyporeactivity to be related to lower total and social anxiety. We found no significant relationships between sensory seeking and anxiety. These results indicate that sensory hyperreactivity and hyporeactivity might be implicated in specific anxiety symptomology. Our results also indicate minimal agreement between parent- and self-reported anxieties, which highlights the limitations of informant reports for anxiety and the pressing need for objective anxiety assessments for autistic children to be developed. Our findings have important implications for limiting the development of anxiety in autistic children and suggest that sensory reactivity differences should be considered when developing targeted interventions for certain anxiety disorders. *Autism Res* 2019, 00: 1–11. © 2019 The Authors. *Autism Research* published by International Society for Autism Research published by Wiley Periodicals, Inc.

Lay Summary: The present study found that when considering autism traits, greater sensory hyperreactivity, such as being oversensitive to sounds, was related to elevated phobia-related symptoms and sensory hyporeactivity, such as being under-responsive to touch, was related to lower total and social anxieties. Sensory seeking, such as a fascination with lights, was not related to anxiety. Our results have important implications for targeted anxiety interventions for autistic children. However, due to minimal agreement between the parent- and child-reported scores, developing more objective measures of anxiety would be beneficial.

Keywords: autism; sensory reactivity; anxiety; anxiety disorders; risk factors; child

Introduction

Autism spectrum conditions (ASCs) are neurodevelopmental conditions typically characterized by restricted and repetitive behaviors (RRBs) and interests, and social interaction and communication differences [DSM-5 American Psychiatric Association, 2013]. Sensory reactivity differences are a new diagnostic criterion for ASC [DSM-5 American Psychiatric Association, 2013], which occur across multiple sensory domains and are characterized by hyperreactivity (over-responsivity), or hyporeactivity (underresponsivity) to sensory stimuli (e.g., sounds or touch), and sensory seeking (e.g., being fascinated by lights) [Miller, Anzalone, Lane, Cermak, & Osten, 2007]. Around

65–80% of autistic¹ children are thought to experience sensory reactivity differences [Lane, Dennis, & Geraghty, 2011; Leekam, Nieto, Libby, Wing, & Gould, 2007; Tavassoli et al., 2016]. Although sensory experiences, particularly seeking behaviors, can be enjoyable for some individuals, other sensory experiences can be very distressing [Uljarević, Lane, Kelly, & Leekam, 2016]. This can have a detrimental impact on developmental outcomes and quality of life [Boyd et al., 2010; Hilton et al., 2010; Pfeiffer, Kinnealey, Reed, & Herzberg, 2005].

Autistic children are also twice as likely to develop anxiety in comparison with nonautistic children, with

¹The terms used in this article are based on the preferred terms that have been outlined by the autistic community (Kenny et al., 2016).

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approximately 55% experiencing clinically elevated levels of anxiety, and up to 40% being diagnosed with at least one anxiety disorder [de Bruin, Ferdinand, Meester, de Nijs, & Verheij, 2007; van Steensel, Bögels, & Perrin, 2011]. Common comorbid anxiety disorders include social anxiety, specific phobia, separation anxiety disorder, generalized anxiety disorder (GAD), and obsessive-compulsive disorder (OCD) [Simonoff et al., 2008]. This can greatly impact school performance, attainments, and quality of life, and consequently, there is an inordinate need to identify risk factors in early development [Factor, Ryan, Farley, Ollendick, & Scarpa, 2017; Simonoff et al., 2008; van Steensel, Bögels, & Dirksen, 2012]. However, there is a barrier in diagnosis for anxiety disorders such as OCD and social anxiety due to the overlapping nature between symptoms of these disorders and autistic traits [Kerns & Kendall, 2012; White, Oswald, Ollendick, & Scahill, 2009]. It is apparent that although there are commonalities in anxiety symptoms for autistic and nonautistic people, there seem to be anxiety symptoms that are experienced more commonly by autistic people compared to other anxiety disorder populations, such as sensory and special-interest fears [Kerns, Renno, Kendall, Wood, & Storch, 2017; Rodgers et al., 2016]. Therefore, it is important to tease apart autism-related differences that are related to the development of anxiety to ensure autistic people receive appropriate support, and to develop anxiety assessments specific for autistic individuals [Kerns et al., 2014]. Sensory reactivity is one area that has been suggested to link to traditional anxiety symptoms [Kerns et al., 2014], as well as anxiety symptoms that are specific to autistic people [South & Rodgers, 2017]. Research has consistently found an association between greater sensory reactivity differences and anxiety in autistic children [Ben-Sasson et al., 2008; Uljarević et al., 2016].

In particular, sensory hyperreactivity can be extremely distressing and has been found to correlate with clinically elevated levels of anxiety [Carpenter et al., 2018; Green & Ben-Sasson, 2010; Green, Ben-Sasson, Soto, & Carter, 2012; Pfeiffer et al., 2005]. It has been suggested that sensory hyperreactivity is predictive of anxiety, but there is an apparent bidirectional relationship, in that greater hyperreactivity increases anxiety, which in turn increases hyperreactivity [Green et al., 2012; Mazurek et al., 2013]. This may be due to sensory hyperreactivity resulting in the avoidance of sensory stimuli, which may be a maladaptive strategy for arousal regulation, that further generates and maintains anxiety [Joosten & Bundy, 2010; Lidstone et al., 2014]. Although research has largely only explored relationships to total anxiety scores, it is ostensible that sensory hyperreactivity relates to anxiety subtypes, and therefore assessing total anxiety scores in research may not be sensitive enough to capture the complex relationship between sensory hyperreactivity and anxiety subtypes. [Black et al., 2017;

Kerns et al., 2014; Rodgers et al., 2016; Simonoff et al., 2008].

Specific phobia is one of the most commonly diagnosed anxiety disorders for autistic people and is present in up to 40% of autistic children [Leyfer et al., 2006; Mayes et al., 2013; White et al., 2009]. Differentially from nonautistic people, 10% of autistic people experience phobias relating to loud noises, which are thought to originate from sensory hyperreactivity to auditory stimuli [Gjevik, Eldevik, Fjæran-Granum, & Sponheim, 2011; Leyfer et al., 2006; Mukaddes & Fateh, 2010; Muskett, Radtke, White, & Ollendick, 2019; White et al., 2009]. Black et al. [2017] explored the links between sensory hyperreactivity and specific phobia, separation anxiety, and social anxiety, and found sensory hyperreactivity related to separation anxiety and specific phobia, but not to social anxiety. Spain, Sin, Linder, McMahon, and Happé [2018] reviewed social anxiety in autistic people, and also outlined that there is minimal evidence of a relationship between sensory hyperreactivity and social anxiety, which could instead be linked to heightened physiological arousal and social skills differences [Bellini, 2006]. However, little is known about how sensory reactivity differences relate to other anxiety subtypes, such as GAD and OCD. Research in nonautistic populations has shown sensory hyperreactivity to correlate with childhood ritualism, and oral and tactile hyperreactivity to relate to OCD symptoms in adults [Dar, Kahn, & Carmeli, 2012]. Additionally, research into “sensory phenomena,” encompassed by uncomfortable experiences or feelings, has shown increased sensory input (e.g., from tactile and auditory stimuli) to precede or accompany OCD dimensions associated with repetitive behaviors and compulsions; symmetry, ordering, and arranging; and contaminating and cleaning [Ferrão et al., 2012]. However, little is known about the links between sensory reactivity differences and OCD in autistic populations.

Additionally, limited research has investigated whether sensory hyporeactivity and sensory seeking relate to anxiety or anxiety subtypes. Theoretically, it is proposed that sensory seeking regulates arousal, either by seeking out stimulation as a result of experiencing hyporeactivity, or by reducing anxiety when experiencing hyperreactivity [Lidstone et al., 2014]. Sensory hyporeactivity has been found to relate to anxiety in younger autistic children [Pfeiffer et al., 2005]. However, it is believed that hyporeactivity has a greater relationship to other mental health disorders associated with suppressed arousal, such as depression [Lane, 2002; Neal, Edelmann, & Glachan, 2002; Pfeiffer et al., 2005]. Sensory reactivity differences are extremely complex, and individuals can present with a mixed pattern of hyperreactivity, hyporeactivity and seeking behaviors, which vary in different environments and for different sensory modalities, such as auditory or visual [Baranek,

David, Poe, Stone, & Watson, 2006; Lidstone et al., 2014]. Therefore, there is a need to understand the differential risk of anxiety resulting from specific sensory reactivity differences, particularly to inform the development of targeted early interventions.

Previous research has largely assessed sensory reactivity differences using the Sensory Profile, or Short Sensory Profile [Dunn, 1999], which disputably overrepresents hyperreactivity [Neil, Green, & Pellicano, 2017; Uljarević et al., 2016]. Therefore, it is imperative to conduct research using sensory assessments, such as the Sensory Processing Scale Inventory (SPSI) [Schoen, Miller, & Sullivan, 2017], which represent sensory hyperreactivity, as well as a greater representation of hyporeactivity and seeking behavior to fully understand if specific sensory reactivity differences relate to anxiety. Additionally, it has recently been suggested that multiple assessments should be used to assess anxiety, such as informant reports, clinical observations, and biological measures, which can capture different perspectives [Spain et al., 2018]. There are currently few direct objective anxiety assessments that can be used for autistic children. The majority of previous research has exclusively employed parent-reported measures; however, relationships could be influenced by common methods variance and it has been suggested that simply using parent report is not appropriate. It has also been argued that self-reports are not appropriate, as autistic people often experience alexithymia, defined as the difficulty in identifying, labeling, and interpreting emotions in the self and others [Liss, Mailloux, & Erchull, 2008]. Consequently, autistic children may struggle to identify their own affect, and parent-reported anxiety may be more accurate than self-reports [Russell & Sofronoff, 2005; White et al., 2009]. As there are currently few objective anxiety measures, presently it may be important to use both parent reports and self-reports in research to be able to access the perspectives of the different informants.

Therefore, the aim of our study was to examine the correlational relationship between sensory reactivity differences (e.g., hyperreactivity, hyporeactivity and seeking) and parent- and self-reported anxiety subtypes (e.g., specific phobia, physical injury fears, social anxiety disorder, GAD, OCD) in autistic children. In light of previous research, we hypothesized that firstly, there would be differential relationships between sensory reactivity differences and anxiety subtypes; greater sensory hyperreactivity would be primarily related to higher total anxiety, separation anxiety, physical injury fears (corresponding to phobia) and OCD; and greater sensory seeking would be related to lower anxiety. Additionally, we predicted there to be no relationship between sensory hyporeactivity and anxiety subtypes.

Table 1. Demographic Characteristics of Participants

Characteristics	Range	<i>M</i>	<i>SD</i>
Age (years)	3–14	8.44	2.86
IQ	77–140	109.03	16.92
AQ	27–49	35.53	5.77
Sex			
Male		68%	
Female		32%	
Clinical diagnosis			
ASC		100%	

Methods

Participants

Forty-one clinically diagnosed autistic children participated in this study (age range 3–14 years) (see Table 1). All children had an official clinical diagnosis of autism according to DSM-IV or DSM-5. The Autism Spectrum Quotient—Child (AQ) [Auyeung, Baron-Cohen, Wheelwright, & Allison, 2008] was used to assess the extent of autistic traits, with high scores associated with a greater degree of autism-related traits or behaviors, and to confirm that all participants scored above the dichotomous scoring cutoff (AQ ≥ 26) [Woodbury-Smith, Robinson, Wheelwright, & Baron-Cohen, 2005]. Forty-three participants were originally recruited for this study; however, two participants were removed due to scoring below the cutoff. The AQ has strong internal consistency ($\alpha = 0.97$), and test-retest reliability ($r = 0.85$, $P < 0.001$) [Auyeung et al., 2008]. Demographic survey questions ensured participants did not have vision or hearing impairments that could affect sensory reactivity. To obtain an indication of the developmental/cognitive functioning of the sample, the Vocabulary and Matrix reasoning subtests were conducted using the Wechsler Abbreviated Scale of Intelligence [Wechsler, 1999] and Wechsler Nonverbal [Naglieri & Brunnett, 2009]. Seven participants were not able to complete the IQ tasks; however, there were no exclusion criteria for cognitive functioning or language level as cognitive levels have not been linked to sensory reactivity in previous research [Siper, Kolevzon, Wang, Buxbaum, & Tavassoli, 2017]. Signed consent was obtained from parents, and verbal assent was obtained from children. Participants were recruited through the University of Reading Centre for Autism participant database and social media platforms, and through Autism Berkshire, a local autism organization. Ethical approval was granted prior to the commencement of this study by the University of Reading Ethics Committee.

Procedure

Sensory reactivity differences, including sensory hyperreactivity, hyporeactivity, and seeking, were assessed through parent reports using the SPSI [Schoen et al.,

2017]. Anxiety was assessed through parent and self-report using the Spence Children's Anxiety Scale—Parent (SCAS-P) [Nauta et al., 2004] and the preschool version, the Preschool Anxiety Scale (PAS) [Edwards, Rapee, Kennedy, & Spence, 2010], and the Dominique Interactive (DI) computer game [Valla et al., 2002]. Children aged 3–6 years were assessed using the SPSI and PAS ($n = 8$) parent reports, and children age 6 years and above were assessed using the SPSI and SCAS-P parent reports, and the DI self-report ($n = 33$).

Measures

Sensory Processing Scale Inventory. The SPSI [Schoen et al., 2017] was further developed from the Sensory Over-Responsivity Scale [Schoen, Miller, & Green, 2008]. It is a standardized, 96-item questionnaire completed by parents to assess a child's sensory reactivity differences across sensory modalities, including vision, hearing, touch, smell, and taste. It generates scores for sensory hyperreactivity, represented by 47 items (e.g., "My child is bothered by fluorescent lights"), sensory hyporeactivity, represented by 21 items (e.g., "My child does not respond to a normal volume speaking voice"), and sensory seeking, represented by 28 items (e.g., "My child has difficulty disengaging from looking at spinning objects"). Items are scored dichotomously (1 = yes, 0 = no), with higher scores indicating the presence of sensory reactivity differences. The SPSI has good internal reliability (hyperreactivity = 0.89; hyporeactivity = 0.88; sensory seeking = 0.93 [Schoen et al., 2017]).

SCAS-P/PAS versions. The SCAS-P [Nauta et al., 2004] and PAS [Edwards et al., 2010] were adapted from the SCAS [Spence, 1998]. The SCAS-P is a standardized 38-item questionnaire that assesses parent-reported observations of anxiety symptoms in children aged 6–18 years. Items are scored on the scale 0 (never) to 3 (always), with higher scores indicating a greater presence of anxiety symptoms. As well as providing a score for total anxiety, the SCAS-P consists of six subscales that provide scores for generalized anxiety disorder (six items), obsessive compulsive disorder (six items), panic attack and agoraphobia (nine items), separation anxiety disorder (six items), physical injury fears (five items), and social anxiety (six items). The SCAS-P has good internal consistency (0.93) and test–retest reliability (0.60) [Nauta et al., 2004]. The PAS is a standardized 30-item questionnaire that assesses parent-reported observations of anxiety symptoms in children aged 3–6 years. Items are scored on the scale 0 (no true at all) to 4 (very often true), with higher scores indicating a greater presence of anxiety symptoms. The PAS also provides a score for total anxiety, as well as subscores for generalized anxiety disorder (five items), obsessive compulsive disorder (five items), separation anxiety disorder (five items),

physical injury fears (seven items), and social anxiety (six items). However, unlike the SCAS-P, it does not provide a score for panic attack and agoraphobia. The PAS also has good internal consistency (0.70) [Edwards et al., 2010]. As the SCAS-P and PAS have a different number of items, scores for total and subscale items for each participant were transformed by converting the raw scores into a percentage of the total score, for example, the SCAS-P has a maximum total score of 114, therefore if a participant scored a total of 65, this would be converted to 57%.

Dominique interactive. The DI [Valla et al., 2002] is a computer-based self-assessment of mental health for school-aged children and adolescents (6–16 years). It assesses 94 symptoms for 7 different clinical disorders, including generalized anxiety disorder, separation anxiety disorder, specific phobia, major depressive disorder, attention deficit hyperactivity disorder, conduct disorder, and oppositional defiance disorder. These are presented in scenarios depicted by the character Dominique and children are required to read and/or listen to the scenarios and click "yes" if they feel the same way or "no" if they do not. Scores are automatically generated for each mental health disorder, along with an indication of the presence of each disorder (likely absent, possible, likely present). The DI has good test–retest validity for each disorder (0.59–0.80) [Valla et al., 2002].

Results

SPSS 24 was used to analyze the data. A Shapiro–Wilk test of normality was conducted, and some of the variables were found to be significant ($P < 0.05$), therefore normality could not be assumed. However, no outliers were identified

Table 2. Descriptive Statistics for Anxiety (SCAS-P/PAS Raw Percentage Scores, and DI Raw Scores), Sensory Reactivity Differences (SPSI Raw Scores), and Autism Traits (AQ Raw Scores)

	Mean	SD
SCAS-P/PAS		
Total anxiety	31.5	16.1
Panic attack and agoraphobia	16.1	15.1
Separation anxiety	37.4	20.4
Physical injury fears	34.2	20.8
Social anxiety	44.2	24.9
OCD	24.4	18.6
GAD	37.7	21.6
DI		
Specific phobia	1.8	1.6
Separation anxiety	1.5	1.7
GAD	6.4	2.6
SPSI		
Hyperreactivity	53.5	21.9
Hyporeactivity	26.8	12.8
Seeking	37.5	18.5
AQ	35.5	5.8

in the data (see Table 2 for descriptive statistics). Due to the different scales of the measures, Z-scores were calculated to standardize each variable for analysis. A non-parametric Spearman's bivariate correlation analysis found IQ was not correlated with total or subscale scores of sensory reactivity differences or SCAS-P/PAS and DI anxiety ($P > 0.05$). Age was found to have a moderate positive correlation with SCAS-P/PAS social anxiety ($r_s(35) = 0.44$, 95% CI [0.1214, 0.6723], $P = 0.009$); however, when including age as a covariate, the results were found to be independent of age effects as correlations between social anxiety and sensory reactivity differences remained nonsignificant. We corrected for multiple comparisons using a Holm-Bonferroni correction [Holm, 1979].

Correlational Analysis of Sensory Reactivity Differences, Anxiety, and Autism Traits

Spearman's analysis found significant correlations between sensory reactivity differences as measured by the SPSI and anxiety (see Table 3 for correlations). Sensory hyperreactivity was found to have a significant moderate positive correlation with total anxiety ($r_s(36) = 0.45$, 95% CI [0.1437, 0.6755], $P = 0.006$), physical injury fears ($r_s(36) = 0.49$, 95% CI [0.1962, 0.7070], $P = 0.002$), and separation anxiety ($r_s(36) = 0.45$, 95% CI [0.1437, 0.6789], $P = 0.006$). No significant correlations were found between GAD (SCAS-P/PAS and DI), panic attack and agoraphobia, social anxiety, OCD, DI separation anxiety and DI-specific phobia, and sensory reactivity differences as measured by the SPSI ($P > 0.05$). Additionally, no significant correlations were found between sensory hyporeactivity and anxiety ($P > 0.05$). Fisher's z-test [Steiger, 1980] was conducted to test the difference between significant and nonsignificant correlations. This showed that the correlation coefficients between sensory hyperreactivity and anxiety

subtypes were not significantly different [$P > 0.05$]. Fisher's z-test also showed that the significant correlation between sensory hyperreactivity and physical injury fears were significantly different to the nonsignificant relationships between both sensory hyporeactivity and seeking and physical injury fears. However, further comparisons of the correlation coefficients between total anxiety and separation anxiety and sensory reactivity differences were not found to be significantly different ($P > 0.05$).

The correlational analysis was also conducted to explore whether autism traits as measured by the AQ related to anxiety and sensory reactivity differences. The analysis found significant correlations between AQ and both anxiety and sensory reactivity differences (see Table 3 for correlations). Total autism traits were found to have a significant moderate positive correlation with total anxiety ($r_s(31) = 0.60$, 95% CI [0.3119, 0.7870], $P < 0.001$), separation anxiety ($r_s(31) = 0.51$, 95% CI [0.1952, 0.7345], $P = 0.003$), and OCD ($r_s(31) = 0.67$, 95% CI [0.4079, 0.8255], $P < 0.001$) as measured by the SCAS-P/PAS, but there were no significant correlations with panic attack and agoraphobia, physical injury fears, social anxiety, and GAD ($P > 0.05$). Total autism traits were found to have a significant moderate positive correlation with sensory hyperreactivity ($r_s(32) = 0.53$, 95% CI [0.2237, 0.7422], $P = 0.002$), and hyporeactivity ($r_s(32) = 0.47$, 95% CI [0.1401, 0.7008], $P = 0.007$), but there was no significant correlation with sensory seeking ($P > 0.05$). No significant correlations were found between autism traits and DI anxiety ($P > 0.05$).

Correlational Analysis of Sensory Hyperreactivity and Anxiety Controlling for Autism Traits

Because autism traits were correlated to both sensory reactivity differences and anxiety, we conducted a Spearman's bivariate correlation analysis controlling for

Table 3. Spearman's Correlations Between Sensory Reactivity Differences (SPSI), Anxiety (SCAS-P/PAS and DI), and Autism Traits (AQ)

	SPSI			AQ
	Hyperreactivity	Hyporeactivity	Seeking	
SCAS-P/PAS				
Total anxiety	0.451**	-0.007	0.279	0.629**
Panic attack and agoraphobia	0.283	0.011	0.223	0.372
Separation anxiety	0.446**	0.048	0.156	0.516**
Physical injury fears	0.493**	-0.226	-0.042	0.108
Social anxiety	0.280	-0.128	0.170	0.514
OCD	0.313	0.207	0.367	0.670**
GAD	0.311	-0.073	0.028	0.436
DI				
Specific phobia	0.329	-0.181	-0.414	-0.092
Separation anxiety	-0.031	-0.109	0.370	0.046
GAD	0.130	0.069	0.136	0.052
AQ	0.545**	0.456**	0.368	-

*Correlation is significant at the 0.05 level (two-tailed) after a Holm-Bonferroni correction; **Correlation is significant at the 0.01 level (two-tailed) after a Holm-Bonferroni correction.

Table 4. Spearman's Correlations Between Sensory Reactivity Differences (SPSI) and Anxiety (SCAS-P/PAS and DI), Controlling for Autism Traits (AQ)

	SPSI		
	Hyperreactivity	Hyporeactivity	Seeking
SCAS-P/PAS			
Total anxiety	0.196	−0.404*	0.072
Panic attack and agoraphobia	0.133	−0.173	0.112
Separation anxiety	0.238	−0.252	−0.047
Physical injury fears	0.513**	−0.318	−0.092
Social anxiety	0.079	−0.397*	0.018
OCD	−0.065	−0.157	0.168
GAD	0.132	−0.314	−0.140
DI			
Specific phobia	0.454*	−0.152	−0.408
Separation anxiety	−0.060	−0.144	0.384
GAD	0.143	0.070	0.140

*Correlation is significant at the 0.05 level (two tailed) after a Holm–Bonferroni correction; **Correlation is significant at the 0.01 level (two tailed) after a Holm–Bonferroni correction.

autism traits to assess the relationship between sensory hyperreactivity as measured by the SPSI, and anxiety as measured by the SCAS-P/PAS and the DI. Partial Spearman's analysis found significant correlations between sensory hyperreactivity as measured by the SPSI and anxiety (see Table 4 for correlations). Sensory hyperreactivity was found to have a significant moderate positive correlation with physical injury fears ($r_s(28) = 0.51$, 95% CI [0.1730, 0.7437], $P = 0.004$), and DI-specific phobia ($r_s(19) = 0.45$, 95% CI [0.0002, 0.7529], $P = 0.039$). Sensory hyporeactivity was found to have a significant moderate negative correlation with social anxiety ($r_s(28) = -0.40$, 95% CI [−0.6707, −0.0280], $P = 0.030$) and total anxiety ($r_s(28) = -0.40$, 95% CI [−0.6752, −0.0364], $P = 0.027$). No significant correlations were found between sensory seeking and anxiety ($P > 0.05$).

Fisher's z-test was conducted to test the difference between significant and nonsignificant correlations. This showed that the correlation coefficients between sensory hyperreactivity and both physical injury fears and separation anxiety were not significantly different ($P > 0.05$). Additionally, the correlation coefficients between sensory hyperreactivity and both DI phobia and DI GAD were not significantly different ($P > 0.05$). Lastly, the correlation coefficients between sensory hyporeactivity and anxiety subtypes were not significantly different ($P > 0.05$). However, all other significant correlation coefficients were significantly different from nonsignificant coefficients ($P < 0.05$). For relationships that changed in significance due to the partial correlation analysis, Fisher's z-test was conducted to identify if there was a significantly different change in correlation coefficients. Fisher's z-test showed that the changes in correlation

coefficients when controlling for autism traits were significantly different ($P < 0.001$).

Agreement between Parent- and Self-Reported Anxieties

The presence of anxiety in the sample was determined by calculating the percentage of participants that scored above and below the standardized cutoffs for the SCAS-P/PAS and the DI (Table 5). The SCAS-P/PAS parent reports identified a high percentage of participants had clinically elevated symptoms indicative of anxiety. The greatest percentage of participants had elevated symptoms for GAD (74.3%) and OCD (71.4%). However, the DI self-reports identified a greater percentage of participants as having no indication of symptoms for each anxiety subtype, compared to elevated symptoms, identifying only 17.9% of participants as having clinically elevated symptoms for GAD. A chi-square test was performed to analyze agreement between the SCAS-P/PAS and the DI for separation anxiety and GAD. The SCAS-P/PAS and the DI had 0.333 (33.3%) agreement for GAD, $X^2(1, N = 21) = 0.96$, $P > 0.05$, and 0.350 (35.0%) agreement for separation anxiety, $X^2(1, N = 21) = 0.48$, $P > 0.05$.

Discussion

This study is the first known study to elucidate that sensory reactivity differences, including sensory hyperreactivity, hyporeactivity, and seeking, relate differentially to anxiety subtypes in autistic children. In accordance with previous research [e.g., Carpenter et al., 2018; Green & Ben-Sasson, 2010; Green et al., 2012; Pfeiffer et al., 2005], primary correlational analysis identified a significant relationship between sensory hyperreactivity and total anxiety. Furthermore, in line with previous findings our results show a significant relationship between sensory hyperreactivity and separation anxiety and phobia/physical injury fears, but not social anxiety [Black et al., 2017; Green & Ben-Sasson, 2010; Kerns et al., 2014; Spain et al., 2018; White et al., 2009]. However, as with previous research [e.g., Kerns et al., 2014] we also identified that autism traits were related to anxiety as well as sensory reactivity differences. Therefore, as the aim of this study was to explore the pure relationship between sensory reactivity differences and anxiety, we reconducted the analysis controlling for autism traits. This showed a different pattern of results, as greater sensory hyperreactivity was significantly related to greater physical injury fears and specific phobia, and greater hyporeactivity was significantly related to lesser total and social anxieties, which suggest that broader autistic traits may influence these relationships. This could be due to overlapping symptoms between sensory hyperreactivity, anxiety, and autism traits. Anxiety and autism share

Table 5. Percentage of Participants Who Scored Above and Below the Cutoff for Total Anxiety and the Anxiety Subscales in the SCAS-P/PAS and DI

	Elevated symptoms (%)	No indication (%)
SCAS-P/PAS parent-report		
Total anxiety (<i>n</i> = 35)	62.9	37.1
Panic attack and agoraphobia (<i>n</i> = 23)	62.5	37.5
Separation anxiety (<i>n</i> = 35)	65.7	34.3
Physical injury fears (<i>n</i> = 35)	48.6	51.4
Social anxiety (<i>n</i> = 35)	62.9	37.1
OCD (<i>n</i> = 35)	71.4	28.6
GAD (<i>n</i> = 35)	74.3	25.7
DI self-report		
Specific phobia (<i>n</i> = 28)	28.6	71.4
Separation anxiety (<i>n</i> = 22)	4.5	95.5
GAD (<i>n</i> = 28)	17.9	82.1

characteristics that can cause problems with overlap in research, such as compulsive and ritualistic behavior, communication differences, and social avoidance [Wood & Gadow, 2010]. As differentiating between behaviors that relate to either autism or anxiety may be impacted by existing measures or caregiver observations, the primary analysis could reflect inflated relationships [Kerns & Kendall, 2012]. Additionally, sensory reactivity differences are a component of the RRBs diagnostic criteria for autism [DSM-5 American Psychiatric Association, 2013], and consequently there may also be overlap in measures of both sensory reactivity and autism traits. Therefore, controlling for AQ as we did may reduce the variability resulting from trait-symptom overlap, or possible measurement or response bias.

Nonetheless, our results showed that when taking autism traits into account, sensory hyperreactivity was significantly related to anxiety symptoms associated with phobia. Additionally, our results suggest that the relationship between sensory hyperreactivity and physical injury fears was independent of broader autism traits as the relationship remained significant. This finding is of particular interest as rates of phobia are considered to be inflated in autistic populations [Gjevik et al., 2011; Leyfer et al., 2006; Lidstone et al., 2014; Mukaddes & Fateh, 2010; Muskett et al., 2019; White et al., 2009]. Furthermore, phobias can often be specific to sensory stimuli, which may result from aversive experiences of sensory stimuli conditioning a fear response [Green & Ben-Sasson, 2010; Leyfer et al., 2006]. Due to this link, it has recently been suggested that sensory hyperreactivity should be targeted in cognitive behavioral therapy interventions that treat anxiety, especially when treating specific phobias related to sensory stimuli [Muskett et al., 2019]. However, due to the nature of phobia being around specific stimuli, questionnaire assessments pose some limitations as they

often ask about a range of specific fears (e.g., dogs, heights, insects, or spiders) rather than assessing the extent of symptoms surrounding any specific fears the child may have. Therefore, further research should aim to elucidate this relationship whilst overcoming the limitations of existing assessments.

Although our results also showed autism traits to be related to OCD, in contrast with previous research we did not find a significant relationship between OCD and sensory hyperreactivity. Previous research with nonautistic children and adults has shown sensory hyperreactivity to be related to OCD symptoms, although there is some debate as to whether this may be due to a crossover between repetitive traits associated with both autism and OCD [Kerns & Kendall, 2012; Leyfer et al., 2006; Pfeiffer et al., 2005; Postorino et al., 2017; White et al., 2009]. However, as we used different sensory and OCD measures compared to previous work, this could account for this finding not being replicated in our results.

Our study was the first known to consider how sensory reactivity differences, including hyporeactivity and seeking, relate to anxiety symptomology in autistic children. Sensory hyporeactivity has previously been thought to be related to depression rather than anxiety in autistic children, and it has previously been proposed that children experience sensory hyporeactivity as a protective response to sensory overload by “shutting off” sensory input in order to cope with the anxiety [Lai, Parham, & Johnson-Ecker, 1999; Pfeiffer et al., 2005]. Although we cannot imply causation from our results, they could be suggestive of the latter as although we found no significant relationships between sensory hyporeactivity and anxiety in our initial analysis, when controlling for autism traits we found significant negative relationships with total and social anxieties. However, as we found no significant differences between significant and nonsignificant correlation coefficients for hyporeactivity and anxiety, these findings should be interpreted with caution. Furthermore, and in contrast to our predictions, our results did not show a significant relationship between sensory seeking and anxiety. Existing theory suggests sensory seeking serves as a regulatory behavior for arousal by limiting feelings of anxiety, or by providing stimulation in instances of hyporeactivity [Lidstone et al., 2014]. Our results could suggest that sensory seeking is not related to arousal regulation. However, as correlations between sensory seeking and specific phobia and social anxiety were trending toward significance, the links between sensory seeking and anxiety should be examined further in future directions.

Nonetheless, our research highlights the importance of assessing sensory reactivity differences independently in anxiety research due to the differential significant relationships found in our results. Previous research has examined links between overall sensory severity, using

an amalgamation of hyperreactivity and hyporeactivity, and anxiety [e.g., Lane, Molloy, & Bishop, 2014; Uljarević et al., 2016]. However, our results suggest that this approach may not account for the complex nature of sensory experiences. Furthermore, our results highlight the importance of understanding how specific differences experienced by autistic people may be risk factors for anxiety disorders, but that it is important for future research to not neglect the relationship between broader autistic traits and anxiety. Existing research has shown links between traits associated with RRBs and anxiety, as well as suggesting that relationships between both sensory hyperreactivity and hyporeactivity and traits associated with RRBs are mediated by anxiety [Rodgers, Glod, Connolly, & McConachie, 2012; Wigham, Rodgers, South, McConachie, & Freeston, 2015]. Therefore, as there may be a differential relationship between sensory hyperreactivity and hyporeactivity, autism traits and specific anxiety symptomology, future work should therefore try to explore the specific autism phenotypes and understand how these relate to different anxiety disorders. This is important for the development of individualized therapeutic interventions for autistic people experiencing anxiety.

In line with the previous literature, our study identified a substantial proportion of the sample presented with clinically elevated levels of anxiety as reported by parents [de Bruin et al., 2007; van Steensel et al., 2011]. However, self-identification of clinically elevated anxiety, assessed using the DI, was significantly lower than identification via parent report for GAD (33.3%) and separation anxiety (35.0%). This may suggest that autistic children struggle to identify their own affect, and therefore parent reports of anxiety may be more accurate than self-reports [Russell & Sofronoff, 2005; White et al., 2009]. As individuals high in alexithymia are also thought to be at greater risk of developing anxiety, and it has also been found to relate to higher sensory hyperreactivity [Liss, Timmel, Baxley, & Killingsworth, 2005; Sivik, 1993], future research could therefore assess alexithymia alongside self-reports. An alternative explanation is that autistic children more accurately report their own experiences of anxiety than their parents. Previous research has shown inflated reporting of anxiety symptoms in parents of autistic children potentially due to a heightened awareness and observation of their children, which may explain the disparity between parent reports and self-reports in our study [Hallett et al., 2013]. Therefore, as parent reports may not always be reliable, it is important to use multiple assessments and get the perspectives of the children [Spain et al., 2018]. This was the first study to use the DI to gain the perspectives of children, and although it has not been validated in an autistic population, it is a child friendly assessment tool supported by pictures and an audio description and has been developed for children with mental health symptoms.

A limitation of our study is the sole use of parent-reported measures for sensory reactivity differences and autism traits, as previous research has suggested that the exclusive use of parent reports is likely to show an inflated relationship between variables [e.g., Green et al., 2012; Wigham et al., 2015]. Therefore, future directions should aim to include more objective assessments, such as assessing autism traits using the Autism Diagnostic Observation Schedule [Lord et al., 2015]. A further limitation is that despite being widely used, the SCAS-P/PAS may not accurately assess anxiety in autistic populations due to the different anxiety phenomenologies in autistic and nonautistic samples [Glod et al., 2017; Kerns et al., 2014]. Although we aimed to reduce the impact of these limitations by controlling for autism traits in our analyses, there is a real need for more autism-specific anxiety assessments for child anxiety, which are objective and for younger autistic children. There are presently few autism-specific assessments for child anxiety, however future research could also include the clinician administered Anxiety Disorders Interview Schedule—Autism Addendum [Kerns et al., 2017], or the Anxiety Scale for Children—Autism Spectrum Disorder [Rodgers et al., 2016], to explore if similar relationships between sensory reactivity differences and anxiety are found.

Conclusions

Our study highlights the importance of understanding how sensory reactivity differences, including hyperreactivity, hyporeactivity, and seeking, relate to anxiety subtypes both dependently and independently of broader autism traits. Sensory hyperreactivity has been repeatedly found to relate to anxiety in autistic children and our results support previous indications that it could be a risk factor for anxiety, particularly specific phobia. Additionally, our results suggest that sensory hyporeactivity may be related to less anxiety, but we did not find convincing evidence of a relationship between sensory seeking and anxiety. Understanding how sensory reactivity differences relate to anxiety subtypes in autistic children has important implications for preventing the development of anxiety and for targeted anxiety interventions. However, future directions should focus on the pressing need for the development of objective, autism-specific anxiety assessments. This is fundamental to progressing anxiety research which can improve the developmental outcomes for autistic people.

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Conflict of Interest

The authors have no conflicts of interest to declare.

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