University of Reading

ELUCIDATING THE RELATIONSHIP BETWEEN SENSORY REACTIVITY AND ANXIETY IN AUTISM

PHD PSYCHOLOGY

SCHOOL OF PSYCHOLOGY AND CLINICAL LANGUAGE SCIENCES

KEREN MACLENNAN

JULY 2021

Declaration of original authorship

Declaration: I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

KEREN MACLENNAN

All paper contribution statements approved by Teresa Tavassoli July 2021.

Acknowledgements

This thesis is dedicated to the memory of my mother, Heather, whose words of support and wisdom in her final months have inspired me to push myself out of my comfort zone, seek new challenges, and do her proud.

Firstly, I must thank my incredible, powerhouse of a supervisor, Teresa Tavassoli, whose unwavering care, and support (and consistent supply of tea and gluten free treats) has provided a safe and positive space for me to learn and grow without judgement. Teresa has always challenged me to push myself, grasp opportunities, and be proud of every achievement. I have enjoyed every minute of our working together and I hope to continue collaborating long into my career.

I would also like to thank my second supervisor Bhismadev Chakrabarti for his ongoing support and feedback, and for challenging me to learn new skills and to think outside the box. Bhisma always made me feel comfortable to ask questions and get involved in group discussions, which has helped me to grow in confidence as a researcher.

Thank you to my brother and my friends (chosen family) who pushed me to start my university journey in the first place and who have picked me up off the floor every time I doubted myself. Special thanks to my brother, Craig Duncan, for always being there and being all the family I could ever ask for. His calm, confident, positive approach to life always gets me back on track when the negative thoughts creep in. Thanks to my wonderful partner, Fulton McLaughlin, who has supporting me through the worries and breakdowns, and forced me take a break when I didn't even know I needed it. Thanks to my friend who's more like my sister, Hayleigh Bosher, for being the world's best personal cheerleader and for always being there for tea, rants, and pep-talks.

Thanks also go to everyone who has provided support throughout these projects, including my research sibling, Timothy Rossow, and the lab's research assistants, Sarah O'Brien, Lauren Roach, Francesca Englezou, Charlotte Daniels, Khadija Kapadia, and Sophie Jesson.

I would also like to thank the funders, MQ and Autistica, as well as Autism Berkshire, for their continuous support and help with recruitment.

Special thanks go to all the individuals and families who took part in the research. This body of work would not have been possible without you.

Lastly, although it may be unusual, I also think it is important to acknowledge myself, as I am so proud to have produced this body of work in between multiple hospital admissions and with a global pandemic thrown on top. My own tenacity, alongside the support of those I have thanked, has pushed me to do my best, and the personal challenges have reminded me to enjoy the PhD journey and to celebrate the wins.

Table of Contents

Abstract

Sensory reactivity differences are commonly experienced by autistic individuals, including sensory hyperreactivity (i.e., strong reactions to sensory input), hyporeactivity (i.e., no, or slower reactions to sensory input), and seeking (i.e., fascination or fixation with sensory input). Sensory hyperreactivity can be particularly distressing and has previously been linked to anxiety in autism, and intolerance of uncertainty (IU) has been suggested to be an interlinking transdiagnostic construct. However, limited research has included sensory hyporeactivity or seeking, or examined links to certain anxiety symptomology, and research in young children and adults is especially lacking. Therefore, the four studies presented in this thesis had the primary aim of 1) elucidating the relationship between sensory reactivity difference and anxiety symptomology in autistic individuals, and secondary aims of 2) understanding the role of IU in this relationship, and 3) understanding more about the sensory experiences of autistic adults.

The first study examined the relationship between sensory reactivity differences and anxiety in autistic children ages 3 – 14 years; the second study examined the relationship between sensory reactivity differences, anxiety, and IU in preschool-age autistic children ages 3 – 5 years; the third pair of studies examined the relationship between sensory reactivity differences, anxiety, and IU in autistic adults ages 18+ years; and the final study, examined the sensory experiences of autistic adults using a coproduced, mixed-methods approach.

The findings robustly support an association between sensory hyperreactivity and anxiety symptomology in autistic individuals, and most notably, a consistent relationship across studies with separation anxiety. Furthermore, IU was found to be a mediating factor associated with anxiety and sensory hyperreactivity in children and adults. Although sensory hyporeactivity and seeking were linked with anxiety in some studies, this was not consistent across the studies. The findings from the mixed methods study provided enriched insights into the findings in this thesis from the perspective of autistic adults and highlighted the complex nature of sensory reactivity differences. This informed the creation of an enhanced model, which could further guide future directions.

Overall, the results in this thesis advance understanding of the relationship between sensory reactivity differences and anxiety symptomology. Understanding the risk factors for anxiety in autism has importance for the development and adaptation of effective interventions for autistic children and adults.

Chapter 1. Introduction

1.1 Autism Spectrum Conditions

Autism Spectrum Conditions (ASC) are neurodevelopmental conditions characterised by restricted and repetitive behaviours and interests (RRBs), and social interaction and communication differences, that present early in childhood (DSM-5 American Psychiatric Association, 2013). Global prevalence rates estimate that between 0.08 - 9.3% of children are on the autism spectrum (Chiarotti & Venerosi, 2020). Within the UK, there are an estimated 700,000 autistic people, with 1 in 100 children having a diagnosis (Brugha et al., 2012; Knapp et al., 2007), whilst estimates in the USA suggest 1 in 54 children have a diagnosis (Maenner et al., 2020). ASC was previously an umbrella term for a variety of associated conditions, including Autism, Asperger's Disorder, Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS), Childhood Disintegrative Disorder, and Rett Syndrome (DSM-IV American Psychiatric Association, 1994). However, the recent update of diagnostic manuals reduced the diagnosis to two categories: Autism Spectrum Disorder (referred to as ASC in this thesis); and Social Communication Disorder, in cases where social and communication differences are present with the absence of RRBs (DSM-5 American Psychiatric Association, 2013). Additionally, autism is now diagnosed with an associated severity level, indicating the required level of support needs, and considers the presence or absence of genetic syndromes and commonly cooccurring conditions, such as intellectual disability.

Autism is a heterogenous condition, characterised by varying strengths, difficulties, and differences, and is often intertwined with cooccurring conditions, such as intellectual disability, and a range of psychiatric conditions (Buck et al., 2014; Leyfer et al., 2006a; Lombardo et al., 2019; Loomes et al., 2017). Until recently, autism has predominantly been explained in the context of a deficit-based model (Robertson, 2009). However, autism advocates have challenged this perspective, underpinned by the social model of disability, proposing that autistic difficulties can also arise and be exacerbated as a result of systemic social barriers in society (Kapp et al., 2013). Consequently, there has been a shift in research to also highlight autistic difference as opposed to focussing on deficit, such as in social communication research (e.g., Crompton et al., 2020). Recognising strengths, differences, as well as difficulties associated with autism should be considered as central to autistic identity (Robertson, 2009), and this perspective has been embraced in the writing of this thesis. This has been particularly considered in the language used throughout this thesis, which reflects preferred terms as supported by research, stakeholders, and our participants. Most notably, identity first language (e.g., "autistic person") has been used, as this has been identified to be preferred by the autistic community over the use of person-first language (e.g., "person with autism"), which accentuates stigma associated with autism (Gernsbacher, 2017; Kenny et al., 2016).

1.2 Sensory reactivity

Sensory reactivity denotes the way that people process, and respond to sensory input received via different domains, such as vision, hearing, and touch. Effective organising of sensory input through

cognitive processing, also known as Sensory Integration, allows us to perceive and respond appropriately to our situation or environment (Ayres, 1972). For instance, we can perceive sensory input as enjoyable, such as feeling the warmth of the sun on our skin, but we can also react quickly to aversive input, such as if we touch a hot stove. Sensory input is captured via receptors: external stimuli from the surrounding environment is captured via auditory, visual, tactile, olfactory, or gustatory receptors; and internal stimuli initiated from inside the body is captured via proprioceptive, vestibular, or tactile receptors. These receptors transform the input into sensory information, which is then processed and organised, and determines the appropriate motor and behavioural response (Galiana-Simal et al., 2020). The perceptual experience is influenced both by the incoming sensory information, but also prior knowledge held about the world (Pellicano & Burr, 2012). This process is depicted in Figure 1.

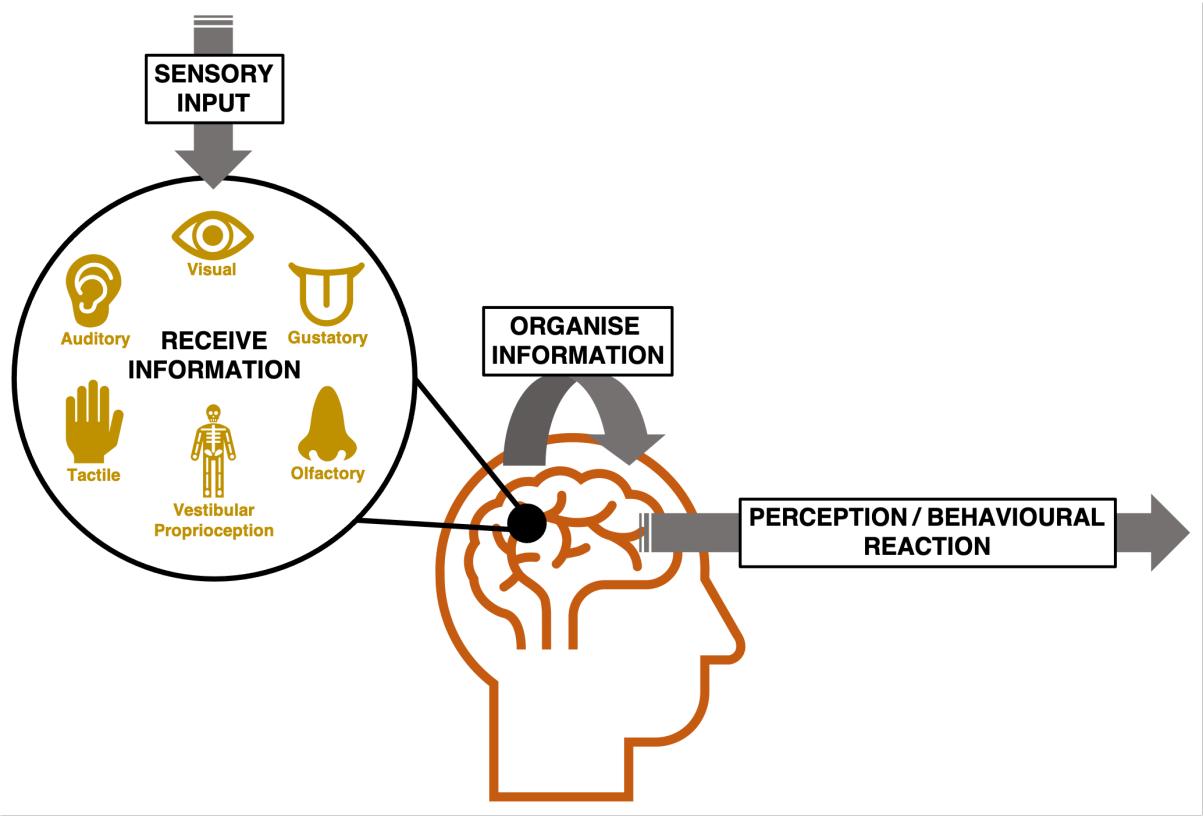

Figure 1
Simplified depiction of the process of sensory reactivity, showing how sensory input is received through the senses, the information is organised/processed, and this informs the way we perceive or react to this input.

However, some individuals may have differences or difficulties in the way they react to sensory input due to altered Sensory Integration, or the way that the sensory systems interpret sensory information, which can impact reactivity, or the behavioural and/or motor responses, to sensory input (Galiana-Simal et al., 2020; Pellicano, 2013). Differences in sensory reactivity can be characterised by: hyperreactivity, perceiving sensory input much more aversively than others; hyporeactivity, not noticing sensory input or perceiving it much less than others; or seeking, being fascinated by or repeatedly seeking out sensory input (Miller et al., 2007).

Individuals who are sensory hyperreactive, also known as hypersensitive, or over-responsive, may experiences sensory input as painful, dysregulating, or overwhelming, and they may avoid sensory input they find aversive. They may cover their ears if they encounter loud and/or unexpected sounds, such as sirens or alarms or hand dryers, or struggle with loud, busy environments, such as shopping centres or the school playground. They may also find bright and/or flashing lights difficult to tolerate, such as overhead fluorescent lighting, and struggle with unexpected touch or certain clothing fabrics, such as wool, as well as scratchy labels in their clothing (Schoen et al., 2017; Siper et al., 2017). Individuals who are sensory hyperreactive often experience sensory input more intensely than others, and this can become overwhelming and lead to states of shutdown, or reduced functioning (Lane, 2002).

Individuals who are sensory hyporeactive, also known as hyposensitive, or under-responsive, may not notice or have a delayed response to certain sensory input. They may not respond if their name has been called or may not hear the phone or doorbell ring. They may also be less likely to visually scan the environment and therefore not notice if someone has entered the room or if something in the environment has changed. Furthermore, they may not respond quickly if they touch something hot, such as the radiator, or notice if someone has touched their arm to get their attention (Schoen et al., 2017; Siper et al., 2017). It has been suggested that sensory hyporeactivity could be an adverse state of sensory hyperreactivity, as it may be present in individuals proceeding severe periods of hyperreactivity when a state of shutdown is induced (Lane, 2002; Liss et al., 2006).

Individuals who are sensory seeking, sometimes referred to as having unusual sensory interests, may be more likely to repeatedly engage with certain sensory input for sustained periods of time. They may listen to the same song or a particular sound clip over-and-over again. They may also be fascinated by, or look closely at, coloured or slowly moving lights or objects that spin, such as the washing machine or a pinwheel. Additionally, they may continually touch soft textures or frequently bump or crash into things on purpose (Schoen et al., 2017; Siper et al., 2017). Sensory seeking is predominantly described as being a behavioural response intertwined with other phenomena. It has been suggested to be a stimulation strategy associated with sensory hyporeactivity, that allows an individual to obtain feedback from the sensory environment (Lidstone et al., 2014). However, it has also been suggested to be associated with sensory hyperreactivity as well as RRBs, as a means for an individual to soothe, regulate, and control the sensory environment and limit the effects of aversive sensory input (Lidstone et al., 2014; Pellicano, 2013; Schulz & Stevenson, 2019).

Differences in sensory reactivity are commonly experienced in autistic people, and are considered to be a core feature of autism, although not an essential criterion for diagnosis (DSM-5 American Psychiatric Association, 2013). Prevalence research has estimated sensory reactivity differences to be present in around 65-80% of autistic children and 94% of autistic adults (Crane et al., 2009; Lane et al., 2011; Leekam et al., 2007; Tavassoli et al., 2016). Individuals often experiences differential patterns of sensory hyperreactivity, hyporeactivity, and seeking, and this can also vary across domains, contexts, and time (Baranek et al., 2006; Lidstone et al., 2014). Figure 2 depicts an autistic individual's own experiences of sensory reactivity differences across domains.

Figure 2
Sensory experiences relating to auditory, visual, and tactile domains. Taken from @21andsensory, an autistic adult with sensory processing disorder who shares their experiences on Instagram (21andsensory, 2020)

However, it is important to note that sensory reactivity differences are not exclusive to autism, but occur throughout the general population, and are often elevated in people with other neurodevelopmental conditions, such as attention-deficit hyperactivity disorder (ADHD) (Ben-Sasson et al., 2009; Reynolds et al., 2010). Sensory reactivity differences seem to be intrinsically linked to autism traits, and have been found to preceded and be an early predictor of core diagnostic traits associated with autism, including both social differences and RRBs, as well as later diagnostic status (Baranek et al., 2013; Boyd et al., 2010; IBIS network et al., 2015; Turner-Brown et al., 2013). Sensory reactivity differences can significantly impact daily living for autistic individuals and have been linked with behavioural difficulties (Dellapiazza et al., 2018; Lane et al., 2010), as well as mental health conditions, such as anxiety (Hwang et al., 2019; Uljarević et al., 2016).

1.3 Anxiety

Anxiety is an inherent fearful response to perceived threat or negative consequences that are less explicit and certain, which is distinct from adaptive fear in response to a known external danger (Barlow, 2000; Bishop, 2007). Anxiety can become problematic when individuals experience excessive and disproportionate fear and worry that disrupts everyday functioning. Characteristically, this may include avoidance or significant distress and somatic symptoms, that are not better explained by another condition (DSM-5 American Psychiatric Association, 2013).

There are several types of disorders classed under anxiety disorders in the DSM-5, including generalised anxiety disorder (GAD), social anxiety disorder, separation anxiety disorder, specific phobia, and panic disorder and agoraphobia, as well as anxiety related conditions, such as obsessive-compulsive disorder (OCD) (DSM-5 American Psychiatric Association, 2013). The definitions are summarised in Table 1. It is important to note that from the DSM-IV to the DSM-5, OCD changed classification from an anxiety disorder to Obsessive-Compulsive and Related Disorders. However, due to its former classification, it is commonly included on existing anxiety assessments, and has therefore been considered as an anxiety related condition in this thesis.

Table 1
Characteristics of DSM anxiety disorder symptomology

DSM anxiety related disorders	Characteristics
Generalised anxiety (GAD)	Persistent and excessive fear and worry that is difficult to control
Social anxiety	Persistent fear of being negatively appraised in social or performance situations
Separation anxiety	Persistent, excessive, and developmentally inappropriate fear related to separation from certain people
Specific phobia	Persistent and excessive fear of a specific object or situation (e.g., heights, animals)
Panic, with/without agoraphobia	Abrupt onset of intense fear or discomfort that reaches a peak within minutes, accompanied by several somatic symptoms. Associated agoraphobia is defined as an excessive fear of certain situations, including being outside the home, in open or enclosed spaces, on public transport, or standing in a line or crowd
Obsessive-compulsive (OCD)	Obsessions and/or compulsions. • Obsessions are the experience of distressing and intrusive persistent and recurrent urges, thoughts, or images, which are ignored, suppressed, or neutralised through thought or action. • Compulsions are excessive or unrealistic repetitive mental acts or behaviours (e.g., counting, praying, or handwashing) in response to an obsession that are meant to prevent or reduce distress or prevent a feared event or situation.

Due to their dimensional nature, anxiety disorders are not always stable across time, as people who overcome symptoms associated with one anxiety disorder can later develop symptoms associated with a different disorder (Bystritsky et al., 2013). Additionally, anxiety disorders also have varying age of onset, and symptoms relating to phobia and separation anxiety are thought to establish earliest (Beesdo et al., 2009).

1.4 Anxiety in autism

Autistic people are at heightened risk of anxiety compared to the general population, with prevalence estimates suggesting clinical levels of anxiety are present in 40% of children and 20% of adults (Nimmo-Smith et al., 2020; van Steensel et al., 2011) compared to 7-9% in the general population (Ghandour et al., 2019; Nimmo-Smith et al., 2020). This has a monumental impact on daily living and the quality of life of individuals (Mason et al., 2019; Robertson et al., 2018; van Steensel et al., 2012), which is often more significant than the impact of being autistic (Ozsivadjian et al., 2012). Autistic people are commonly diagnosed with a variety of anxiety conditions, however, prevalence estimates for specific conditions vary greatly across studies and autistic sub-groups, such as those with and without cooccurring intellectual disability (de Bruin et al., 2007; Kerns et al., 2020; Leyfer et al., 2006a; Simonoff et al., 2008; van Steensel et al., 2011). For instance, Simonoff et al., (2008) found social anxiety was

the most common anxiety disorder in autistic children (age 10-14 years), with a reported prevalence of 29%. Whereas a meta-analysis, conducted by van Steensel et al., (2011), found that specific phobia was the most common anxiety disorder in autistic children (age < 18 years), with a reported prevalence of 30%. A recent study by Kerns et al., (2020) also found that specific phobia was the most commonly diagnosed anxiety disorder in autistic children (age 9-13 years), with a reported prevalence of 44%, and it was also found to be the most common condition in children with cooccurring intellectual disability. Whereas in adults (age 18 – 27 years), phobic anxiety conditions, including social phobia, as well as OCD have been found to be most prevalent (Nimmo-Smith et al., 2020).

It has also become apparent that as well as presenting with traditional anxiety symptoms in line with the DSM, autistic individuals experience distinct, autism-related anxiety symptoms. This can include unusual phobias, which may be uncommon and related to sensory stimuli such as balloons; social fears which are unrelated to negative appraisal, such as fearing social situations without worry associated with being negatively judgement by others; and fears associated more specifically with change that are not better explained by generalised worries (Kerns et al., 2014, 2017). Although autistic people frequently have distinct presentations of clinical anxiety, they also commonly meet for diagnoses in alignment with traditional DSM symptomology (Kerns et al., 2020). Additionally, there are currently few standardised anxiety assessments suitable for young autistic children, or autistic people with cooccurring intellectual disability and who speak few-to-no words (see section 2.7: Measuring sensory reactivity and anxiety in autism). Thus, this thesis focusses on clusters or ‘subtypes’ of symptoms that are associated with traditional classifications of anxiety conditions that align with the DSM, rather than distinct symptomology in autism.

Due to the inordinate risk of anxiety for autistic people, there has been a growing focus in research to identify potential risk factors linked to autism that may explain this heightened risk. A range of constructs have been found to be implicated in anxiety in autism, including broader autism traits, such as RRB’s, as well as alexithymia or emotional awareness, and intolerance of uncertainty (Pickard et al., 2020; South & Rodgers, 2017; Wigham et al., 2015). Furthermore, sensory reactivity differences, primarily hyperreactivity, have also frequently been identified to be associated with anxiety (Amos et al., 2019; Bitsika et al., 2019; Black et al., 2017; Carpenter et al., 2018; Glod et al., 2019; Green et al., 2012; Horder et al., 2014; Hwang et al., 2019; Lidstone et al., 2014; Liss et al., 2008; Mazurek et al., 2013; Uljarević et al., 2016; Wigham et al., 2015). South and Rodgers (2017) proposed a theoretical model of the relationships between these contributing factors and anxiety in autism (Figure 3).

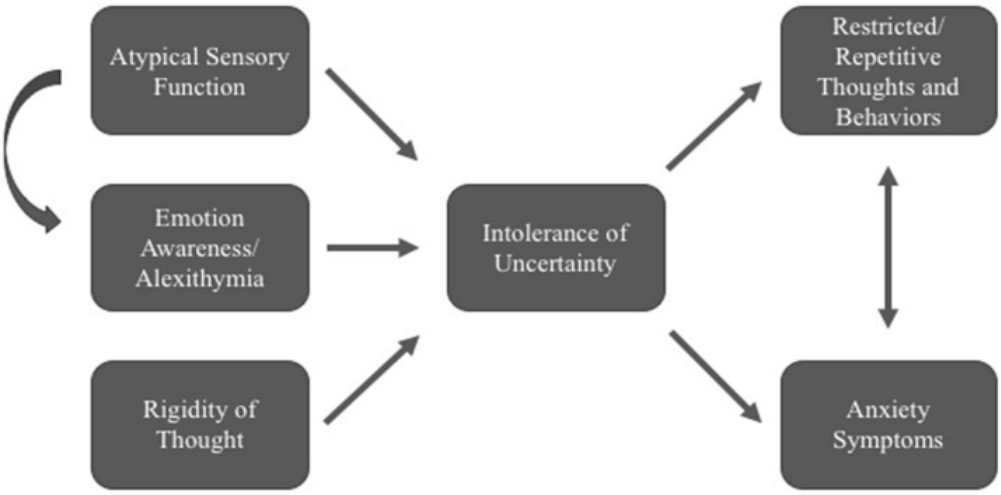

Figure 3
Proposed model by South and Rodgers (2017) of the possible pathways between factors relating to anxiety in autism.

As it is beyond the scope of the aims of this thesis to explore all the wider factors that relate to anxiety in autism, this thesis aims to delve deeper into the relationships between subtypes of sensory reactivity differences and anxiety. However, some of these factors were considered in the studies in this thesis. Firstly, as IU has been suggested to be an important interrelated construct with sensory reactivity and anxiety, this has been examined in preschool-age children in the study in Chapter 3, and adults in the study in Chapter 4. Intolerance of uncertainty (IU), broadly defined as the negative appraisal of contexts and situations that are unpredictable or unforeseen, is a construct which has been found to be common in autistic individuals and associated with the development and maintenance of anxiety (Buhr & Dugas, 2006; Dugas et al., 1998; Freeston et al., 1994). IU has commonly been identified as a factor associated with both sensory reactivity and anxiety, and is thought to be a key factor underlying anxiety in autism (Glod et al., 2019; Hwang et al., 2019; Jenkinson et al., 2020; Neil et al., 2016; Wigham et al., 2015). Secondly, due to the possible wider influence of broader autism traits, most notably RRBs as highlighted by South and Rodgers (2017), the approach was taken to measure and control for variance that could be explained by autism traits in the studies in Chapters 2, 3, and 4.

1.5 Sensory reactivity differences and anxiety

1.5.1 Sensory hyperreactivity and anxiety

Sensory hyperreactivity can be extremely distressing and has frequently been linked to anxiety in autistic children and adolescents (Carpenter et al., 2018; Green et al., 2012; Uljarević et al., 2016; Wigham et al., 2015). To date, most research has examined links between sensory hyperreactivity and total anxiety and there is minimal research into the links between sensory hyperreactivity and certain anxiety symptomology. It is important to note that although autistic individuals present with traditional and distinct anxiety symptomology, sensory hyperreactivity has been found to predict traditional rather than distinct anxiety in autistic children, which may instead be predicted by other autistic traits (Kerns et al., 2014). Research by Black et al., (2017) suggested that sensory hyperreactivity may be

differentially related to anxiety symptomology. Their study in autistic children and adolescents (ages 7 – 17 years), using questionnaires completed by parents, found that sensory hyperreactivity was significantly related to specific phobia and separation anxiety, but not to social anxiety. More recent studies that have examined correlates in specific anxiety conditions, rather than comparing conditions, have also found sensory hyperreactivity to be significantly related to GAD in autistic children and adolescents (ages 6 – 18 years) (Bitsika et al., 2019), and to social anxiety in autistic adolescents (ages 11 – 17 years) (Pickard et al., 2020). Links to OCD have not yet been examined in autistic populations, but tentative links have been found between sensory hyperreactivity and OCD in young non-autistic children (ages 4 – 6 years) (Dar et al., 2012). Overall, examining the differential links between sensory hyperreactivity and anxiety symptomology has been an uncommon approach in previous research, thus there is still very little known about how sensory hyperreactivity links to anxiety symptomology in autistic children.

So far, most of the research has primarily examined the links between sensory hyperreactivity and anxiety in autistic children and adolescents, and there have only been a handful of studies that have examined this in adults. Nonetheless, these studies have also consistently found sensory hyperreactivity to be related to anxiety in autistic adults (Hwang et al., 2019; Syu et al., 2020; Syu & Lin, 2018), as well as in non-autistic adults (Amos et al., 2019; Engel-Yeger & Dunn, 2011; Horder et al., 2014; Liss et al., 2008). Additionally, links between sensory reactivity differences and anxiety have also been highlighted in qualitative research with autistic adults (Robertson & Simmons, 2015). However, there is no know research that has yet examined if sensory hyperreactivity is related to certain anxiety symptomology in autistic adults.

Green and Ben-Sasson (2010) conceptualised three theoretical models that may explain the association between sensory hyperreactivity anxiety in autism. Firstly, the primary anxiety model suggests that anxiety is a cause of sensory hyperreactivity. Due to characteristics of anxiety, such as hypervigilance, avoidance, attentional bias, and hyperarousal, individuals are more likely to attend and overreact to sensory stimuli, which is then maintained and intensified through conditioning. Secondly, the primary hyperreactivity model suggests that sensory hyperreactivity is a cause for anxiety. Unpleasant sensory input can be conditioned, either towards a specific stimulus, causing the development of a phobia, or across contexts due to the uncontrollability or unpredictability of stimuli, causing more generalised anxious responses such as with GAD or social anxiety. Thirdly, it may be that there is a non-causal link between sensory hyperreactivity and anxiety, and rather an additional factor explains the link, such as diagnostic overlap or similarities in amygdala activation. To test these models, Green et al., (2012) conducted a study in autistic toddlers (mean age = 28 months) to examine the longitudinal association between sensory hyperreactivity and anxiety. Their results showed that sensory hyperreactivity predicted anxiety a year later, whilst anxiety did not predict anxiety across time. This suggests that sensory hyperreactivity may precede and be an early risk factor for anxiety and support the primary hyperreactivity model, as proposed by Green and Ben-Sasson (2010). However, research has also shown support for there being a non-causal link between sensory hyperreactivity and

anxiety, suggesting they may instead share a common neural basis, linked with overactivation in the amygdala and hippocampus (Green et al., 2013).

1.5.2 Sensory hyporeactivity and anxiety

The links between sensory hyporeactivity and anxiety in autistic children have been comparatively under-researched, and findings have mostly been inconsistent. Research by Glod et al., (2019) found sensory hyporeactivity to be related to greater anxiety in autistic children (ages 4 – 9 years). However, this direct association has not always been found in studies with autistic children and adolescents (ages 6 – 17 years and ages 8 – 16 years) (Pfeiffer et al., 2005; Wigham et al., 2015). Additionally, no known research has yet aimed to understand if it may be differentially related to anxiety symptomology.

Furthermore, there is only one known study that has examined the link between sensory hyporeactivity and anxiety in autistic adults, which in line with Glod et al., (2019), found a significant link between sensory hyporeactivity and anxiety in autistic adults (Hwang et al., 2019). Hwang et al., (2019), using self-report questionnaires, found that sensory hyporeactivity was significantly correlated with anxiety, but also found that intolerance of uncertainty mediated this relationship. Unsurprisingly, research is yet to examine if sensory hyporeactivity is related to anxiety symptomology in autistic adults.

As sensory hyporeactivity can have negative consequences for an individual, such as injuries from being under responsive to pain or not noticing signs of danger, this could lead to the conditioning of generalised worry and anxiety. However, there is some suggestion that sensory hyporeactivity may not be directly associated with anxiety, but rather indirectly associated through the presentation of RRB's (Wigham et al., 2015). Alternatively, it has been suggested that sensory hyporeactivity may be more implicated in depression, given their characteristic similarity of low levels of arousal (Lane, 2002; Pfeiffer et al., 2005). Individuals may experience sensory hyporeactivity to disengage from aversive or anxiety provoking sensory input and/or in response to sensory overload, which is followed by a period of low arousal and possibly depression (Lane, 2002; Pfeiffer et al., 2005). There is often cooccurrence between anxiety and depression, as well as sensory hyperreactivity and hyporeactivity in individuals (Baranek et al., 2006; Nimmo-Smith et al., 2020; Pollack, 2005). Thus, sensory hyporeactivity may be related to lower anxiety, or it may be an associated outcome with other factors that are linked with sensory hyperreactivity and anxiety, rather than being direct related.

1.5.3 Sensory seeking and anxiety

Sensory seeking is predominantly absent from the literature on sensory reactivity and anxiety. However, research by Lidstone et al., (2014) did not find evidence of a significant link between sensory seeking and anxiety in autistic children and adolescents (ages 2 – 17 years). But so far, no known further research has examined the links between sensory seeking and anxiety, including certain symptomology, in autistic children.

Although the links between sensory seeking and anxiety have not yet been examined in autistic adults, this has previously been examined in non-autistic adults. Similarly to Lidstone et al., (2014), no

significant relationships between sensory seeking and anxiety were found in non-autistic adults (Engel-Yeger & Dunn, 2011; Levit-Binnun et al., 2014). However, the findings of qualitative studies with autistic adults have suggested that sensory seeking may be a soothing experience (Robertson & Simmons, 2015; Smith & Sharp, 2013). For instance, a study by Robertson & Simmons (2015), which conducted a focus group with 6 autistic adults, suggested that seeking out certain enjoyable sensory experiences, such as music, can be comforting and calming when stressed. Whilst it is possible that sensory seeking could reduce anxiety in individuals, it may be that sensory seeking is indirectly related to anxiety as a means for arousal regulation when individuals are under-aroused, or interlinked with RRB's to soothe when over-aroused (Lidstone et al., 2014).

1.6 Measuring sensory reactivity and anxiety in autism

1.6.1 Sensory reactivity measures

There are a growing number of measures for sensory reactivity, but questionnaires are the most used method. Questionnaires are a beneficial method of data collection as they are easy to distribute both in person and online, the latter of which has been particularly important due to the impact of the pandemic on face-to-face testing. There are a variety of questionnaire measures that assess sensory reactivity differences in autistic children and adults. Measures available for use with autistic children include the Sensory Experiences Questionnaire (SEQ; Baranek et al., 2006), which measures sensory hyperreactivity and hyporeactivity in children ages 5 months – 6 years, the Sensory Processing Measure (Miller-Kuhaneck et al., 2007), which measures social participation, praxis, and sensory processing difficulties in children ages 5 – 12 years, and preschool version for ages 2 – 5 years. Measures available for use with autistic adults include the Glasgow Sensory Questionnaire (Robertson & Simmons, 2013), which measures sensory hyperreactivity and hyporeactivity, and the Sensory Processing 3-Dimensions Scale (Mulligan et al., 2019), which measures sensory hyperreactivity, hyporeactivity, and seeking. Additionally, there is the Sensory Processing Scale Inventory (SPSI; Schoen et al., 2017), which measures sensory hyperreactivity, hyporeactivity, and seeking, and is appropriate for use with both autistic children and adults. The Sensory Profile (Dunn, 1999), in its different versions, assesses sensory reactivity differences relating to poor registration, sensory sensitivity, sensory avoiding, and sensory seeking and is the most widely used sensory questionnaire with both autistic children and adults. However, there are some limitations to this measure in the context of the research conducted in this thesis. Firstly, there is a disproportionate representation of items that align with sensory hyperreactivity, compared to sensory hyporeactivity and seeking (Neil et al., 2017; Uljarević et al., 2016). Secondly, the questionnaire includes items that assess wider behaviours that often overlap with autism traits and anxiety, such as items related to conduct and social emotional responses, as well as items that directly refer to anxious affect, for example: *Becomes anxious when standing close to others.* Therefore, the Sensory Profile may not be appropriate when researching links between sensory reactivity and anxiety, as the measure overlap could inflate correlations. Thus, it has not been included in the studies for this thesis. Instead, the Sensory Processing Scale Inventory (SPSI; Schoen et al., 2017) was used as the parent-report measure in the studies in Chapters 2 and 3, and the adult self-report measure in the studies in Chapter 4.

As sensory reactivity is an internal phenomenon, it has been suggested that it should be assessed using a multi-measure approach, including observations and physiological assessments (Burns et al., 2017). Observational assessments provide an objective means to assess sensory reactivity differences in autistic individuals and can be used in conjunction with questionnaires to provide a more objective measure of sensory reactivity differences, although none currently exist for use with autistic adults. Observations that can be used to assess sensory reactivity in autistic children include the Sensory Processing Assessment (Baranek, 1999), a semi-structure play based observation for use with ages 9 months to 6 years to be used in conjunction with the SEQ, the Sensory Integration and Praxis Test, which assesses sensory integration in children ages 4 – 8 years, 11 months, and the Sensory Assessment of Neurodevelopmental Differences (SAND; Siper et al., 2017). The SAND is a direct observation of responses to the presentation of sensory toys and an associated parent interview. The SPSI and the SAND are validated measures (psychometric properties for these assessments are provided in Chapters 2, 3, and 4) that focus on dichotomously scoring (*yes/no*) behavioural responses to sensory input across modalities, providing sub-scales for sensory hyperreactivity, hyporeactivity, and seeking. Due to their similarities in scoring (both dichotomous – *yes/no*) and constructs (both assessing hyperreactivity, hyporeactivity, and seeking) between measures, the SPSI and SAND are appropriate to use in conjunction in research (Chapter 3). Although the SAND was also used for data collected for Chapter 2, floor effects in scores were interpreted as the measure not being appropriate for use in older children and those without cooccurring intellectual disability, and so it was excluded.

1.6.2 Anxiety measures

As with measuring sensory reactivity, a multidisciplinary approach to assessing anxiety should be adopted to incorporate multiple perspectives from different reporters, including questionnaires, interviews, observations, and psychophysiological measures (Spain et al., 2018; White et al., 2009). However, this can currently be difficult to achieve due to the lack of assessments validated for use in autistic individuals.

Questionnaires validated in non-autistic people are the most common method for measuring anxiety in research, due to the lack of validated scales for use in autistic individuals (Vasa et al., 2016). There are a variety of questionnaire measures that assess anxiety in children and adults. Commonly used questionnaires that have been used with autistic children include the Screen for Child Anxiety Related Emotional Disorders (Birmaher et al., 1997), which can be used in children and adolescents aged 8 – 18 years, the Child Behaviour Checklist (Achenbach & Ruffle, 2000), which has an anxiety subscale and can be used with children and adolescents ages 6 – 18 years, Multidimensional Anxiety Scale for Children (March et al., 1997), which can be used with children and adolescents aged 8 – 18 years. The Spence Anxiety Scales (Spence, 1998) are the most commonly used in research with both autistic and non-autistic children, and they provide an overall total score for anxiety, as well as subscales scores for GAD, social anxiety, separation anxiety, OCD, panic and agoraphobia, and physical injury fears. The Preschool Anxiety Scale (PAS; Edwards et al., 2010) is validated for use with children ages 3 – 6 years and the Spence Children's Anxiety Scale – Parent is validated for use with children ages 6 – 14 years (SCAS-P; Nauta et al., 2004). Although these measures were also not designed for use with autistic

children, the SCAS-P has psychometric properties that are promising for use in this population, albeit with studies finding inconsistent factor structures (Glod et al., 2017; Jitlina et al., 2017; Magiati et al., 2017; Zainal et al., 2014). As the Spence Anxiety Scales were the only questionnaire measures able to assess anxiety, and anxiety symptomology, in preschool-age as well as school-age children, these were included in the studies in Chapters 2 and 3.

Furthermore, as parents-reports can capture inflated responses, it is also important to include self-reports when possible to gain additional perspectives (Hallett et al., 2013; Spain et al., 2018). Although there is the Spence Children's Anxiety Scale (Spence et al., 2003), which is a self-report version that can be used with children ages 7 – 19 years, autistic children can struggle to report their affect, thus, it can be helpful to provide clear examples and explanations to assist them in self-reporting (Vasa et al., 2016). Therefore, although also not validated in autistic children, the Dominique Interactive (Valla et al., 2002) may be an appropriate self-report measure for mental health as it provides clear examples of scenarios from the cartoon character Dominique and asks the children to click *yes* or *no* to say if they have felt the same as Dominique, and therefore it was included in the study in Chapter 2.

As research into autistic adults is lacking, little is known about the efficacy of measures of traditional anxiety in this age group. The Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983), although not designed for use with autistic adults, is the only questionnaire measure of anxiety to have been validated in this population (Uljarević et al., 2018). However, as it does not screen for specific anxiety symptomology, it was not suitable for the adult studies in Chapter 4. Instead, the Screen for Adult Anxiety Related Disorders (SCAARED; Angulo et al., 2017) was used, as the Screen for Child Anxiety Related Emotional Disorders (SCARED; Birmaher et al., 1997) has been used in research with autistic children and shown to have good psychometric properties in this population (details in Chapter 4; van Steensel et al., 2013). But the validity of the adult measure has not yet been examined in autistic adults.

More recently, tools have been designed to assess anxiety specifically in autistic individuals, such as the Anxiety Disorders Interview Schedule – Autism Addendum (ADIS-ASA; Kerns et al., 2017) and the Anxiety Scale for Children with Autism Spectrum Disorder (ASC-ASD; Rodgers et al., 2016). However, there are some limitations to using these assessments. Firstly, as the ADIS-ASA is a diagnostic tool designed for differentiating anxiety in autistic individuals, it can be informative in identifying the presence or absence of anxiety conditions. However, due to the cooccurring dimensional nature of anxiety conditions, treatments can often be based on the symptomology, rather than the presence or absence of a diagnosis (Bystritsky et al., 2013). Therefore, scale measures that can assess the extent of anxiety symptoms and symptomology may be more informative in studies examining relationships between anxiety and other constructs, as within this thesis. Secondly, the ASC-ASD only assesses anxiety symptoms that are distinct in autism, providing subscales such as *Performance Anxiety, Anxious Arousal, Separation Anxiety,* and *Uncertainty,* and are not aligned with current DSM symptomology, which is important for clinical impact, and would make findings difficult to compare to existing research and studies with non-autistic populations. While autism distinct measures could be used in conjunction with measures of traditional anxiety symptomology, the ASC-ASD is not validated for use in younger

children, under 6 years, and may not be suitable for individuals with cooccurring intellectual disability. Although these measures were originally included in the study in Chapter 3, they were not suitable for most participants due to their young age and were excluded. However, sensory reactivity differences have been found to be associated with traditional anxiety symptomology, rather than distinct symptoms in autism (Kerns et al., 2014). Additionally, some of the common additional fears experienced in autism relate to sensory reactivity and uncertainty (Lau et al., 2020), constructs which are both assessed separately in this thesis and would likely increase the overlap in traits/symptoms. Therefore, the use of measures that assess traditional anxiety is not perceived as problematic for the studies in this thesis.

1.7 Aims, objectives, and significance of this thesis

The aim of the studies in this thesis are to elucidate the relationships between sensory reactivity differences and anxiety symptomology in autistic people. Due to the heightened prevalence of anxiety in the autistic population, and the debilitating impact of anxiety on the quality of life of individuals, it is important to understand more about autism-related risk factors for anxiety. Understanding if sensory reactivity differences are associated with certain anxiety symptomologies has important implications for treatment approaches, as anxiety conditions are often approached differentially in treatment.

Although previous research has consistently found links between sensory hyperreactivity and anxiety in autistic individuals, there are still many gaps in the literature. Firstly, although there is strong evidence of a link between sensory hyperreactivity and anxiety, minimal research has sought to understand the links between sensory hyporeactivity and seeking, and anxiety. Secondly, minimal research has explored links between sensory hyperreactivity and specific anxiety symptomology, and research is yet to understand if sensory hyporeactivity and seeking are differentially related to certain anxiety symptomology (also referred to as anxiety subtypes in this thesis). Finally, the links between sensory reactivity differences and anxiety have primarily been examined in school-aged autistic children, with minimal research in young children or adults.

Therefore, the primary research question for this thesis was:

1) Are sensory reactivity differences, including hyperreactivity, hyporeactivity, and seeking, differentially related to anxiety symptomology in autistic children and adults?

Additionally, IU has been suggested to be an interrelated construct in the relationship between sensory hyperreactivity and hyporeactivity and anxiety, however minimal research has examined its association with sensory seeking or specific anxiety symptomology. Furthermore, sensory reactivity differences are not commonly researched in autistic adults, especially regarding sensory hyporeactivity and seeking. Therefore, little is known about autistic adults' experiences of sensory reactivity differences across modalities. It has become increasingly important for research to be co-produced with stakeholders, so that it reflects and represents lived experiences and is more likely to improve outcomes for autistic people (Fletcher-Watson et al., 2018).

Therefore, the secondary research questions for this thesis were:

2) Is IU a mediating factor in the relationship between sensory reactivity differences and anxiety symptomology in autistic children and adults

3) What are autistic adults' experiences of sensory reactivity differences?

These questions were addressed across four studies. Table 2 provides a summary of the key details of these studies to accompany the below descriptions.

The first study (Chapter 2) examined the correlational relationships between sensory reactivity differences and anxiety symptomology in autistic children (age 3 – 14 years). Existing work has

frequently highlighted a relationship between sensory hyperreactivity and total anxiety in autistic children (e.g., Green et al., 2012; Hwang et al., 2019; Wigham et al., 2015). Additionally, there is some evidence of a differential relationship with anxiety symptomology (Black et al., 2017; Kerns et al., 2014; Pickard et al., 2020; Spain et al., 2018). Therefore, this first study built on existing work to understand if sensory reactivity differences, including hyperreactivity, hyporeactivity, and seeking, were differentially related to anxiety symptomology, including GAD, separation anxiety, OCD, physical injury fears, and social anxiety, in autistic children.

The second study (Chapter 3) examined the correlational and cross-sectional mediating relationships between sensory reactivity differences, anxiety symptomology, and IU in preschool-aged autistic children (age 3 – 5 years). Existing work in autistic toddlers has suggested that sensory hyperreactivity is an early predictor of anxiety (Green et al., 2012). Additionally, research in older children and adults has suggested that IU may be a key associated construct in this relationship (Hwang et al., 2019; Neil et al., 2016; South & Rodgers, 2017; Wigham et al., 2015). Therefore, this study aimed to replicate and extend on the findings from Chapter 2 in a more focussed age range, to understand if sensory reactivity differences, including hyperreactivity, hyporeactivity, and seeking, were differentially related to anxiety symptomology, including GAD, separation anxiety, OCD, physical injury fears, and social anxiety, in early childhood. But also, to understand the predictive relationship between these factors and the role of IU at this early stage.

The third pair of complementary studies (Chapter 4) examined the correlational and cross-sectional mediating relationships between sensory reactivity differences, anxiety symptomology, and IU in autistic adults. Study 1 examined the relationship between sensory reactivity differences and anxiety symptomology, whilst Study 2 examined the relationship between sensory reactivity differences, anxiety symptomology, and IU in autistic adults. Although the links between sensory hyperreactivity and certain anxiety symptomology has been examined in autistic children (e.g., Black et al., 2017; Pickard et al., 2020), this has not yet been examined in autistic adults. Additionally, IU has been found to partially mediate the relationship between both sensory hyperreactivity and hyporeactivity, and anxiety in autistic adults (Hwang et al., 2019), but links between sensory seeking and anxiety symptomology have not yet been examined. Thus, these studies aimed to replicate and extend on the findings from Chapter 2 and 3 in adults, by understanding how sensory reactivity differences, including hyperreactivity, hyporeactivity, and seeking, were differentially related to anxiety symptomology, including GAD, separation anxiety, and social anxiety, and IU in autistic adults.

The final study of this thesis (Chapter 5) examined the sensory experiences of autistic adults using a mixed methods approach. Although sensory reactivity is commonly researched in autistic children, it has been comparatively under-researched in autistic adults, despite the perseverance into adulthood (Crane et al., 2009; Tavassoli et al., 2014). Existing qualitative research has proposed models of sensory reactivity in autistic adults (Robertson & Simmons, 2015; Smith & Sharp, 2013), however these have been rather over-simplistic or over-complex, have not examined experiences relating to all types of sensory reactivity differences, and have not included stakeholders in the research process. Therefore, this study, co-produced with autistic adults, aimed to, firstly, understand sensory input

associated with sensory reactivity differences, including hyperreactivity, hyporeactivity, and seeking, as well as different domains. Secondly, it aimed to understand more about the sensory experiences of autistic adults to develop an enhanced model that highlights factors involved in sensory reactivity differences in adulthood. This study was important to examine if the results from the quantitative studies in this thesis aligned with the lived experiences of autistic adults and to identify possible future directions.

Table 2
Summary of studies in this thesis, including the age range of participants, the variables measured, and the measures used.

	Age range	Variables	Measures
Chapter 2	3 – 14 years	Sensory reactivity differences • Hyperreactivity • Hyporeactivity • Seeking	Sensory Processing Scale Inventory (SPSI)
		Anxiety • Total • GAD • Separation • Social • OCD • Physical Injury fears • Specific Phobia	Spence Children's Anxiety Scale (SCAS) Dominique Interactive (DI)
Chapter 3	3 – 5 years	Sensory reactivity differences • Hyperreactivity • Hyporeactivity • Seeking	Sensory Processing Scale Inventory (SPSI) Sensory Assessment for Neurodevelopmental Differences (SAND)
		Anxiety • Total • GAD • Separation • Social • OCD • Physical Injury fears • Specific Phobia	Preschool Anxiety Scale (PAS)
		Intolerance of uncertainty	Responses to Uncertainty and Low Environmental Structure questionnaire (RULES)
Chapter 4	18 years +	Sensory reactivity differences • Hyperreactivity • Hyporeactivity • Seeking	Sensory Processing Scale Inventory (SPSI)
		Anxiety • Total • GAD • Separation • Social	Screen for Adult Anxiety Related Disorders (SCAARED)
		Intolerance of uncertainty	Intolerance of Uncertainty Scale (IUS)
Chapter 5	18 years +	Sensory experiences	Mixed methods online-survey (Appendix 3)

Note. GAD: Generalised anxiety disorder; OCD: Obsessive-compulsive disorder; DI: Dominique Interactive

Chapter 2. The relationship between sensory reactivity differences and anxiety subtypes in autistic children

Keren MacLennan, Lauren Roach & Teresa Tavassoli

First published: 07 January 2020 by *Autism Research,* https://doi.org/10.1002/aur.2259

2.1 Paper contribution

I had a significant contribution to this paper. The data was collected as part of a wider study, in which I worked as part of the research team (other team members mentioned in acknowledgements) to develop the study design and aims and collect the data. Lauren Roach was responsible for data inputting. I independently conducted the analyses and wrote the manuscript with feedback provided from the other authors, as well as reviewers through the peer-review process.

2.2 Abstract

Autistic children are at greater risk of developing anxiety than their non-autistic 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.

2.3 Introduction

Autism Spectrum Conditions (ASC) are neurodevelopmental conditions typically characterised by restricted and repetitive behaviours and interests (RRBs), 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 characterised by hyperreactivity (over-responsivity), or hyporeactivity (under-responsivity) to sensory stimuli (e.g. sounds or touch), and sensory seeking (e.g. being fascinated by lights) (Miller et al., 2007). Around 65-80% of autistic 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 behaviours, can be enjoyable for some individuals, other sensory experiences can be very distressing (Uljarević et al., 2016). This can have a detrimental impact on developmental outcomes and quality of life (Boyd et al., 2010; Hilton et al., 2010; Pfeiffer et al., 2005).

Autistic children are also twice as likely to develop anxiety in comparison to non-autistic children, with approximately 55% experiencing clinically elevated levels of anxiety, and up to 40% being diagnosed with at least one anxiety disorder (de Bruin et al., 2007; van Steensel et al., 2011). Common co-morbid anxiety disorders include social anxiety, specific phobia, separation anxiety disorder, generalised 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 et al., 2017; Simonoff et al., 2008; van Steensel et al., 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 non-autistic 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 et al., 2012; Green & Ben-Sasson, 2010; 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 sub-types, and therefore assessing total anxiety scores in research may not be sensitive enough to capture the complex relationship between sensory hyperreactivity and anxiety sub-types. (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 non-autistic 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 sub-types, such as GAD and OCD. Research in non-autistic populations has shown sensory hyperreactivity to correlate with childhood ritualism, and oral and tactile hyperreactivity to relate to OCD symptoms in adults (Dar et al., 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 behaviours 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 sub-types. 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 related to 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 behaviours, which vary in different environments and for different sensory modalities, such as auditory or visual (Baranek et al., 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 over-represents hyperreactivity (Neil et al., 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), that represent sensory hyperreactivity, as well as a greater representation of hyporeactivity and seeking behaviour 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-report 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, labelling, and interpreting emotions in the self and others (Liss et al., 2008). Consequently, autistic children may struggle to identify their own affect, and parent-reports of 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 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 sub-types (e.g. specific phobia, physical injury fears, social anxiety disorder, GAD, OCD) in autistic children. In light of previous research, we hypothesised that firstly, there would be differential relationships between sensory reactivity differences and anxiety sub-types; 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 sub-types.

2.4 Methods

2.4.1 Participants

Forty-one clinically diagnosed autistic children participated in this study (age range 3 – 14 years) (see Table 3). 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 behaviours, and to confirm that all participants scored above the dichotomous scoring cut-off (AQ ≥ 26) (Woodbury-Smith et al., 2005). Forty-three participants were originally recruited for this study; however, two participants were removed due to scoring below the cut-off. The AQ has strong internal consistency (α = 0.97), and test-retest reliability (r = 0.85, p < .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 (WASI-II; Wechsler, 1999) and Wechsler Non-Verbal (WNV; Naglieri & Brunnert,

2009). Seven participants were not able to complete the IQ tasks, however there was no exclusion criteria for cognitive functioning or language level as cognitive levels have not been linked to sensory reactivity in previous research (Siper et al., 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*.

Table 3
Demographic characteristics of participants

Characteristics	*Range*	*M*	*(SD)*
Age (years)	3 - 14	8.44	2.86
IQ	77 - 140	109.03	16.92
AQ	27 - 49	35.53	5.77
Sex		*Percentage*	
Male		68%	
Female		32%	
Clinical Diagnosis			
ASC		100%	

Note. AQ: Autism Spectrum Quotient; ASC: Autism Spectrum Condition.

2.4.2 Procedure

Sensory reactivity differences, including sensory hyperreactivity, hyporeactivity and seeking, were assessed through parent-report using the Sensory Processing Scale Inventory (SPSI; Schoen, Miller, & Sullivan, 2017). Anxiety was assessed through caregiver 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 age 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).

2.4.3 Measures

Sensory Processing Scale Inventory (SPSI)

The SPSI (Schoen et al., 2017) was further developed from the Sensory Over-Responsivity (SensOR) 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

* University of Reading PCLS ethics code: 2017-047-TT

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 = .89; hyporeactivity = .88; sensory seeking = .93 (Schoen et al., 2017).

Spence Children’s Anxiety Scale - Parent and Preschool versions (SCAS-P / PAS)

The SCAS-P (Nauta et al., 2004) and PAS (Edwards et al., 2010) were adapted from the Spence Children’s Anxiety Scale (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 provides scores for generalized anxiety disorder (6 items), obsessive compulsive disorder (6 items), panic attack and agoraphobia (9 items), separation anxiety disorder (6 items), physical injury fears (5 items) and social anxiety (6 items). The SCAS-P has good internal consistency (.93) and test-retest reliability (.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 sub-scores for generalized anxiety disorder (5 items), obsessive compulsive disorder (5 items), separation anxiety disorder (5 items), physical injury fears (7 items) and social anxiety (6 items). However, unlike the SCAS-P, it does not provide a score for panic attack and agoraphobia. The PAS also has good internal consistency (.70) (Edwards et al., 2010). As the SCAS-P and PAS have a different number of items, scores for total and sub-scale items for each participants were transformed by converting the raw scores into a percentage of the total score, e.g. 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 (DI)

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 hyperreactivity 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 (.59 - .80) (Valla et al., 2002).

2.5 Results

SPSS 24 was used to analyse the data. A Shapiro-Wilk test of normality was conducted and some of the variables were found to be significant ($p < .05$), therefore normality could not be assumed. However,

no outliers were identified in the data (see table 4 for descriptive statistics). Due to the different scales of the measures, Z scores were calculated to standardise each variable for analysis. A nonparametric spearman's bivariate correlation analysis found IQ was not correlated with total or sub-scale scores of sensory reactivity differences or SCAS-P/PAS and DI anxiety (p > .05). Age was found to have a moderate positive correlation with SCAS-P/PAS social anxiety ($r_s(35)$ = .44, 95% CI [.1214, .6723], p = .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 non-significant. We corrected for multiple comparisons using a Holm-Bonferroni correction (Holm, 1979).

Table 4
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

Note. SCAS-P/PAS: Spence Children's Anxiety Scale Parent and Preschool; OCD: Obsessive-compulsive disorder; GAD: Generalised anxiety disorder; DI: Dominique Interactive; SPSI: Sensory Processing Scale Inventory; AQ: Autism Spectrum Quotient.

2.5.1 Correlational analysis of sensory reactivity differences, anxiety, and autism traits

Nonparametric 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 ($r_s(36)$ = .45, 95% CI [.1437, .6755], p = .006), physical injury fears ($r_s(36)$ = .49, 95% CI [.1962, .7070], p = .002), and separation anxiety ($r_s(36)$ = .45, 95% CI [.1437, .6789], p = .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 > .05).

Additionally, no significant correlations were found between sensory hyporeactivity and anxiety (p > .05). Fisher's z test (Dunn & Clark, 1969) was conducted to test the difference between significant and non-significant correlations. This showed that the correlation coefficients between sensory hyperreactivity and anxiety subtypes[†] were not significantly different (p > .05). Fisher's z test also showed that the significant correlation between sensory hyperreactivity and physical injury fears was significantly different to the non-significant 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 > .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 5 for correlations). Total autism traits were found to have a significant moderate positive correlation with total anxiety, (r_s(31) = .60, 95% CI [.3119, .7870], p < .001), separation anxiety (r_s(31) = .51, 95% CI [.1952, .7345], p = .003), and OCD (r_s(31) = .67, 95% CI [.4079, .8255], p < .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 > .05). Total autism traits were found to have a significant moderate positive correlation with sensory hyperreactivity (r_s(32 = .53, 95% CI [.2237, .7422], p = .002), and hyporeactivity (r_s(32) = .47, 95% CI [.1401, .7008], p = .007), but there was no significant correlation with sensory seeking (p > .05). No significant correlations were found between autism traits and DI anxiety (p > .05).

[†] *Note:* We tested if the significant relationships between sensory hyperreactivity and both separation anxiety and physical injury fears were significantly different from the non-significant relationships between sensory hyperreactivity and the other anxiety subtypes (panic/agoraphobia, social anxiety, OCD, and GAD). Dunn & Clark's z (1969) did not provide test statistics, only an indication if it was significant or not significant at the alpha level of .05.

Table 5
Spearman's correlations between sensory reactivity differences (SPSI), anxiety (SCAS-P/PAS and DI), and autism traits (AQ).

	SPSI			
	Hyperreactivity	Hyporeactivity	Seeking	AQ
SCAS-P/PAS				
Total anxiety	**.451****	-.007	.279	**.629****
Panic attack and agoraphobia	.283	.011	.223	.372
Separation anxiety	**.446****	.048	.156	**.516****
Physical injury fears	**.493****	-.226	-.042	.108
Social anxiety	.280	-.128	.170	.514
OCD	.313	.207	.367	**.670****
GAD	.311	-.073	.028	.436
DI				
Specific phobia	.329	-.181	-.414	-.092
Separation anxiety	-.031	-.109	.370	.046
GAD	.130	.069	.136	.052
AQ	**.545****	**.456****	.368	-

*. Correlation is significant at the $p \leq 0.05$ level (2-tailed) after a Holm-Bonferroni correction.
**. Correlation is significant at the $p \leq 0.01$ level (2-tailed) after a Holm-Bonferroni correction.
Note. SPSI: Sensory Processing Scale Inventory, SCAS-P/PAS: Spence Children's Anxiety Scale Parent and Preschool; OCD: Obsessive-compulsive disorder; GAD: Generalised anxiety disorder; DI: Dominique Interactive; AQ: Autism Spectrum Quotient.

2.5.2 Correlational analysis of sensory hyperreactivity, and anxiety controlling for autism traits

Since autism traits were correlated to both sensory reactivity differences and anxiety, we conducted a spearman's bivariate correlation controlling for 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 nonparametric spearman's analysis found significant correlations between sensory hyperreactivity as measured by the SPSI and anxiety (see Table 6 for correlations). Sensory hyperreactivity was found to have a significant moderate positive correlation with physical injury fears ($r_s(28) = .51$, 95% CI [.1730, .7437], $p = .004$), and DI specific phobia ($r_s(19) = .45$, 95% CI [.0002, .7529], $p = .039$). Sensory hyporeactivity was found to have a significant moderate negative correlation with social anxiety ($r_s(28) = -.40$, 95% CI [-.6707, -.0280], $p = .030$), and total anxiety ($r_s(28) = -.40$, 95% CI [-.6752, -.0364], $p = .027$). No significant correlations were found between sensory seeking and anxiety ($p > .05$).

Fisher's *z* test was conducted to test the difference between significant and non-significant correlations. This showed that the correlation coefficients between sensory hyperreactivity and both physical injury fears and separation anxiety were not significantly different ($p > .05$). Additionally, the correlation coefficients between sensory hyperreactivity and both DI phobia and DI GAD were not significantly different ($p > .05$). Lastly, the correlation coefficients between sensory hyporeactivity and anxiety subtypes were not significantly different ($p > .05$). However, all other significant correlation coefficients were significantly different from non-significant coefficients ($p < .05$). 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 ($p < .001$).

Table 6
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	.196	**-.404***	.072
Panic attack and agoraphobia	.133	-.173	.112
Separation anxiety	.238	-.252	-.047
Physical injury fears	**.513****	-.318	-.092
Social anxiety	.079	**-.397***	.018
OCD	-.065	-.157	.168
GAD	.132	-.314	-.140
DI			
Specific phobia	**.454***	-.152	-.408
Separation anxiety	-.060	-.144	.384
GAD	.143	.070	.140

*. Correlation is significant at the $p \leq 0.05$ level (2-tailed) after a Holm-Bonferroni correction.
**. Correlation is significant at the $p \leq 0.01$ level (2-tailed) after a Holm-Bonferroni correction.
Note. SPSI: Sensory Processing Scale Inventory, SCAS-P/PAS: Spence Children's Anxiety Scale Parent and Preschool; OCD: Obsessive-compulsive disorder; GAD: Generalised anxiety disorder; DI: Dominique Interactive.

2.5.3 Agreement between parent and self-reported anxiety

The presence of anxiety in the sample was determined by calculating the percentage of participants that scored above and below the standardised cut-offs for the SCAS-P/PAS and the DI (Table 7). 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-report identified a greater percentage of participants as having no-indication of symptoms for each anxiety sub-type, compared to elevated symptoms, identifying only 17.9% of participants as having clinically elevated symptoms for GAD. A chi-square test was performed to analyse 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, $p > 0.05$.

Table 7
Percentage of participants who scored above and below the cut-off for total anxiety and the anxiety sub-scales in the SCAS-P/PAS and DI.

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

Note. SCAS-P/PAS: Spence Children's Anxiety Scale Parent and Preschool; OCD: Obsessive-compulsive disorder; GAD: Generalised anxiety disorder; DI: Dominique Interactive.

2.6 Discussion

This study is the first known study to elucidate that sensory reactivity differences, including sensory hyperreactivity, hyporeactivity and seeking, relate differentially to anxiety sub-types 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 re-conducted 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 anxiety, which suggests 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 characteristics that can cause problems with overlap in

research, such as compulsive and ritualistic behaviour, communication differences, and social avoidance (Wood & Gadow, 2010). As differentiating between behaviours 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 restricted and repetitive behaviours (RRB's) 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 Behavioural Therapy (CBT) 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 non-autistic 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 anxiety and social anxiety. However, as we found no significant

differences between significant and non-significant 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 behaviour 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 seeing is not related to arousal regulation. However, as correlations between sensory seeking and specific phobia and social anxiety were trending towards 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 RRB's and anxiety, as well as suggesting that relationships between both sensory hyperreactivity and hyporeactivity and traits associated with RRB's are mediated by anxiety (Rodgers, Glod & Connolly, 2012; Wigham et al., 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 individualised therapeutic interventions for autistic people experiencing anxiety.

In line with 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 et al., 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 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-report 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 (ADOS; 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 phenomenology in autistic and non-autistic 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, that 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 (ADIS/ASA; Kerns et al., 2017), or the Anxiety Scale for Children – Autism Spectrum Disorder (ASC-ASD; Rodgers et al., 2016), to explore if similar relationships between sensory reactivity differences and anxiety are found.

2.6.1 Conclusion

Our study highlights the importance of understanding how sensory reactivity differences, including hyperreactivity, hyporeactivity and seeking, relate to anxiety sub-types 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 sub-types 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 improving anxiety research which can improve the developmental outcomes for autistic people.

2.6.2 Acknowledgements

Special thanks to all the families who participated. Thanks to Francesca Englezou, Charlotte Daniels, Phoebe Waite, and James Eavis for assisting with data collection, and the Centre for Autism at the University of Reading and Autism Berkshire for helping with recruitment.

Chapter 3. The relationship between sensory reactivity, intolerance of uncertainty and anxiety subtypes in preschool-age autistic children

Keren MacLennan, Timothy Rossow & Teresa Tavassoli

First published: 24 May 2021 by *Autism,* https://doi.org/10.1177/13623613211016110

3.1 Paper contribution

I had a significant contribution to this paper. This included working with the other members of the research team to develop the study design and aims and collect the data. I inputted and processed the data, along with support from our research assistants (in acknowledgements). I independently conducted the analyses and wrote the manuscript with feedback provided from the other authors, as well as reviewers through the peer-review process.

3.2 Abstract

Sensory reactivity differences are a diagnostic criterion of autism. Sensory hyperreactivity has been linked to intolerance of uncertainty (IU) and anxiety in autistic children. However, research is yet to explore the mediating relationships or sensory hyporeactivity, seeking, and anxiety subtypes in preschool-age autistic children. Therefore, we aimed to elucidate the relationships between sensory reactivity, IU and anxiety subtypes in a heterogeneous group of 54 preschool-age autistic children, age 3-5 years, using observation and parent-report assessments.

Correlational analysis found sensory hyperreactivity, IU, and total anxiety were significantly intercorrelated. Additionally, sensory hyperreactivity was significantly correlated with separation anxiety when controlling for autism traits. Serial mediation analyses indicated significant full mediation between sensory hyperreactivity and anxiety through IU, and significant full mediation between sensory hyperreactivity and IU through anxiety.

Our results suggest that sensory hyperreactivity is a key early factor in the development of anxiety, and supports that IU is an important interrelated construct in the development and maintenance of anxiety in autism. Our findings have important implications for the development of effective interventions. However, due to limitations with the measures, our research also highlights a pressing need for objective assessments of anxiety and IU that can be used with preschool-age autistic children.

Key Words: Autism, anxiety, sensory, uncertainty, preschool, children, mental health

3.3 Introduction

Autism spectrum conditions (ASC) are neurodevelopmental conditions with characteristics related to restricted and repetitive behaviours and interests (RRBs), and social interaction and communication differences (DSM-5 American Psychiatric Association, 2013). Sensory reactivity differences, including sensory hyperreactivity (e.g. strong reaction to touch), hyporeactivity (e.g. no or slower reaction to sounds), and seeking (e.g. fascinated by lights) are commonly experienced by approximately 65 – 85% of autistic children (Leekam et al., 2007; Miller et al., 2007; Tavassoli et al., 2016). Due to this prevalence, sensory reactivity differences have become a diagnostic criterion for ASC, under the RRBs domain (DSM-5; American Psychiatric Association, 2013). However, they are also common across other neurodevelopmental conditions, such as ADHD (Miller et al., 2012). Sensory reactivity differences can be experienced differentially and across a range of modalities, such as vision, hearing, and touch (Miller et al., 2007). Although some sensory experiences may be pleasant, others can be extremely distressing, which can greatly impact developmental outcomes and quality of life (Pfeiffer et al., 2005; Uljarević et al., 2016). Sensory hyperreactivity has previously been linked to anxiety and intolerance of uncertainty (IU) in autistic individuals (Carpenter et al., 2018; Green et al., 2012; Hwang et al., 2019; Neil et al., 2016; Pfeiffer et al., 2005; Uljarević et al., 2016). However, research has yet to explore the relationship between sensory reactivity differences, including hyperreactivity, hyporeactivity and seeking, IU and anxiety subtypes in preschool-age autistic children. Understanding the early emergence of these relationships has important implications for early anxiety interventions.

3.3.1 Sensory reactivity differences and anxiety

Autistic children are twice as likely to develop an anxiety condition compared to non-autistic children (van Steensel et al., 2011). Research has suggested that around 49% of autistic children will have at least one cooccurring anxiety condition; commonly generalized anxiety (GAD), social anxiety, or specific phobia, or anxiety related conditions such as OCD (Simonoff et al., 2008; van Steensel et al., 2011; White et al., 2009). Anxiety diagnoses are not always straight forward due to some degree of overlap between traits common in autistic children and anxiety symptomology, for instance social avoidance which can be present in both autism and social anxiety (Kerns & Kendall, 2012; White et al., 2009). As well as presenting with traditional anxiety symptomology, autistic people can also present with some unique symptoms; such as unusual phobias, sensory fears, social distress unrelated to fears of negative evaluation, and compulsive behaviours that are not driven by distress relief (Kerns et al., 2014, 2017, 2020; South & Rodgers, 2017). Anxiety symptoms develop early (i.e., before the age of 6) and are enhanced in autistic children and increase over time (Vasa et al., 2020). Thus, there is an imperative need to identify early risk factors.

Research has repeatedly shown links between sensory hyperreactivity and anxiety in autistic children (Green et al., 2012; Green & Ben-Sasson, 2010; Pfeiffer et al., 2005; Vasa et al., 2020; Wigham et al., 2015). Sensory hyperreactivity may be an early risk factor for the development of anxiety as it has been suggested to emerge earlier and to unidirectionally predict anxiety in both autistic and non-autistic samples (Carpenter et al., 2018; Green et al., 2012). Green et al. (2012) explored the bidirectional

relationship between sensory hyperreactivity and anxiety in autistic toddlers in a longitudinal study. They found that whilst sensory hyperreactivity remained stable over time, anxiety increased. Furthermore, sensory hyperreactivity predicted an increase in anxiety, however anxiety did not predict changes in sensory hyperreactivity (Green et al., 2012). There is also research in autistic children and adolescents to suggest that sensory hyperreactivity is implicated in specific anxiety conditions, such as separation anxiety, social anxiety, and specific phobia (Black et al., 2017; MacLennan et al., 2020; Pickard et al., 2020). Understanding if sensory reactivity is an early predictor for certain anxiety symptomology pertaining to the current diagnostic criteria has important clinical implications for early identification and targeted intervention therapies.

There is limited and inconclusive research into the relationships between both sensory hyporeactivity, and sensory seeking and anxiety in autistic children. Some research has found links between sensory hyporeactivity and anxiety in autistic children and adolescents (Glod et al., 2019), as well as specific links to social anxiety (MacLennan et al., 2020). However, links between sensory hyporeactivity and anxiety have not been consistently found in research (Wigham et al., 2015). Sensory seeking is often neglected in research and direct links to anxiety have rarely been found (Levit-Binnun et al., 2014; Lidstone et al., 2014; MacLennan et al., 2020). There is evidence to suggest that sensory seeking may be indirectly linked with anxiety through sensory hyperreactivity and over-focussing behaviours (Liss et al., 2006). Therefore, it would be advantageous to continue to explore how both sensory hyporeactivity and seeking relate to anxiety in autistic children.

3.3.2 Intolerance of uncertainty, sensory reactivity differences, and anxiety

Intolerance of uncertainty (IU) is broadly characterised by a difficulty with situations or contexts that are unforeseen or unpredictable (Buhr & Dugas, 2006). It is considered to be a key cognitive component in the development and maintenance of anxiety through negatively appraising ambiguous or uncertain events (Dugas et al., 1998; Freeston et al., 1994). Greater IU has been linked with anxiety in non-autistic populations, and may be a key transdiagnostic feature across anxiety conditions (Carleton et al., 2012). Although argued to be a distinct construct, there is also some degree of similarity between the characteristics of IU and some autistic traits, such as difficulty with change and unpredictability (Boulter et al., 2014; Chamberlain et al., 2013). However, IU has been identified as a recognisable construct in autistic children and has been found to be higher in autistic groups (Boulter et al., 2014; Hodgson et al., 2017; Vasa et al., 2018).

Existing research has aimed to elucidate the relationship between sensory reactivity, anxiety, and IU. A key theoretical model of anxiety in autism by South and Rodgers (2017), proposes that IU is a principal mediator in the relationship between sensory reactivity and anxiety. In support of this, research has found IU to partially mediate the relationship between both sensory hyperreactivity, and hyporeactivity and anxiety in autistic adults (Hwang et al., 2019). However, there is currently mixed, and sometimes conflicting, evidence to support this. Research has found IU to mediate the relationship between autism traits and both anxiety, and sensory hyperreactivity (Boulter et al., 2014; Hwang et al., 2019; Neil et al., 2016). Additionally, research has found anxiety to mediate the relationship between

IU and sensory hyperreactivity in autistic children (Neil et al., 2016). Therefore, research is still needed to elucidate the relationship between sensory reactivity, IU, and anxiety in autistic children.

3.3.4 The present study

Symptoms of anxiety are present in autistic children at an early age and there is an early, unidirectional association between sensory hyperreactivity and anxiety in autistic toddlers. Although there may be a differential relationship between sensory hyperreactivity and symptoms associated with anxiety subtypes, such as social anxiety and specific phobia, this is an under-researched area. Additionally, sensory hyporeactivity and seeking are often neglected in research, and there is inconclusive evidence of the relationships between sensory reactivity, IU, and anxiety.

Fundamentally, the links between sensory reactivity, IU, and anxiety has only been explored in autistic children above the age of 6, without intellectual disability (ID) and with proficient language skills, and research with preschool-age autistic children (age 3-5 years) is yet to be done. Targeting risk factors for anxiety in its earliest stages is important to improve later outcomes (Rapee et al., 2010; Yap et al., 2016). Ages 3-5 years is a critical time when sensory reactivity differences and anxiety symptoms are emerging in autistic children, and early interventions for anxiety already show efficacy (Ben-Sasson et al., 2007, 2008; Driscoll et al., 2020; Green et al., 2012; Vasa et al., 2020).

Therefore, we aimed to elucidate the relationship between sensory reactivity differences, IU, and anxiety in preschool-age autistic children. Firstly, in line with previous findings (Carpenter et al., 2018; Neil et al., 2016; Pfeiffer et al., 2005; Uljarević et al., 2016; Wigham et al., 2015), we expected to find greater sensory hyperreactivity to be significantly related to greater anxiety symptoms, and for IU to be a mediator in the predictive relationship. Secondly, in line with our previous work, that showed a differential relationship between sensory hyperreactivity and anxiety subtypes in older children (MacLennan et al., 2020), we explored if sensory reactivity, and IU were differentially related to anxiety subtypes, including GAD, separation anxiety symptoms, OCD, physical injury fears, and social anxiety symptoms.

Moreover, due to conflicting theoretical models in existing literature, we aimed to test the predictive relationship between sensory reactivity, anxiety, and IU. We expected that sensory hyperreactivity would predict anxiety, as hyperreactivity has been shown to predict anxiety unidirectionally (Green et al., 2012). But that the relationship between sensory hyperreactivity and anxiety would be mediated by IU, as IU has consistently been found to be a mediating, transdiagnostic construct (Boulter et al., 2014; Hwang et al., 2019; Neil et al., 2016; Wigham et al., 2015).

3.4 Methods

3.4.1 Participants

In total 65 children with a) a clinical diagnosis of autism or b) suspected autism were recruited for the current study. 54 children (41 males, 13 females) aged 3-5 years (M = 4.02, SD = 0.77) met inclusion criteria of a) having a formal clinical diagnosis of autism which included a direct observation as well as

developmental history (n=42) or b) having suspected autism and meeting cut-off scores on the Autism Diagnostic Observation Schedule (ADOS-2; Lord et al., 2012) (Module 1 few-to-no words cut off: 11; Module 1 some words cut off: 8; Module 2 < 5years cut off: 7; Module 2 ≥ 5 years cut off: 8), and the Autism Spectrum Quotient: Child Version (AQ; Auyeung et al., 2008) (cut off ≥ 76) (n=12), and were therefore included in the final analysis. 31 children completed a Module 1, 19 completed a Module 2 and 4 were unable to complete the ADOS-2 during testing, however these children already had a formal diagnosis (see Table 8 for additional demographic information).

Table 8
Demographic characteristics of participants (N = number, M = mean, SD = standard deviation)

Characteristics	*N*	*Range*	*M*	*(SD)*
Age (years)	54	3 - 5	4.0	0.8
IQ	22	52 - 141	108.4	23.6
Sex		*Percentage*		
Male	41	75.9%		
Female	13	24.1%		
Ethnicity				
White British	32	59.2%		
White Swedish	1	1.9%		
Mixed Race – White Asian	5	9.2%		
Mixed Race - Other	3	5.5%		
Asian Indian	10	18.5%		
Asian Pakistani	1	1.9%		
North African	1	1.9%		
Undeclared	1	1.9%		

To indicate the cognitive level of the sample, we conducted the Matrix reasoning subtests of the Wechsler Non-Verbal (WNV; Wechsler & Naglieri, 2006) and the British Ability Scale (BAS; Elliott et al., 1983). However, 31 participants were unable to complete the IQ tasks either due to cognitive delay or behavioural difficulties (e.g. demand avoidance). Of these participants, 25 completed an ADOS-2 Module 1, 2 completed a Module 2, and 4 were also unable to complete the ADOS-2 assessment. IQ and verbal language level was taken into consideration in the analyses. Signed consent was obtained from parents, and verbal assent was obtained from children who were able to, otherwise voluntary task compliance was considered assent. Families were provided with a social story for the children prior to testing to outline what their participation would entail. We recruited participants through the University of Reading Centre for Autism participant database, social media platforms, local NHS CAMHS services, 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[‡] and the Berkshire Healthcare NHS Foundation Trust Health Research Authority[§].

[‡] University of Reading ethics code: 2018-086-TT

[§] IRAS project ID: 249952, protocol number: 2017-047-TT

3.4.2 Measures

Sensory Processing Scale Inventory (SPSI)

The SPSI (Schoen et al., 2017) was used to measure sensory reactivity differences. It is a standardized, 96 item parent report questionnaire that assesses the degree of sensory reactivity differences in children. It produces subscales for sensory hyperreactivity (47 items, e.g. "*These garments bother my child: Seams in clothing*"), sensory hyporeactivity (21 items, e.g. "*My child has a less intense response than others to: Getting hurt, bruises or cuts*"), and sensory seeking (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 a greater extent of sensory reactivity differences. The SPSI has strong internal reliability (hyperreactivity = .89; hyporeactivity = .88; sensory seeking = .93 (Schoen et al., 2017). As in our previous work (MacLennan et al., 2020), we chose to use the SPSI over other commonly used measures such as the Sensory Profile (SP; Dunn, 1999) as the SPSI has a comparatively greater representation of hyporeactivity and seeking compared to the SP, which more heavily represents hyperreactivity (Neil et al., 2017; Uljarević et al., 2016).

Sensory Assessment for Neurodevelopmental Differences (SAND)

The SAND (Siper et al., 2017) was also used to measure sensory reactivity differences. It is a standardised observational assessment and associated caregiver interview, which assesses sensory reactivity differences in line with the ASC diagnostic criteria (DSM-5 American Psychiatric Association, 2013). In the direct observation, children are presented with a range of sensory toys with tactile (e.g. textured toy), auditory (e.g. musical toy), and visual (e.g. flashing toy) components. The assessment commences and concludes with 1-2 minutes of unstructured play to help the child familiarise with the situation, followed by presentation of the sensory toys. The children are scored for behavioural responses consistent with sensory hyperreactivity, hyporeactivity, and seeking. The administration is conducted by a trained examiner, and behaviours are scored dichotomously (i.e. 1 = present, 0 = not present) across 36 items, and if a behaviour is present there is the additional coding of a severity score (1 = mild, 2 = moderate to severe).

The subsequent interview component requires the caregiver to indicate whether their child presents with the various sensory reactivity differences in visual, tactile and auditory domains (1 = present, 0 = not present), and to rate the severity if present (1 = mild, 2 = moderate to severe). The items of this interview map onto the scoring for the observation. Observed and reported scores can then combined to produce a total score (0 – 90) and subscales for sensory hyperreactivity, hyporeactivity, and seeking (0-30), with higher scores reflecting greater sensory reactivity differences. The SAND has been found to have strong internal consistency (.90), test-retest reliability (.97, $p < .001$), and moderate convergent validity (-.63) (Siper et al., 2017).

Preschool Anxiety Scale (PAS)

The PAS (Edwards et al., 2010) was used to measure anxiety symptoms. It is a standardized 30 item parent report questionnaire that assesses anxiety symptoms in children aged 3 – 6 years, adapted from the Spence Children's Anxiety Scale (SCAS; Spence, 1998). Items are scored on the scale 0 (no true at all) to 4 (very often true), with higher scores indicating a greater extent of anxiety symptoms, and scores above cut-off indicate clinically elevated symptoms. The PAS produces a score for total anxiety (total score 120) and subscales for symptoms related to GAD (5 items, total score of 20, e.g. *"Has difficulty stopping him/herself from worrying"*), social anxiety (6 items, total score of 24, e.g. *"Worries that he/she will do something embarrassing in front of other people"*), separation anxiety (5 items, total score of 20, e.g. *"Is reluctant to go to sleep without you or to sleep away from home"*), physical injury fears (7 items, total score of 28, e.g. *"Is afraid of crowded or closed-in places"*), and OCD (5 items, total score of 20, e.g. *"Washes his/her hands over and over many times each day"*). The PAS has moderate internal consistency (α = .70) (Edwards et al., 2010). The PAS was selected over other measures of anxiety as it has sub-scales for early symptomology relating to anxiety subtypes.

Responses to Uncertainty and Low Environmental Structure questionnaire (RULES)

The RULES (Sanchez et al., 2017) was used to measure IU. It is a parent report questionnaire and is validated to assess IU in children aged 3 – 10 years. It contains 17 items (e.g. *"My child has a hard time coping with even minor changes"*), rated on a scale of 1 (not at all) – 5 (very much). Scores can range from 17 – 85 with higher scores reflecting greater intolerance of uncertainty. The RULES has strong internal consistency (α = .93) and convergent validity (.67) (Sanchez et al., 2017).

3.4.3 Analysis

The data were analysed using SPSS 27 (IBM Corp, 2020) and JASP (JASP team, 2020). Following normality checks, we conducted a Spearman's bivariate correlation analysis to elucidate the correlational relationship between sensory reactivity differences, anxiety, IU, and potential covariates. We then conducted partial correlation analyses and sub-group comparisons to ensure the relationships were independent of the effects of covariates. Significance was indicated by a Bonferroni corrected *p*-value of $p \leq .01$.

We then conducted a series of simple mediation analyses to understand the mediating relationship between sensory reactivity, anxiety, and IU. We defined the analysis to conduct bootstrapping with 1,000 resamples to adjust for measurement error and generated accelerated 95% confidence intervals. Full mediation is present if the indirect effect between the predictor and outcome variable is significant, and the direct effect is not significant. Partial mediation is present if both the direct and indirect effect between the predictor and outcome variable are significant. Significance is indicated by confidence intervals (CI's) not overlapping with zero and Bonferroni corrected *p*-value of $p \leq .008$.

3.4.4 Community involvement

The research questions for this project aligned with Autistica's research priorities, which were identified by stakeholders. Throughout our project, we sought feedback from the families who took part in our study on our testing sessions and procedures, interpretations of our results, and the language used in the manuscript.

3.5 Results

3.5.1 Descriptive analyses

Descriptive analysis showed that the data was not normally distributed as a Shapiro–Wilk test of normality was significant for total anxiety and the anxiety subtypes ($p < .05$). However, no outliers were present in the data (see Table 9 for descriptive statistics). To avoid inflated correlations due to bias and multiple comparisons, parent-reported and observed sensory reactivity measures were combined (Kim & Lord, 2012; Spain et al., 2018). SPSI and SAND construct scores were significantly correlated for sensory hyperreactivity (r_s (52) = .60, $p < .001$), hyporeactivity (r_s (52) = .38, $p = .005$), and seeking (r_s (52) = .50, $p < .001$); suggesting both sensory measures are assessing related constructs. Therefore, SPSI and SAND *z* scores were averaged to create standardised sensory composite scores for sensory hyperreactivity, hyporeactivity, and seeking (Song et al., 2013).

Table 9
Descriptive statistics for sensory reactivity differences (SPSI and SAND raw scores; z-score composites), anxiety (PAS raw scores), intolerance of uncertainty (RULES raw score), and autism traits (AQ and ADOS raw comparison scores).

	Mean	*SD*	*Clinically elevated (%)*
SPSI			
Hyperreactivity	12.8	5.5	-
Hyporeactivity	11.3	4.7	-
Seeking	10.0	5.0	-
SAND			
Hyperreactivity	9.2	3.9	-
Hyporeactivity	8.4	5.6	-
Seeking	17.4	3.6	-
PAS			
Total anxiety	33.2	24.3	46%
GAD	7.6	6.4	60%
Social anxiety	7.6	6.4	34%
OCD	3.9	4.1	46%
Physical injury fears	7.8	5.9	22%
Separation anxiety	6.3	5.1	42%
IU	50.4	19.6	-
ADOS-2 comparison score	6.2	2.8	-
AQ	100.1	17.6	-

Note. SPSI: Sensory Processing Scale Inventory; SAND: Sensory Assessment for Neurodevelopmental Differences; PAS: Preschool Anxiety Scale; GAD: Generalised anxiety symptoms; OCD: Obsessive-compulsive symptoms; IU: Intolerance of Uncertainty; ADOS: Autism Diagnostic Observation Schedule-2; AQ: Autism Spectrum Quotient.

3.5.2 Correlational analyses

Spearman's correlation analysis showed that sensory hyperreactivity was significantly positively correlated with total anxiety, GAD, social anxiety, OCD, physical injury fears, separation anxiety, and IU. IU was also significantly positively correlated with total anxiety, GAD, social anxiety, OCD, physical injury fears, and separation anxiety (see Table 10 for correlations).

Table 10
Spearman's correlations between sensory reactivity differences (SPSI and SAND composite z-scores), anxiety (PAS), intolerance of uncertainty (RULES), autism traits (AQ), and age.

	Hyperreactivity	Hyporeactivity	Seeking	IU	AQ	Age
Total anxiety	**.520* (.000)**	-.193 (.180)	.115 (.426)	**.796* (.000)**	**.539* (.000)**	.299 (.035)
GAD	**.451* (.001)**	-.212 (.140)	.099 (.496)	**.728* (.000)**	**.461* (.000)**	.337 (.017)
Social anxiety	**.422* (.002)**	-.222 (.121)	.130 (.369)	**.708* (.000)**	**.534* (.000)**	.143 (.321)
OCD	**.414* (.003)**	-.048 (.742)	.246 (.085)	**.706* (.000)**	**.473* (.000)**	.172 (.232)
Physical injury fears	**.435* (.002)**	-.280 (.049)	-.086 (.551)	**.544* (.000)**	**.397* (.004)**	.224 (.118)
Separation anxiety	**.472* (.000)**	-.181 (.208)	.132 (.361)	**.727* (.000)**	**.435* (.002)**	**.453* (.000)**
IU	**.554* (.000)**	-.025 (.867)	.221 (.131)	-	-	-
AQ	**.413* (.002)**	.059 (.680)	.268 (.054)	**.641* (.000)**	-	-
Age	.305 (.028)	-.266 (.057)	-.094 (.509)	.144 (.328)	.014 (.924)	-

*. Correlation is significant at the $p \leq 0.01$ level (2-tailed) after a Bonferroni correction
Note. GAD: Generalised anxiety symptoms; OCD: Obsessive-compulsive symptoms; IU: Intolerance of Uncertainty; ADOS-2: Autism Diagnostic Observation Schedule-2

Spearman's correlation analysis also showed that age was significantly positively correlated with separation anxiety. Additionally, autism traits were significantly positively correlated with sensory hyperreactivity, total anxiety, GAD, social anxiety, OCD, physical injury fears, separation anxiety, and IU. Post-hoc partial correlation analyses controlling for age found that the correlations between sensory reactivity, anxiety subtypes and IU sustained their significance ($p \leq .01$) or non-significance ($p > .01$), suggesting the relationships are independent from the effects of age. However, when controlling for autism traits, the relationships between sensory hyperreactivity and GAD, social anxiety, OCD, and physical injury fears were no longer significant ($p > .01$) (see Appendix 1 for correlation table). Fisher's z test (Steiger, 1980) was conducted to test if the significant correlation coefficient between sensory hyperreactivity and separation anxiety was significantly different from the non-significant correlation coefficients between sensory hyperreactivity and the other anxiety subtypes. This showed that the significant relationship with separation anxiety was not significantly different from the non-significant relationships between sensory hyperreactivity and GAD ($z = 1.143$, $p = .253$), social anxiety ($z = .190$, $p = .848$), OCD ($z = .890$, $p = .373$), and physical injury fears ($z = .374$, $p = .709$).

Additionally, we explored the effects of IQ and verbal language ability. As we only had IQ scores for 41% of the sample, we conducted a Spearman's correlation analyses independently for the group with IQ scores and the group without to see if correlations between sensory reactivity and anxiety differed between groups. The analysis showed that sensory hyperreactivity was significantly related to anxiety in those who were unable to do an IQ test (without IQ score) ($r_s(30) = .56$, $p = .001$), but not in those who were able to conduct an IQ test (with IQ score) ($r_s(20) = .38$, $p = .09$). However, Fisher's z test confirmed that these correlation coefficients were not significantly different ($p > .05$). As for verbal language, correlation analysis showed that sensory hyperreactivity was significantly related to anxiety in those who had few-to-no words and completed the ADOS-2 Module 1 ($r_s(28) = .62$, $p < .001$), but not in those who were able to use sentences and completed the ADOS-2 Module 2 (r_s (18) = .29, $p > .05$).

However, Fisher's z test confirmed that these correlation coefficients were not significantly different (p > .05). Furthermore, independent samples t-test indicated that there were no significant group differences in sensory hyperreactivity or anxiety scores for those with or without an IQ score, or those who did the ADOS-2 Module 1 or Module 2 (p > .05). Therefore, we did not take IQ or verbal language ability into account in further analyses as the non-significant subgroup findings are likely due to lack of power.

3.5.3 Mediation analyses

As sensory hyperreactivity, IU, and total anxiety were intercorrelated, we conducted a series of simple mediation analyses to understand the predictive relationship between these constructs. To achieve this, we tested all possible iterations of the model; including sensory hyperreactivity, IU, and total anxiety as predictor, outcome and mediating variables (see Table 11 for mediation analyses). As correlational analyses indicated that these relationships were independent from the effects of age, autism traits, IQ, and verbal language level, we did not control for these in the analyses. We applied a Bonferroni significance correction to control for type 1 error due to multiple analyses ($p \leq .008$).

Table 11
Mediation analyses between sensory hyperreactivity (SPSI and SAND composite z-score), anxiety (PAS), and intolerance of uncertainty (RULES).

Predictor	Mediator	Outcome	Total effect					Direct effect					Indirect effect				
			B	se	LL	UL	*p*	B	se	LL	UL	*p*	B	se	LL	UL	*p*
Hyper	IU	Anxiety	.63	.13	**.35**	**.92**	**<.001**	.16	.12	-.00	.40	.184	.47	.12	**.28**	**.66**	**<.001**
Hyper	Anxiety	IU	.66	.13	**.38**	**.89**	**<.001**	.24	.12	-.03	.55	.036	.42	.12	**.23**	**.72**	**<.001**
Anxiety	IU	Hyper	.50	.10	**.32**	**.69**	**<.001**	.22	.17	.01	.52	.184	.28	.14	-.02	.56	.040
Anxiety	Hyper	IU	.79	.09	**.60**	**.99**	**<.001**	.67	.10	**.41**	**.94**	**<.001**	.12	.06	.01	.32	.055
IU	Anxiety	Hyper	.53	.11	**.25**	**.75**	**<.001**	.36	.17	.02	.66	.036	.18	.14	-.03	.42	.192
IU	Hyper	Anxiety	.80	.09	**.60**	**.96**	**<.001**	.71	.11	**.51**	**.90**	**<.001**	.08	.06	.00	.23	.202

Note. Hyper: Sensory hyperreactivity; IU: Intolerance of uncertainty; *se*: standard error; LL and UL: 95 % confidence intervals lower limit and upper limit. Significant relationships at the p<0.008 level after a Bonferroni correction highlighted in bold.

Mediation analysis indicated significant indirect effects between sensory hyperreactivity and anxiety through IU (B = .47, Lower Limit (LL) = .28, Upper Limit (UL) = .66, p < .001). A significant indirect effect was also found between sensory hyperreactivity and IU through anxiety (B = .42, LL = .23, UL = .72, p < .001). As the direct effects were not significant for both of these models (Bonferroni corrected p > .008 and 95% confidence intervals containing 0), this indicates full mediation (Figure 4). No mediation was indicated when IU was entered as the predictor for sensory hyperreactivity through anxiety, and for anxiety through sensory hyperreactivity, or when anxiety was entered as the predictor for IU through sensory hyperreactivity, or for sensory hyperreactivity through IU, as the indirect effects were not significant (Bonferroni corrected p > .008 and 95% confidence intervals containing 0).

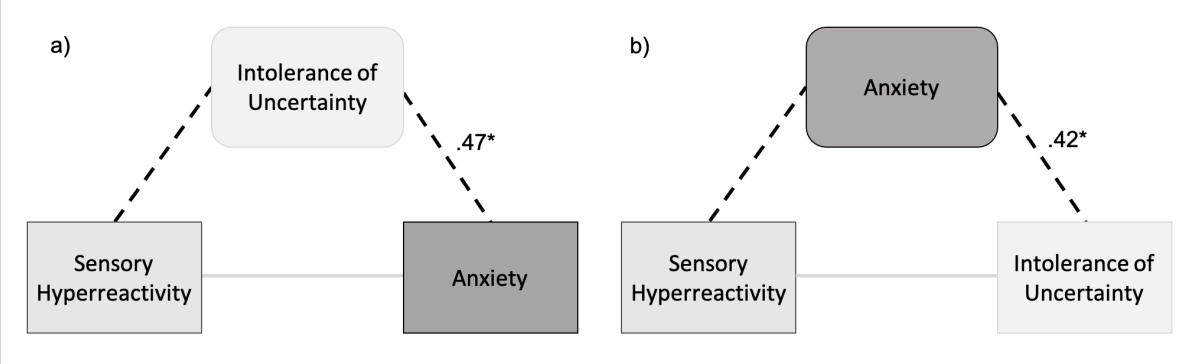

Figure 4

Depicting the relationship between sensory hyperreactivity and anxiety fully mediated by IU, and b) the relationship between sensory hyperreactivity and IU fully mediated by anxiety.

Note. Direct relationships are indicated by a solid line, indirect relationships are indicated by a dashed line. Significant relationships are indicted by a black line, non-significant with a grey. B coefficients are shown for each relationship.

3.6 Discussion

Our study has been the first to explore the relationship between sensory reactivity differences, IU, and anxiety in a heterogenous group of preschool-age autistic children. In line with our expectations, we found sensory hyperreactivity, IU, and anxiety to be interrelated. Additionally, we found that IU fully mediates the relationship between sensory hyperreactivity and anxiety, but that anxiety also fully mediates the relationship between sensory hyperreactivity and IU. We did not find sensory hyporeactivity or seeking to be significantly related to anxiety or IU.

We found, in line with previous findings (Hwang et al., 2019; Neil et al., 2016; Wigham et al., 2015), sensory hyperreactivity to be significantly related to total anxiety in autistic children. In our initial correlation analysis, we did not find sensory hyperreactivity to be differentially related to anxiety subtypes. However, when controlling for autism traits, we found sensory hyperreactivity to be significantly related to separation anxiety. As suggested in our previous work, controlling for AQ may limit measurement or response bias, or variability from trait–symptom overlap (MacLennan et al., 2020). Although existing findings have also shown links between sensory hyperreactivity and separation anxiety (Black et al., 2017), our previous work with older children found sensory hyperreactivity to be related to symptoms associated with physical injury fears and specific phobia (MacLennan et al., 2020). Inconsistencies across studies could be due to the use of different measures or the differing age and developmental level of the participants, as research has found differential prevalence of anxiety conditions across ages of autistic children and adolescents (van Steensel et al., 2011). This may be due to differential conditioning implicated in the development of certain anxiety conditions, such as context conditioning in GAD (Green & Ben-Sasson, 2010). It would be beneficial for future research to explore differential relationship over time and to further understand the association of IU when relationships are differential.

As previous literature has proposed disputing theoretical models that have included sensory hyperreactivity, IU and anxiety, here we tested a series of mediation models. We found that IU fully mediates the relationships between sensory hyperreactivity and anxiety in preschool-age autistic

children, and that anxiety fully mediates the relationship between sensory hyperreactivity and IU. Critically, in line with our predictions we found that sensory hyperreactivity was the predictor in both significant mediation models. This reflects previous longitudinal research in younger children that found sensory hyperreactivity to unidirectionally predict anxiety symptoms, suggesting that sensory hyperreactivity emerges earlier than anxiety (Green et al., 2012). However, our results also suggest that IU is an important early factor in the development and maintenance of anxiety in autism. Aversive sensory experiences can be unpredictable and not always specific to an object or situation, which is associated with greater avoidance and anxious behavioural responses, and associated amygdala activation (Green et al., 2015; Herry et al., 2007). Altered sensory interpretation in autism can enhance the perceived unpredictability of sensory input (Fiser et al., 2010; Pellicano & Burr, 2012). As IU is associated with alerting in attentional networks, individuals with higher IU may be more hypervigilant and biased to process uncertain information as threatening (Dugas et al., 2005; Fergus & Carleton, 2016). Thus, IU and anxiety may reciprocally be maintained in response to sensory hyperreactivity. Due to the constraints of cross-sectional mediation models, next steps in research would be to longitudinally test these mediating relationships.

As our results support that sensory hyperreactivity is a predictive factor for anxiety early in development, this could be an important target for early interventions. Sensory integration-based approaches are widely used and are deemed to be effective in targeting early sensory reactivity difficulties (Schaaf et al., 2017; Schoen et al., 2019), but little is known about how these impact anxiety development. Alternatively, Cognitive Behavioural Therapy (CBT) could be adapted to target sensory hyperreactivity (Edgington et al., 2016), as CBT has shown efficacy in young autistic children (Driscoll et al., 2020). However, IU may also be an important transdiagnostic mechanism to target in intervention (Hallett et al., 2021; Rodgers et al., 2017). There is evidence that targeting IU in clinical interventions effectively reduces anxiety in non-autistic cohorts (Boswell et al., 2013; Buhr & Dugas, 2006; Dugas et al., 2010; McEvoy & Mahoney, 2012). This has recently been extended into autism research, with the development of a manualised parent group-based intervention programme, such as Predictive Parenting (Hallett et al., 2021), and Coping with Uncertainty in Everyday Situations (CUES©; Rodgers et al., 2017; 2018). These interventions aim to enable children to become more tolerant of uncertainty and have shown promise in their efficacy.

In contrast to previous research (Glod et al., 2019; Hwang et al., 2019; MacLennan et al., 2020), we did not find sensory hyporeactivity to relate to anxiety or IU in our study. This may be due to the varying measures and age groups across studies. Alternatively, sensory hyporeactivity may be more related to depressive conditions, characterised by suppressed arousal, rather than anxiety (Lane, 2002; Neal et al., 2002; Pfeiffer et al., 2005). Or it may be more related to other autistic traits, such as communication differences, emotional, cognitive and behavioural differences, or RRB's (Glod et al., 2015; South & Rodgers, 2017; Wigham et al., 2015). As for sensory seeking, we did not find it to be significantly related to anxiety in autistic children, which reflects previous findings (MacLennan et al., 2020). Sensory seeking may be indirectly linked to anxiety or interlinked with sensory hyperreactivity and hyporeactivity, such as being a stimulatory strategy in response to sensory hyporeactivity (Lidstone et al., 2014; Liss

et al., 2006). Future directions should aim to further understand how sensory hyporeactivity and seeking are related to anxiety.

There is a pressing need for research to include participants with few-to-no words or ID (Russell et al., 2019), thus, our heterogenous sample is a key strength of the study. However, our relatively small sample size may have impacted the power of our subgroup analysis, as well as relationships with anxiety subtypes. Additionally, there are few suitable objective assessments for IU and anxiety, especially for this demographic, and therefore we had to rely on parent-reports. Although total anxiety scores have been found to be reliable in autistic populations, subscales for anxiety on parent-reports may need to be interpreted with caution in autistic children, especially those with cooccurring ID and who speak few-to-no words (Kerns et al., 2020; Toscano et al., 2020). Understanding the risk factors for traditional anxiety symptomology has clinical significance for existing anxiety interventions, however, it is also important that distinct anxiety symptoms in autistic children are recognised (Kerns et al., 2020). Therefore, there is a need for the development of autism-specific, measures that can be used to screen for early anxiety symptomology in young autistic children. But also, further research examining anxiety in autistic subgroups, such as those with few-to-no words or ID.

In conclusion, our study is the first to explore the relationship between sensory reactivity differences, anxiety subtypes, and IU in preschool-age autistic children. Our findings indicates that sensory hyperreactivity, IU, and anxiety are interrelated in preschool-age autistic children, and that sensory hyperreactivity may be specifically related to separation anxiety when taking broader autism traits into account. Additionally, they suggest sensory hyperreactivity is an early predictor of anxiety and IU, which may both be reciprocally mediating factors in the maintenance of anxiety and IU in autism. The results of this study have important clinical implications for early anxiety interventions in preschool-age autistic children. However, there is still an imperative need to develop objective assessments, especially for IU and anxiety, for preschool-age autistic children, and those who speak few-to-no words. This is fundamental for research and clinical services that aim to support autistic individuals.

3.6.1 Acknowledgements

Special thanks to all the families who participated. Thanks to Francesca Englezou, Charlotte Daniels, and Khadija Kapadia of the University of Reading for assisting with data collection, and the Centre for Autism at the University of Reading, Autism Berkshire, and NHS Berkshire Healthcare CAMHS for helping with recruitment.

Chapter 4. Sensory reactivity, anxiety, and intolerance of uncertainty in autistic adults: Examining the correlational and predictive relationships across two complementary studies

Keren MacLennan, Isabelle Verhulst & Teresa Tavassoli

In preparation for submission to *Journal of Affective Disorders*

4.1 Paper contribution

I had a significant contribution to this paper. For Study 1, I designed the study and independently collected and processed the data. Study 2 was part of a wider study that was led by Isabelle Verhulst and I was not part of the data collection. I then independently conducted the analyses for both studies and wrote the manuscript with feedback provided from the other authors.

4.2 Abstract

Background Sensory reactivity differences are common in autism spectrum conditions, including sensory hyperreactivity (i.e., strong reactions), hyporeactivity (i.e., no, or slower reactions), and seeking (i.e., fascination or fixation). Rates of clinical anxiety are also inordinately high in autistic adults, which may be due to sensory reactivity differences, as well as intolerance of uncertainty (IU). Thus, we conducted two complementary online studies to examine the correlational and predictive associations between these factors.

Methods Study 1 included 94 autistic adults, aged 18 – 70 years, and assessed self-reported sensory reactivity differences and anxiety. Study 2 included 246 autistic adults, aged 18 – 76 years, and assessed self-reported sensory reactivity differences, anxiety, and IU.

Results Study 1 found sensory hyperreactivity to be correlated with total anxiety and separation anxiety, and sensory hyporeactivity to be correlated with separation anxiety, but only sensory hyperreactivity significantly predicted anxiety. Study 2 found sensory hyperreactivity and seeking to be correlated with GAD, separation anxiety, and social anxiety, and IU was also intercorrelated. IU was found to mediate the relationships between hyperreactivity and anxiety, and anxiety mediated the relationship between hyperreactivity and IU.

Limitations Differences in the sensory measures across studies (e.g., additional items associated with other domains, such as proprioception) limited the ability to compare results across studies.

Conclusions Sensory hyperreactivity may predict anxiety symptomology in autistic adults, and sensory hyporeactivity and seeking may also be related. Additionally, IU may be an important related factor in the development and maintenance of anxiety. These findings have clinical relevance for the treatment of anxiety in autistic adults.

4.3 Introduction

Autism spectrum conditions (ASC) are neurodevelopmental conditions with diagnostic criteria relating to social interaction and communication differences, and restricted and repetitive behaviours and interests (RRBs; DSM-5 American Psychiatric Association, 2013). Sensory reactivity differences are a criterion under the RRBs domain, and include sensory hyperreactivity (i.e., strong reactions to sensory input), hyporeactivity (i.e., no, or slower reactions to sensory input), and seeking (i.e., fascination or fixation with sensory input). Individuals often experience varying patterns of differences across a range of contexts and modalities, such as vision, hearing, and touch (Baranek et al., 2006; Lidstone et al., 2014; Miller et al., 2007). Although sensory reactivity differences are also present in other neurodevelopmental conditions, such as Attention Deficit and Hyperactivity Disorder (ADHD) (Miller et al., 2012), they are commonly experienced by approximately 94% of autistic adults (Crane et al., 2009).

Autistic adults are also at greater risk of experiencing clinical anxiety compared to the general population, with recent population prevalence estimates suggesting it affects 20% of autistic adults, compared to only 8.7% of non-autistic adults (Nimmo-Smith et al., 2020). Prevalence rates for specific anxiety conditions vary across studies, but generalised anxiety disorder (GAD), separation anxiety, and social anxiety disorder are all commonly diagnosed in autistic children and adults (Kerns et al., 2020; Nimmo-Smith et al., 2020; Simonoff et al., 2008). As anxiety has a monumental impact on an individual's daily living and quality of life (Robertson et al., 2018), it is important to understand autism-specific risk factors for anxiety. Sensory reactivity differences can often be distressing, and sensory hyperreactivity has frequently been linked to anxiety in autistic children and adults (Black et al., 2017; Green et al., 2012; Hwang et al., 2019; MacLennan et al., 2020, 2021; Uljarević et al., 2016), and has been suggested to be an early, unidirectional predictor of anxiety in autism (Green et al., 2012). Although autistic individuals can also experience distinct autism-related anxiety symptomology, such as social fears unrelated to negative self-appraisal, sensory hyperreactivity has been found to predict traditional rather than distinct anxiety symptomology (Kerns et al., 2014). Although research has primarily examined links between sensory hyperreactivity and total anxiety symptoms, research in autistic children has suggested that it may be differentially related to certain anxiety conditions, including generalised anxiety disorder (GAD), separation anxiety, and specific phobia (Bitsika et al., 2019; Black et al., 2017; Kerns et al., 2014; MacLennan et al., 2020).

Relatively less research has examined if sensory hyporeactivity and seeking relate to anxiety in autism. Research that has included sensory hyporeactivity has inconsistently found evidence of a significant relationship to anxiety. Some previous work has found greater sensory hyporeactivity to be related to greater anxiety in autistic adults and children (Glod et al., 2019; Hwang et al., 2019). Whereas our previous work in autistic children found it to be related to lower anxiety, including symptomology relating to social anxiety when controlling for broader autistic traits (MacLennan et al., 2020). Alternatively, research in autistic children has suggested that sensory hyporeactivity may instead be indirectly related to anxiety through RRBs (Wigham et al., 2015). As for sensory seeking, research in autistic children and non-autistic adults has not found a significant link with anxiety (Levit-Binnun et al., 2014; Lidstone et al., 2014; MacLennan et al., 2020, 2021), although research has yet to examine if it is implicated in

specific anxiety symptomology in autistic adults. It has been suggested that sensory seeking may be indirectly linked to anxiety as a strategy to regulate arousal, either seeking out sensory input in response to hyporeactivity, or interlinked with RRBs to soothe in response to sensory hyperreactivity (Lidstone et al., 2014). Additionally, qualitative research in autistic adults has suggested that sensory seeking can be a soothing strategy that can be calming in times of stress (Robertson & Simmons, 2015; Smith & Sharp, 2013). Enhancing understanding of the relationships between sensory reactivity differences and anxiety in autistic adults has important implications for treatment approaches that are effective and suitable for autistic adults.

Intolerance of uncertainty (IU), which is a difficulty with contexts or situations that are unexpected or unpredictable, is understood to be an important factor in the development and maintenance of anxiety (Buhr & Dugas, 2006; Dugas et al., 1998; Freeston et al., 1994). Although IU has some overlap with autistic traits, such as difficulty with change, it is recognised as a distinct construct that is relatively higher in autistic groups (Boulter et al., 2014; Chamberlain et al., 2013; Hodgson et al., 2017; Vasa et al., 2018). Research has commonly found IU to relate to autistic traits, anxiety, and sensory reactivity differences in autistic individuals, and many studies have found it to be a mediating factor (Boulter et al., 2014; Hwang et al., 2019; Neil et al., 2016; South & Rodgers, 2017; Wigham et al., 2015). Previous research has suggested that IU partially mediates the relationship between both sensory hyperreactivity and hyporeactivity, and anxiety in autistic adults (Hwang et al., 2019). Furthermore, our recent work in preschool-age autistic children (ages 3 – 5 years) indicated that IU mediates the relationship between sensory hyperreactivity and anxiety, but also, that anxiety mediates the relationship between sensory hyperreactivity and IU (MacLennan et al., 2021). As IU is proposed to be a central transdiagnostic factor in anxiety presentations in autistic individuals, interventions targeting IU have been developed, and are showing promising efficacy (Hallett et al., 2021; Rodgers et al., 2017, 2018). Yet, more research is needed to understand the relationship between IU and anxiety in adulthood (Jenkinson et al., 2020), and research is yet to examine if sensory seeking is related to anxiety and IU in autistic adults. This has important implications for the development of effective anxiety interventions for this population.

Existing research in this field has commonly focussed on autistic children, and research in adults is comparatively lacking. Within this, research has yet to examine whether sensory reactivity differences are related to certain anxiety symptomology in autistic adults, and there are no known studies that have explored the links between sensory seeking and anxiety in autistic adults. Therefore, we conducted two complementary online studies that were the first known to examine the relationships between sensory reactivity differences (including hyperreactivity, hyporeactivity, and seeking), anxiety subtypes (including GAD, separation anxiety, and social anxiety), and IU in autistic adults. In Study 1, we aimed to understand if sensory reactivity differences are differentially related to, and predict, anxiety subtypes. Similarly, in Study 2 we aimed to replicate if sensory reactivity differences are differentially related to anxiety subtypes in a larger sample, but also extended on this to replicate our earlier work (MacLennan et al., 2021); understanding if IU mediates the relationship between sensory reactivity and anxiety, and if anxiety mediates the relationship between sensory reactivity and IU.

4.4 Study 1

4.4.1 Methods – Study 1

Participants

We recruited 121 diagnosed autistic adults to take part in this online study. Firstly, to take part in the study participants were required to state that they had an official autism diagnosis, and prior to analysis, participants were excluded if they scored below the cut-off on the AQ-10 (<6). Therefore 94 participants were included in the analyses aged 18 – 70 years (m = 39.06, sd = 14.34), 57 females, 22 males, 6 trans males, 8 non-binary, 1 agender. Participants were recruited via Autistica's Discover Network, MQ's Participate platform, the Centre for Autism Database at the University of Reading, and social media platforms. Participants provided informed consent to take part. Ethical approval was granted prior to the commencement of this study by the University of Reading Ethics Committee[**].

Measures

Sensory Processing Scale Inventory (SPSI)

The SPSI is a self-report questionnaire assessment of sensory reactivity differences for use in children and adults. It has good internal reliability (hyperreactivity = 0.89; hyporeactivity = 0.88; sensory seeking = 0.93), and discriminant validity (medium to large effect sizes; .56–.1.53; Schoen et al., 2008, 2017). The SPSI assesses sensory hyperreactivity, hyporeactivity, and seeking across a range of domains (e.g., auditory, vision, tactile). It is usually scored dichotomously (1 = yes, 0 = no), however, to capture a wider range scores and more sensitive differences between participants, Likert-scale scoring was used, in-line with the Sensory Profile scoring (1 – 5; almost always, frequently, occasionally, seldom, almost never; Brown et al., 2001). Furthermore, for this initial study, we administered a reduced version of the scale that only included items relating to the auditory, visual, and tactile domains.

Screen for Adult Anxiety Related Disorders (SCAARED)

The SCAARED (Angulo et al., 2017) is a self-report questionnaire screening assessment of DSM anxiety disorders for use in adults. The SCAARED assesses total anxiety symptoms, as well as specific anxiety disorders including GAD, social anxiety, separation anxiety, and is scored 0 – 2 using a Likert-scale (not true or hardly ever true, somewhat true or sometimes true, very true or often true). It has good to excellent internal consistency (0.86 - 0.94), and discriminant validity (Angulo et al., 2017). Although the SCAARED has not yet been validated for use with autistic people, the scale is adapted from the child version (Screen for Child Anxiety Related Emotion Disorders; Birmaher et al., 1997), which has been found to have comparable psychometric properties across autistic and non-autistic samples (van Steensel et al., 2013).

[**] University of Reading ethics code: 2019-090-TT

Autism Spectrum Quotient – 10 (AQ-10)

The AQ-10 (Allison et al., 2012) is a brief, 10-item, self-report questionnaire screening assessment of autistic traits for use in adults. It is scored dichotomously with higher scores relating to higher autistic traits. Scores about the cut off (≥6) are indicative of autism. The AQ-10 has good internal consistency (>.85) and discriminate validity (Allison et al., 2012; Booth et al., 2013).

Analysis

Statistical analysis was conducted using JASP (JASP team, 2020). Following normality checks, we firstly conducted a Spearman's bivariate correlation analysis to examine the relationships between sensory reactivity (hyperreactivity, hyporeactivity, and seeking), and anxiety (total anxiety, GAD, separation anxiety, social anxiety), as well as the covariates (autism traits and age). Secondly, we conducted multiple regression analysis to test if sensory reactivity predicts anxiety in autistic adults.

4.4.2 Results – Study 1

Descriptive statistics

Shapiro–Wilk test of normality indicated that not all the variables were normally distributed ($p < .05$) (see Table 12 for descriptive statistics). 100% of the participants scored above the cut-off for GAD, separation anxiety disorder, and social anxiety disorder, indicating the possible clinical presence of these anxiety disorders.

Table 12
Descriptive statistics for sensory reactivity differences (SPSI), anxiety (SCAARED), and autism traits (AQ-10).

	Range	Mean	SD	SE
Hyperreactivity	12 - 35	27.81	4.72	0.49
Hyporeactivity	5 - 20	11.49	3.38	0.35
Seeking	4 - 19	9.63	3.49	0.36
Total anxiety	31 - 79	65.22	8.94	0.92
GAD	16 - 39	33.62	4.73	0.49
Social anxiety	8 - 21	18.68	2.96	0.31
Separation anxiety	7 - 20	12.93	3.53	0.36
AQ	6 - 10	8.69	1.24	0.13
Age	18 - 70	38.55	14.61	1.52

Note. GAD: Generalised anxiety symptoms; AQ: Autism spectrum quotient.

Correlation analysis

We conducted a Spearman's bivariate correlation analysis to examine the relationships between sensory reactivity and anxiety, as well as the covariates; autism traits and age (see Table 13 for correlation results). To control for multiple comparisons, we applied a Bonferroni correction. Neither age nor AQ were found to be significantly correlated with anxiety or sensory reactivity differences (7 comparisons: adjusted $p > .007$).

Correlation analysis, with a Bonferroni corrected alpha level of $p \leq .013$ (.05/4) found that sensory hyperreactivity was significantly correlated with total anxiety ($r^2 = .340$, $p < .001$), and separation anxiety ($r_s = .320$, p = .002), and sensory hyporeactivity was significantly correlated with separation anxiety ($r_s = .289$, p = .005). Fisher's *z* test (Steiger, 1980) was conducted to test if the significant correlation coefficients for the relationships between sensory hyperreactivity/hyporeactivity and separation anxiety was significantly higher than the non-significant correlation coefficients for the relationships between sensory hyperreactivity/hyporeactivity and GAD, and sensory hyperreactivity/hyporeactivity and social anxiety. This showed that the relationship between sensory hyperreactivity and separation anxiety was not significantly different from GAD ($z = 0.78$, $p = .435$) or social anxiety ($z = 1.24$, $p = .215$). But the relationship between sensory hyporeactivity and separation anxiety was significantly different from GAD ($z = 2.28$, $p = .023$) and social anxiety ($z = 2.16$, $p = .031$).

Table 13
Spearman's correlations between sensory reactivity differences (SPSI), anxiety (SCAARED), and autism traits (AQ).

	Hyperreactivity	Hyporeactivity	Seeking	AQ
Total anxiety	**.340*** (.000)**	.187 (.071)	.112 (.283)	.202 (.088)
GAD	**.244 (.018)**	.061 (.556)	.109 (.295)	.185 (075)
Social anxiety	.176 (.090)	.033 (.033)	.004 (.966)	.061 (.556)
Separation anxiety	**.320** (.002)**	**.289** (.005)**	.112 (.281)	**.204 (.049)**
AQ	**.242 (.019)**	.111 (.286)	.138 (.184)	-

*. Correlation is significant at the Bonferroni corrected $p \leq 0.013$ (.05/4) level (2-tailed)
**. Correlation is significant at the $p \leq 0.01$ level (2-tailed)
***. Correlation is significant at the $p \leq 0.001$ level (2-tailed)
Correlations significant prior to Bonferroni correction are indicated in bold without being flagged.
Note. GAD: Generalised anxiety symptoms; AQ: Autism Spectrum Quotient.

Multiple regression analysis

Based on the correlation analysis, multiple regression analyses, with a Bonferroni corrected alpha level of $p \leq .025$ (.05/2), were conducted to test if sensory hyperreactivity is a significant predictor of total anxiety, and if sensory hyperreactivity and hyporeactivity are significant predictors of separation anxiety (see Table 14). The results indicated that total anxiety was significantly predicted by sensory hyperreactivity ($\beta = .317$, $p = .002$) and it explained 10% of the variance ($R^2 = .100$, $F(1,92) = 10.25$, $p = .002$). Separation anxiety was significantly predicted by sensory hyperreactivity ($\beta = .261$, $p = .014$), but not sensory hyporeactivity after the Bonferroni corrected alpha level ($\beta = .219$, $p = .037$). These predictors explained 15.8% of the variance ($R^2 = .158$, $F(2,91) = 8.54$, $p < .001$).

Table 14
Multiple regression analysis showing sensory hyperreactivity and hyporeactivity predicting total anxiety and separation anxiety.

Model		B	SE	β	t	p
Total anxiety	**Hyperreactivity**	**.600**	**.188**	**.317**	**3.201**	**.002***
Separation anxiety	**Hyperreactivity**	**.195**	**.077**	**.261**	**2.518**	**.014***
	Hyporeactivity	**.229**	**.108**	**.219**	**2.119**	**.037**

*. Predictor is significant at the $p \leq 0.025$ level (2-tailed) after a Bonferroni correction (.05/2)
Predictors significant prior to Bonferroni correction are indicated in bold without being flagged.

4.4.3 Discussion – Study 1

This study examined the relationships between sensory hyperreactivity, hyporeactivity, and seeking, and anxiety subtypes in autistic adults. Firstly, in line with previous research, our results found that sensory hyperreactivity was significantly related to total anxiety in autistic adults (Hwang et al., 2019). Additionally, in line with research in children, we found sensory hyperreactivity to be significantly related to separation anxiety but not to social anxiety (Black et al., 2017; MacLennan et al., 2020; Spain et al., 2018). Although, we interpret this cautiously as the correlation coefficients for the significant and non-significant relationships were not significantly different. Secondly, in line with previous research (Hwang et al., 2019), we found a positive relationship between sensory hyporeactivity and total anxiety, but our results also suggest that sensory hyporeactivity may be specifically implicated in separation anxiety. However, the regression analyses suggest that sensory hyperreactivity may be a better predictor of both total anxiety and separation anxiety. Lastly, in support of our previous work in children, we did not find a significant relationship between sensory seeking and anxiety in autistic adults (MacLennan et al., 2020, 2021).

However, this study included a relatively small sample of autistic adults for an online study, with an unusually high prevalence of clinically elevated anxiety. Additionally, as research, including our own (e.g., Hwang et al., 2019; MacLennan et al., 2021; Wigham et al., 2015), has suggested that IU may be an important construct in the relationships between sensory reactivity and anxiety in autism, we conducted a second extended study, in a larger sample of autistic adults, that aimed to replicate the results of this study and to also examine the role of IU.

4.5 Study 2

4.5.1 Methods – Study 2

Participants

We recruited 282 diagnosed autistic adults for this online study. Firstly, to take part in the study participants were required to state that they had an official autism diagnosis, and prior to analysis, participants were excluded if they scored below the cut-off on the AQ-10 (<6). Therefore 246 participants were included in the analyses, aged 18 – 76 years (m = 41.86, sd = 13.70), 143 females, 21 trans females, and 82 males. Participants were recruited via the Centre for Autism Database at the University of Reading, the Autism Research Centre, and UK autistic adults' charities Facebook pages. The data for Study 2 was independently collected from Study 1 and only 17% of participants from Study 1 also took part in Study 2. Therefore, the sample for Study 2 was primarily made up of unique participants. Informed consent was provided before the participants took part. Ethical approval was granted prior to the commencement of this study by the University of Reading Ethics Committee[††].

[††] University of Reading ethics code: 2018-120-TT

Measures

Sensory Processing Scale Inventory (SPSI)

Similarly to Study 1, the SPSI (Schoen et al., 2008, 2017) was used to measure sensory reactivity differences, using Likert-scale scoring in-line with the Sensory Profile scoring (almost always, frequently, occasionally, seldom, almost never; Brown et al., 2001). However, in this second study we administered the extended version of the scale, which also included additional items relating to vestibular, proprioceptive, gustatory, and olfactory domains, in addition to auditory, visual, and tactile domains measured in Study 1.

Screen for Adult Anxiety Related Disorders (SCAARED)

Similarly to Study 1, the SCAARED (Angulo et al., 2017) was used to measure anxiety. See Study 1 for description of this assessment.

Intolerance of Uncertainty Scale (IUS)

The IUS (Buhr & Dugas, 2002) is a self-report questionnaire assessment of IU for use in adults. It is scored from 1 – 5 (not at all characteristic of me, somewhat characteristic of me, entirely characteristic of me) with higher scores indicating greater IU. The IUS has excellent internal consistency (.94) and good test-retest reliability (.74) (Buhr & Dugas, 2002).

Autism Spectrum Quotient – 10 (AQ-10)

Similarly to Study 1, the AQ-10 (Allison et al., 2012) was used to measure autistic traits. See Study 1 for description of this assessment.

Analysis

Statistical analysis was conducted using JASP (JASP team, 2020). Following normality checks, we first conducted a Spearman's bivariate correlation analysis to examine the relationships between sensory reactivity (hyperreactivity, hyporeactivity, and seeking), IU, and anxiety (total anxiety, GAD, separation anxiety, social anxiety), as well as the covariates (autism traits and age).

Secondly, in line with the results of our previous work (MacLennan et al., 2021), we conducted mediation analyses to test if IU mediates the relationship between sensory reactivity differences and anxiety, and if anxiety mediates the relationship between sensory reactivity differences and IU. To adjust for measurement error, we defined the analysis to conduct bootstrapping with 1,000 resamples and generated accelerated 95% confidence intervals. Full mediation is indicated by a significant indirect effect between the predictor and outcome variables, and a non-significant direct effect, whilst partial mediation is indicated by a significant direct and indirect effect between the predictor and outcome variables. Significance is indicated by a Bonferroni corrected alpha level of $p \leq .025$ (.05/2) and confidence intervals (CI's) not overlapping with zero.

4.5.2 Results – Study 2

Descriptive statistics

Shapiro–Wilk test of normality indicated that not all the variables were normally distributed ($p < .05$) (see Table 15 for descriptive statistics). 85% scored above the cut-off for GAD, 68% scored above the cut-off for separation anxiety disorder, and 85% scored above the cut-off for social anxiety disorder, indicating the possible presence of these anxiety disorders.

Table 15
Descriptive statistics for sensory reactivity differences (SPSI), anxiety (SCAARED), intolerance of uncertainty (IUS), and autism traits (AQ-10).

	Range	Mean	SD	SE
Hyperreactivity	15 - 73	51.21	10.82	.69
Hyporeactivity	12 - 46	25.76	6.37	.41
Seeking	10 - 46	24.32	7.38	.47
Total anxiety	0 - 54	33.15	11.27	.72
GAD	0 - 26	18.18	6.29	.40
Social anxiety	0 - 14	10.24	3.82	.24
Separation anxiety	0 - 14	4.74	3.57	.23
IU	16 - 60	46.12	9.78	.62
AQ	6 - 10	8.48	1.28	.08
Age	18 - 76	41.86	13.70	.87

Note. GAD: Generalised anxiety symptoms; IU: Intolerance of uncertainty; AQ: Autism spectrum quotient.

Correlation analysis

We conducted a Spearman's bivariate correlation analysis to examine the relationships between sensory reactivity, anxiety, and IU (see Table 16 for correlation results). Neither age nor AQ were found to be significantly correlated with anxiety or sensory reactivity differences (8 comparisons: adjusted $p > .006$). Correlation analysis, with a Bonferroni corrected alpha level of $p \leq .013$ (.05/4), found that sensory hyperreactivity was significantly correlated with total anxiety ($r_s = .383$, $p < .001$), GAD ($r_s = .274$, $p < .001$), separation anxiety ($r_s = .405$, $p < .001$), and social anxiety ($r_s = .405$, $p < .001$). Sensory seeking was significantly correlated with total anxiety ($r_s = .295$, $p < .001$), GAD ($r^2 = .279$, $p < .001$), separation anxiety ($r_s = .297$, $p < .001$), and social anxiety ($r_s = .192$, $p < .001$). Correlation analysis, with a Bonferroni corrected alpha level of $p \leq .007$ (.05/7), also found that IU was significantly related to sensory hyperreactivity ($r_s = .492$, $p < .001$), sensory hyporeactivity ($r_s = .173$, $p = .007$), sensory seeking ($r_s = .243$, $p < .001$), total anxiety ($r_s = .563$, $p < .001$), GAD ($r_s = .511$, $p < .001$), separation anxiety ($r_s = .386$, $p < .001$), and social anxiety ($r_s = .469$, $p < .001$).

Table 16
Spearman's correlations between sensory reactivity differences (SPSI), anxiety (SCAARED), intolerance of uncertainty (IUS), and autism traits (AQ).

	Hyperreactivity	Hyporeactivity	Seeking	IU	AQ
Total anxiety	**.381*** (.000)**	**.151 (.014)**	**.289*** (.000)**	**.566*** (.000)**	.033 (.605)
GAD	**.271*** (.000)**	**.131 (.030)**	**.272*** (.000)**	**.514*** (.000)**	.001 (.985)
Social anxiety	**.406*** (.000)**	.104 (.104)	**.195** (.002)**	**.470*** (.000)**	.075 (.241)
Separation anxiety	**.381*** (.000)**	**.136 (.021)**	**.284*** (.000)**	**.391*** (.000)**	.075 (.244)
IU	**.495*** (.000)**	**.178** (.007)**	**.251*** (.000)**	-	**.141 (.028)**
AQ	**128 (.046)**	**135 (.035)**	.056 (.386)	-	-

*. Correlation is significant at the Bonferroni corrected $p \leq 0.013$ (.05/4) level (2-tailed)
**. Correlation is significant at the Bonferroni corrected $p \leq 0.007$ (.05/7) level (2-tailed)
***. Correlation is significant at the $p \leq 0.001$ level (2-tailed)
Correlations significant prior to Bonferroni correction are indicated in bold without being flagged.
Note. GAD: Generalised anxiety symptoms; IU: Intolerance of Uncertainty; AQ: Autism Spectrum Quotient.

Mediation analysis

As the correlation analysis found IU to be intercorrelated with sensory hyperreactivity, sensory seeking, and anxiety, mediation analysis was conducted to test if a) IU mediated the relationship between both sensory hyperreactivity and seeking, and anxiety, and if b) anxiety mediated the relationship between both sensory hyperreactivity and seeking, and IU (mediating relationships depicted in Figure 5). Firstly, mediation analysis indicated that IU fully mediates the relationship between sensory hyperreactivity and anxiety, as the indirect effect was significant (B = .024, Lower Limit (LL) = .016, Upper Limit (UL) = .034, $p < .001$), whilst the direct effect was not significant (B = .006, LL = -.004, UL = .021, p = .13), but there was no indication that IU mediates the relationship between sensory seeking and anxiety, as the indirect effect was not significant (B = .002, LL = -.008, UL = .010, p = .73), or that sensory seeking predicts anxiety, the direct effect was not significant at the Bonferroni corrected alpha level of $p \leq .013$ (B = .016, LL = .002, UL = .033, p = .038). Secondly, mediation analysis indicated that anxiety partially mediates the relationship between sensory hyperreactivity and IU, as the indirect effect (B = .016, LL = .009, UL = .022, $p < .001$) and direct effect was significant (B = .030, LL = .020, UL = .041, $p < .001$), but there was no indication that anxiety mediates the relationship between sensory seeking and IU, or that sensory seeking predicts IU, as neither the indirect effect (B = .008, LL = .000, UL = .017, p = .053) or the direct effect was significant (B = -.005, LL = -.020, UL = .009, p = .46) (See Appendix 2 for full mediation statistics).

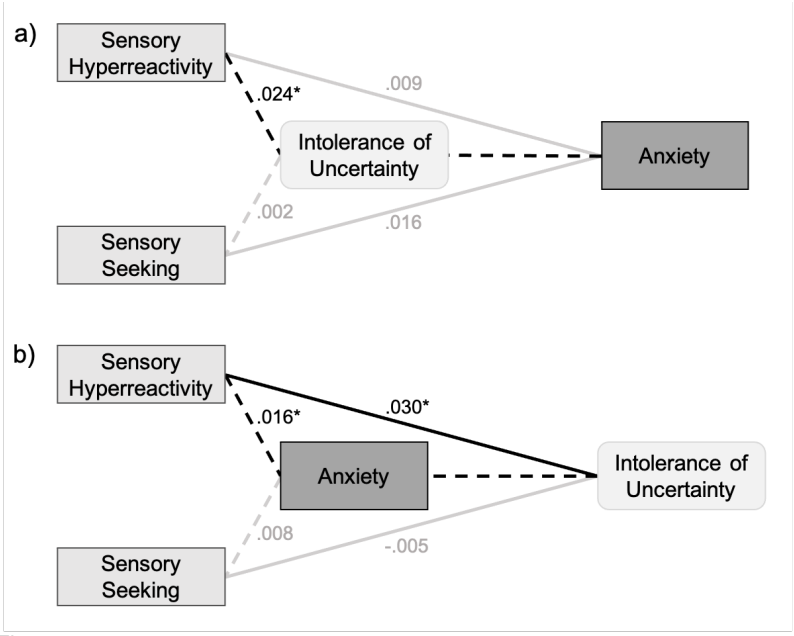

Figure 5
Mediation figure showing a) sensory hyperreactivity and seeking predicting anxiety with intolerance of uncertainty as the mediator, and b) sensory hyperreactivity and seeking predicting intolerance of uncertainty with anxiety as the mediator. *Note.* Direct relationships are indicated by a solid line, indirect relationships are indicated by a dashed line. Significant relationships are indicted by a black line, non-significant with a grey. *B* coefficients are shown for each relationship.

4.5.3 Discussion – Study 2

This study examined the relationship between sensory reactivity differences, anxiety subtypes, and IU in autistic adults. In contrast to Study 1, and our previous work in children (MacLennan et al., 2020), we found that sensory hyperreactivity was significantly related to anxiety but was not differentially related to anxiety subtypes. Also, in contrast to Study 1 and previous work (Hwang et al., 2019), we did not find sensory hyporeactivity to be significantly related to anxiety. Interestingly, and in contrast to both Study 1 and our previously published work with autistic children (MacLennan et al., 2020, 2021), this study found a significant link between sensory seeking and anxiety.

Although previous research found IU to partially mediate the relationship between sensory hyperreactivity and anxiety (Hwang et al., 2019), we found IU to fully mediate the relationship between sensory hyperreactivity and anxiety, and anxiety to partially mediate the relationship between sensory hyperreactivity and IU. Thus, although Study 1 suggests sensory hyperreactivity predicts anxiety in autistic adults, Study 2 extends on these findings to suggest that IU may fully mediate this relationship. Furthermore, despite the significant intercorrelation between sensory seeking, anxiety, and IU, sensory seeking was not found to be a significant predictive factor.

4.6 Cross-study sample comparisons

To examine if there were differences between the samples of the two studies that could explain the differences in results, we conducted independent samples t-tests (Mann-Whitney U) to test if the groups significantly differed on age, autism traits, total anxiety, GAD, separation anxiety, and social anxiety (Figure 6). This indicated that the Study 1 sample and Study 2 sample did not differ significantly in age

(Z = 1.88, p = .60) or autism traits (Z = -1.43, p = .15). However, it indicated that the sample in Study 1 had significantly higher scores than the sample in Study 2 for total anxiety (Z = -13.93, p < .001), GAD (Z = -13.80, p < .001), separation anxiety (Z = -12.56, p < .001), and social anxiety (Z = -13.22, p < .001).

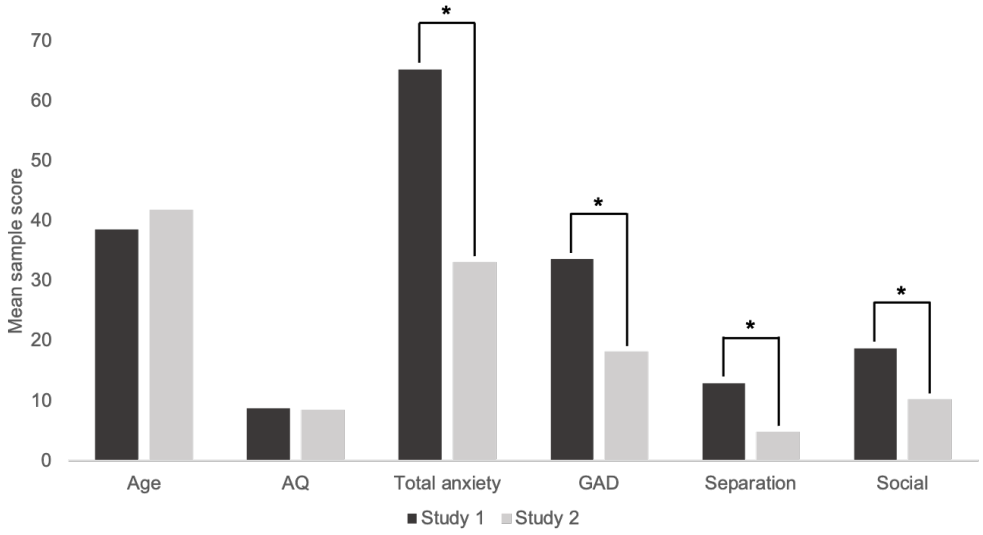

Figure 6
Graph showing Study 1 and Study 2 sample mean scores for age, autism traits (AQ), total anxiety, generalised anxiety (GAD), separation anxiety, and social anxiety.
*Note. * indicates significant mean differences between samples*

Furthermore, as sensory hyporeactivity and seeking were found to be significantly correlated with anxiety, but not found to significantly predict anxiety, and it has been suggested that sensory hyporeactivity and seeking may be inversely linked with sensory hyperreactivity (Liss et al., 2006), we wanted to understand if their association with sensory hyperreactivity was similar across groups. Fisher's *z* test indicated that the correlation coefficients for the relationship between sensory hyperreactivity and hyporeactivity was not significantly different between studies (z = 1.11, p = 0.26), but that the correlation coefficients for the relationship between sensory hyperreactivity and seeking was significantly stronger in Study 2 compared to Study 1 (z = -2.10, p = 0.036).

4.7 General discussion

These complementary studies enhance our understanding of the relationships between sensory reactivity differences, anxiety subtypes, and IU in autistic adults. Overall, the results suggest that IU fully mediates the relationships between sensory hyperreactivity and anxiety, and that anxiety also partially mediates the relationship between sensory hyperreactivity and IU. Although we also found significant associations between both sensory hyporeactivity and seeking, and anxiety, Study 1 and Study 2 did not find a replicated pattern of significant correlations. The possible reasons for this will be discussed in detail.

The studies found sensory hyperreactivity to be related to total anxiety, which is in line with previous work in autistic children (Green et al., 2012; MacLennan et al., 2020; Wigham et al., 2015) and adults (Hwang et al., 2019) Additionally, significant relationships were also found between sensory hyperreactivity and GAD, separation anxiety, and social anxiety, which is in line with research in autistic children and adolescents (Bitsika et al., 2019; Black et al., 2017; MacLennan et al., 2020; Pickard et al., 2020). Our previous work in autistic children has found sensory hyperreactivity to be specifically related to certain anxiety symptomology, including phobia/physical injury fears separation anxiety, when controlling for broader autism traits (MacLennan et al., 2020, 2021). However, the present studies did not find a significant association between autism traits and sensory reactivity or anxiety. This may have been due to the use of the short AQ-10, which is better suited as a screening tool rather than being used as a continuous scale measure in research. Our results support previous work in autistic adults (Hwang et al., 2019) to suggest that IU is a mediator in the relationships between sensory hyperreactivity and anxiety. However, our results also suggest that, as well as sensory hyperreactivity directly predicting IU, anxiety also mediates this relationship, the latter also reflecting our previous work in preschool-age autistic children (MacLennan et al., 2021). The unpredictability of aversive sensory input may lead to the development of anxiety through context conditioning, with increased hypervigilance, negative bias, and avoidance of generalised contexts (Green & Ben-Sasson, 2010; Grillon, 2008). Additionally, higher IU may lead to greater hypervigilance and a bias to perceive uncertainty as a threat (Dugas et al., 2005; Fergus & Carleton, 2016). Although we did not find robust evidence that sensory hyperreactivity is differentially related to anxiety symptomology, IU has previously been suggested to be a component of GAD and social anxiety in non-autistic populations (Boelen & Reijntjes, 2009; Dugas & Ladouceur, 2000; Holaway et al., 2006), and recent research has also found IU to be implicated in social anxiety in autistic individuals (Pickard et al., 2020). As interventions that target IU are showing promising efficacy (Hallett et al., 2021; Rodgers et al., 2017, 2018), our research can help inform further development of adult interventions for anxiety.

A contrasting pattern of results was found for sensory hyporeactivity and seeking across the two studies. Although both studies found links between sensory hyporeactivity and anxiety, in Study 2 these became non-significant due to the adjusted alpha level after Bonferroni correction. Research has commonly been inconsistent in regard to sensory hyporeactivity, with some finding it to be related to anxiety in autistic adults and children (Glod et al., 2019; Hwang et al., 2019; MacLennan et al., 2020; Rossow et al., 2021), whilst others have not (MacLennan et al., 2021; Wigham et al., 2015). As for sensory seeking, in contrast to Study 1 and previous work in children (Lidstone et al., 2014; MacLennan et al., 2020, 2021), Study 2 was the first to find a significant association between sensory seeking and anxiety in autistic adults. Although the different findings across the studies may be due to differential measures used, or the lower power in the first study, it may be due to additional factors. Sensory hyporeactivity has been suggested to be experienced after periods of hyperreactivity, where individuals may inversely ‘shutdown’ from sensory input (Lane, 2002; Liss et al., 2006). Whereas, sensory seeking may be a compensatory strategy enhanced in adulthood whereby individuals focus on certain sensory input to soothe and moderate arousal when faced with aversive input (Liss et al.,

2006). Additionally, the sample in Study 1 had significantly higher anxiety than the sample in Study 2. This was likely due to the use of the MQ: Mental Health Participate platform in Study 1, that aims to assist with recruitment for mental health studies and therefore this participants pool would likely have a high rate of mental health conditions. As sensory hyperreactivity and seeking were more strongly correlated in Study 2 compared to Study 1, It may be that autistic adults with lower rates of anxiety are more able to utilise sensory seeking as a strategy to moderate sensory input associated with sensory hyperreactivity. However, as a reduced version of the SPSI was used to assess sensory reactivity in Study 1, whilst the full measure was used in Study 2, we are unable to compare the rates of sensory reactivity differences across the two samples. Alternatively, as Study 2 contained additional items relating to wider domains, including vestibular, proprioceptive, gustatory, and olfactory, it may be that sensory reactivity differences within domains are differentially related to anxiety, and explain the differences in results between studies. Therefore, these could be important considerations for future research.

4.7.1 Limitations

Although the differences between studies could be due to the different sensory measures used across studies, Study 1's sample presenting with significantly higher anxiety than in Study 2, or due to Study 1 being under-powered compared to Study 2, inconsistencies between the two studies could also be due to other unknown differences in sample characteristics. Due to the heterogeneous nature of autism, individuals present with varying strengths and difficulties as well as cooccurring conditions (Vasa & Mazurek, 2015). Therefore, it could have been informative to collect additional demographic information, such as cooccurring diagnoses (e.g., Intellectual Disability or ADHD), to ascertain if there were other key group differences. Furthermore, the impact of broader autism traits may not have been reliably examined due to the limited range of scores from the AQ-10, which we used to reduce the burden on participants in these online studies. Future research should examine the influence of other individual factors, as well as aiming to replicate these findings in more specific subgroups of autistic adults, as this may have important implications for treatment.

Questionnaire measures are an effective means for collecting larger samples of data with ease. However, the sole use of questionnaire measures means that it is possible that relationships between sensory reactivity and anxiety are due to overlapping questionnaire items. Anxiety and sensory hyperreactivity can be difficult to distinguish and measures can sometimes have overlapping items (Ben-Sasson et al., 2007; Green & Ben-Sasson, 2010). However, this was considered in the study design as we selected to use the SPSI, rather than other commonly used assessments such as the Sensory Profile (Dunn, 1999), as it can be seen as a 'purer' measure of sensory reactivity differences and includes less items related to emotional affect and behaviours related to anxious responses. Future work could aim to also include more objective assessments, such as the Anxiety Disorders Interview Schedule – Autism Addendum (Kerns et al., 2017), that would facilitate greater detangling of traits/symptoms associated with both sensory reactivity and anxiety.

Although GAD, separation anxiety, and social anxiety all cooccur in autistic individuals, this research did not include other common anxiety conditions, such as specific phobia (Kerns et al., 2020; Nimmo-Smith et al., 2020). There are challenges with assessing phobic symptoms in questionnaire measures, due to the specific and individual nature of phobias. However, autistic people can develop idiosyncratic phobias that are associated with sensory input (Kerns et al., 2014), for instance, balloons due to the aversive experience of the sound when they burst. Specific phobias have been found to be more prevalent in autistic individuals with cooccurring intellectual disability (Kerns et al., 2020). Therefore, it is important for future research in autistic adults to understand risk factors for additional anxiety symptomology, such specific phobias, including the role of sensory reactivity.

4.7.2 Conclusion

These complementary studies have importantly examined the correlational and cross-sectional predictive relationship between sensory reactivity differences, anxiety subtypes, and IU in autistic adults for the first time. Our results support that sensory reactivity differences, including hyporeactivity and seeking, are related to anxiety, and sensory hyperreactivity is a predictive factor. Furthermore, they further support that IU is an important mediator in the relationship between sensory hyperreactivity and anxiety. These findings have clinical relevance for when considering approaches for treatment of anxiety symptomology in autistic adults.

4.7.3 Acknowledgements

Special thanks to all the autistic adults who participated in our research. Thanks to Sarah Cragg and Jessica Carter of the University of Reading for assisting with data collection. As well as MQ, Autistica, the Centre for Autism at the University of Reading, and Autism Berkshire for helping with recruitment.

Chapter 5. In our own words: The complex sensory experiences of autistic adults

Keren MacLennan, Sarah O'Brien & Teresa Tavassoli

Accepted for publication: 29 July 2021 by *Journal of Autism and Developmental Disorders,* https://doi.org/10.1007/s10803-021-05186-3

5.1 Paper contribution

I had a significant contribution to this paper. This included conceptualising the study and working with the other members of the research team to develop the study design and aims and collect the data. I inputted and processed the data. I independently conducted the data analyses and wrote the manuscript with feedback provided from the other authors, as well as member of the autistic community (as outlined in the acknowledgements).

5.2 Abstract

Autistic adults commonly experience sensory reactivity differences. Sensory hyperreactivity is frequently researched, whilst hyporeactivity and seeking, and experiences across domains, e.g., vision, are often neglected. Therefore, we aimed to understand more about the sensory experiences of autistic adults. We conducted a mixed-methods study, co-produced with stakeholders; recruiting 49 autistic adults who completed an online survey. Firstly, quantitative results and content analysis enhanced our understanding of sensory input/contexts associated with sensory hyperreactivity, hyporeactivity, and seeking across modalities. Secondly, thematic analysis developed themes relating to 'Outcomes', 'Control', 'Tolerance and management', and 'The role of other people', informing a theoretical model of sensory reactivity differences in autistic adults. These findings have implications for support services and improving quality of life for autistic adults.

Key Words: autism, autistic, adult, sensory, participatory, qualitative

5.3 Introduction

Autism Spectrum Conditions (ASC) are neurodevelopmental conditions typically characterised by social communication differences, and restricted and repetitive interests and/or behaviours (RRBs) (DSM-5 American Psychiatric Association, 2013). Sensory reactivity differences, a sub-criterion under RRBs, are suggested to be present in up to 94% of autistic adults (Crane et al., 2009). Sensory reactivity differences can occur across multiple sensory domains, such as vision or touch, and are characterised by hyperreactivity, hyporeactivity, and sensory seeking (DSM-5 American Psychiatric Association, 2013). Individuals who are sensory hyperreactive often experience sensory input more intensely compared to others, and may find it painful, dysregulating, or overwhelming (Lane, 2002). Individuals who are sensory hyporeactive often have a delayed response, or may not notice, sensory input, and it may be experienced by individuals after periods of hyperreactivity (Lane, 2002; Liss et al., 2006). Individuals who are sensory seeking often engage with sensory input repeatedly and/or for sustained periods of time, and it may be a stimulatory or regulatory strategy associated with RRBs, sensory hyperreactivity and/or hyporeactivity (Lidstone et al., 2014; Pellicano et al., 2013; Schulz & Stevenson, 2019). Sensory experiences can be complex and although some sensory experiences can be enjoyable for individuals, other experiences can be very distressing, impacting on quality of life and correlating with mental health conditions, such as anxiety and depression (Carpenter et al., 2018; Elwin et al., 2012; Forsyth & Trevarrow, 2018; Green et al., 2012; Hwang et al., 2019; MacLennan et al., 2020, 2021; Rossow et al., 2021). It is therefore unsurprising that difficulty with sensory input has been suggested to be a barrier for autistic adults engaging in spaces, both public and occupational (Amos et al., 2019). Thus, understanding the complexities of sensory experiences has important implications for autistic people's physical and mental wellness, social inclusion, and future prospects.

Previous qualitative findings have shown that autistic adults experience sensory hyperreactivity across multiple domains, such as finding sounds too loud and painful, becoming distracted by nearby conversations, as well as having aversions to competing sounds, bright colours, bright or flickering lights, light touch, clothing, overpowering scents, and food tastes and textures (Chamak et al., 2008; Jones et al., 2003; Robertson & Simmons, 2015). Additionally, sensory hyperreactivity can result in autistic adults feeling overwhelmed, and this can be exacerbated when experiencing heightened stress and depleted energy levels (Chamak et al., 2008; Robertson & Simmons, 2015; Smith & Sharp, 2013). This can create a vicious cycle, where sensory hyperreactivity creates stress, which amplifies sensory hyperreactivity, leading to more stress (Smith & Sharp, 2013).

However, existing research has provided much less insight into experiences of sensory hyporeactivity and seeking. Recent research has shown that although sensory hyporeactivity may be less pronounced in adulthood, it is still present (Hwang et al., 2019). Qualitative research has suggested that autistic adults experience sensory hyporeactivity to pain, hunger, temperatures, scents, flavours, as well as certain sounds (Chamak et al., 2008; Elwin et al., 2012). As for sensory seeking, research has thought that it may be more prominent in childhood compared to adulthood (Kern et al., 2007). However, qualitative research has suggested that autistic adults seek out enjoyable and soothing sensory perceptual experiences, such as favourite music, and feeling certain textures such as cold, smooth

surfaces (Jones et al., 2003; Robertson & Simmons, 2015). But, due to the underrepresentation of sensory hyporeactivity and seeking in research, there is an imperative need to understand more about autistic adults' experiences of these types of sensory reactivity.

Despite evidence suggesting that sensory reactivity differences persist into adulthood (Crane et al., 2009), the sensory experiences of autistic adults have been under-represented in research. Furthermore, sensory hyperreactivity is often a key focus of research, despite evidence that autistic adults experience varying patterns of sensory reactivity differences (Crane et al., 2009). Research has yet to comprehensively identify sensory input that is related to sensory reactivity differences in autistic adults, especially input relating to hyporeactivity and seeking, across modalities (e.g., vision, touch). Furthermore, it is yet to examine autistic adults' experiences of these sensory reactivity differences, also involving autistic individuals in the research process. Therefore, the present mixed-methods study aimed to elucidate the complex sensory experiences of autistic adults using a novel online survey approach. Firstly, we sought to understand more about elements of the sensory environment relating to sensory hyperreactivity, hyporeactivity, and seeking across sensory domains, such as visual, auditory, and tactile. Secondly, we sought to understand more about autistic adults' sensory experiences related to these sensory reactivity differences, to develop a theoretical model reflecting these experiences. Importantly, this research was co-produced with autistic adults following a participatory research framework (Pellicano et al., 2013), to ensure the research was shaped by autistic individuals and relevant and consistent with their values.

5.4 Methods

5.4.1 Design

This study adopted a mixed-methods design, using both quantitative and qualitative approaches, as well as principles of a participatory research framework (Pellicano et al., 2013). The research team included a doctoral researcher (KM) and an associate professor (TT), who specialise in autism and sensory research, as well as an autistic researcher (SOB), with lived experience and autism research expertise. Feedback from members of the autistic community, external to the research team, was sought at key stages of the projects to improve accessibility, such as the design of recruitment materials, the information sheet, and the questionnaire, as well as an insight group with four autistic adults to discuss the interpretation of results.

The data was collected using an online mixed-methods survey, including both closed and open-ended questions. Collecting the qualitative data using an online survey was chosen over other methods, such as focus groups or interviews. This is because qualitative surveys have the advantage of being able to capture what is important to participants using their own language and terminology (Frith, 2000), and this can easily be combined with the simultaneous collection of quantitative data online. Qualitative surveys are argued to achieve the depth and richness needed for qualitative research through a 'wide-angle lens'; gaining perspectives and experiences from a diverse range of voices from widely geographically dispersed populations (Braun et al., 2017; Toerien & Wilkinson, 2004). This is especially

important when the group of interest are large or diverse (Braun et al., 2017), which is effective for research with autistic populations, due to their heterogeneous nature. Online methods also improve the feeling of anonymity, reducing social desirability, and also lessen the burden of participation as the survey can be completed flexibly in a time, pace, and place that suits the participant (Braun et al., 2020).

5.4.2 Participants

The data of 49 autistic adults was included in the analysis, age range 20 – 55 years (mean = 34.5, SD = 10.6), although 14 adults chose not to disclose their age (see Table 17). All participants self-reported that they had been clinically diagnosed as autistic. None of the participants had significant hearing or visual impairments that could confound their sensory reactivity. Specific data on socioeconomic status and educational attainment levels were not obtained for this study.

Table 17
Demographic characteristics of participants

	N
Gender	
Male	11 (22.5%)
Female	33 (67.5%)
Non-binary	5 (10.0%)
Ethnicity	
White British	19 (38.8%)
White European	3 (6.1%)
White British/American	1 (2.0%)
White non-specified	21 (43.0%)
Ashkenazi Jewish	1 (2.0%)
Latina	1 (2.0%)
Not specified	3 (6.1%)
Self-reported clinical diagnoses	
ASC	49 (100%)
Anxiety	21 (43.0%)
Depression	14 (28.6%)
ADHD	9 (18.4%)
Bipolar disorder	4 (8.2%)
Anorexia nervosa	4 (8.2%)
Intellectual disability	2 (4.1%)
Borderline personality disorder	1 (2.0%)
No diagnoses in addition to ASC	14 (28.6%)

Note. ASC: Autism Spectrum Condition; ADHD: Attention Deficit Hyperactivity Disorder.

Eighty-three participants were originally recruited for the study; however, 34 participants did not proceed with the study after completing the demographic information and were excluded. Out of the 49 participants that were included in the study, 40 provided responses to the multiple-choice questions, 49 completed the first section of open questions, and 29 completed the full qualitative questionnaire (Figure

7). The autistic adults were recruited via the Centre for Autism, University of Reading, participant database, and through Facebook and Twitter social media posts. All participants provided informed consent online before commencing with the study. Ethical approval was granted prior to the commencement of this study by the University of Reading Ethics Committee[‡‡].

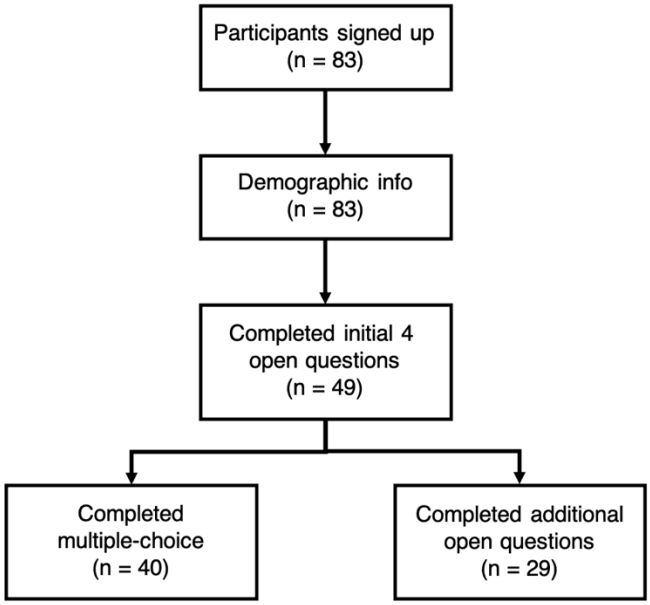

Figure 7
Flow diagram showing the number (n) of participants included at each stage.

5.4.3 Measures

We developed an online questionnaire including demographic questions followed by 34 questions to capture information about the sensory experiences of autistic adults; 28 were open ended and 6 were multiple choice (Appendix 3). We also provided descriptions of sensory hyperreactivity, hyporeactivity and seeking, and these terms were used throughout the questionnaire. The questionnaire was designed to capture participants' general experiences of being sensory hyperreactive, hyporeactive, seeking and/or neutral to the sensory environment, as well as for each modality; visual, auditory, tactile, interoception, gustatory, and olfactory. The initial 4 questions asked broadly about 1) sensory hyperreactivity, 2) sensory hyporeactivity, 3) sensory seeking, and 4) neutral sensory experiences, e.g., "*Describe your experience of being sensory hyperreactive*". Followed by questions asking about sensory experiences relating to sensory modalities, e.g., "*Describe your experiences of being hyperreactive to the visual environment*". Additionally, the questionnaire included six multiple-choice questions that asked participants if they experienced sensory reactivity differences (hyperreactivity, hyporeactivity, seeking, and/or neutral) to pre-defined aspects of the sensory environment in each modality (e.g., visual: bright lights), and an 'other' option for them to add their own. These stimuli were identified from existing literature and tools (Brown et al., 2001; Schoen et al., 2008), and from a group of autistic adults during the development of the questionnaire. These closed questions were included

[‡‡] University of Reading PCLS ethics code: 2018-198-TT

to provide examples to assist in answering the qualitative questions and allowed participants who may struggle with open questions to still share their sensory experiences.

5.4.4 Procedure

Autistic adults were invited to take part in an online questionnaire about their sensory experiences. Participants were able to read the study information and then provide informed consent via an online form. It was also highlighted that although the answers to questions had to be their own, they should seek support with completing the questionnaire if required. Participants then completed the survey, which was anticipated to take between 15 – 60 minutes depending on the depth of information provided.

5.4.5 Analysis

To address our research aims, we used a mixed-methods analysis approach. The data was analysed using NVivo (Castleberry, 2012) primarily by one of the researchers (KM), but the development and interpretation of categories, codes and themes were discussed and confirmed by all members of the research team (SOB and TT), as well as the four autistic adults from the insight group.

To elucidate the elements of the sensory environment associated with sensory reactivity differences, including hyperreactivity, hyporeactivity, and seeking for each modality, we firstly analysed the multiple-choice data by calculating the percentage of participants that identified as having these experiences in each modality. Secondly, we analysed the qualitative data using content analysis, which is an objective systematic way of quantifying and describing data (Elo & Kyngäs, 2008; Krippendorff, 2018). The categories contain words and phrases that share meaning (Cavanagh, 1997). To achieve our aims, deductive, a priori coding was adopted to predetermine the categories of sensory reactivity differences and domain, however we adopted an unconstrained matrix where we used an inductive process to identify sub-categories of common stimuli and contexts within these bounds (Elo & Kyngäs, 2008).

Then, to understand more about autistic adults' sensory experiences, we analysed the data using thematic analysis; identifying patterns of meaning in the data (Braun & Clarke, 2006). We took an inductive approach so our analysis was driven by the data rather than preconceived coding or perceptions, and we adopted an iterative framework to develop meaning from the data (Srivastava & Hopwood, 2009). Thus, our approach was a continuous and deeply reflexive process, which recognised that categories and themes do not emerge on their own but are driven by what we as researchers aimed to know and how we interpreted the data. The framework proposes three questions as reference points, 1) What are the data telling me? 2) What is it I want to know? 3) What is the dialectical relationship between what the data are telling me and what I want to know? Through this cyclical approach, categories and themes were reflexively revised and refined, considering researcher biases, and incorporating insights from the analysis process and from checks with the research team and members of the autistic community. Once the final themes were developed, these were then adapted into a theoretical model. The importance of highlighting the interconnected nature of the themes was emphasised by the autistic adults in the feedback group. Therefore, the model is informed by the themes

and provides enhanced representation of the lived experience of sensory reactivity differences for autistic adults.

5.5 Results

5.5.1 Quantitative analysis

Responses to the multiple-choice questions found that 93.9% percent of the autistic adults identified as experiencing sensory hyperreactivity, 28.6% identified as experiencing sensory hyporeactivity, and 41.4% identified as experiencing sensory seeking (Figure 8; See Table 18 for sensory input/contexts associated with sensory reactivity differences in each modality). Furthermore, 22.5% identified as experiencing only either sensory hyperreactivity, hyporeactivity, or seeking (20.5% hyperreactivity; 0% hyporeactivity; 2.0% seeking), 49.0% identified as experiencing 2 of these (4.1% hyperreactivity and hyporeactivity; 44.9% hyperreactivity and seeking; 0% hyporeactivity and seeking), and 24.5% identified as experiencing all 3. Although all participants reported qualitative experiences of sensory reactivity differences, 4.1% of the autistic adults identified as having no sensory reactivity differences.

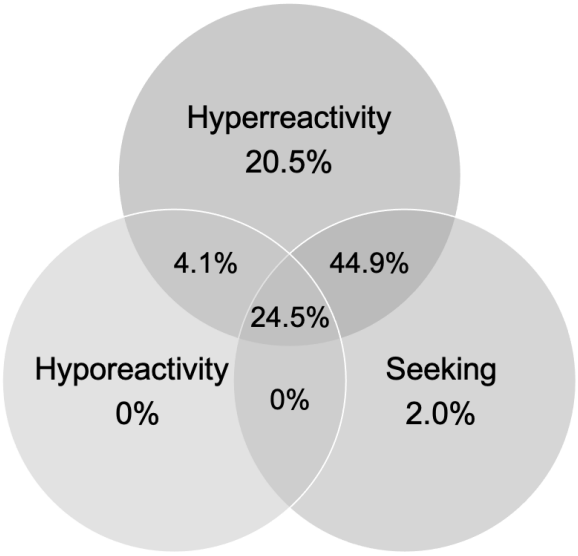

Figure 8

Depicting the percentage of participants (n=49) self-identifying as experiencing only sensory hyperreactivity, hyporeactivity, or seeking, or experiencing hyperreactivity and hyporeactivity, hyperreactivity and seeking, or hyporeactivity and seeking, or experiencing all three.

Sensory hyperreactivity

Responses to the multiple-choice items showed that autistic adults identified they are commonly hyperreactive to bright and flashing lights (75%), loud noises (87.5%), lots of conversations (82.5%), high-pitch noises (77.5%), music (75%), public transport sounds (70%), clothing (75%), different textures (62.5%), hot temperatures (55%), food textures (65%), strong scents (65%), and the scent of perfume (60%).

Sensory hyporeactivity

Overall, in the multiple-choice items, sensory hyporeactivity was minimally selected as being experienced across domains. The most endorsed hyporeactive experiences were in the interoceptive domain, including being hyporeactive to physical pain (30%), and hot (15%) and cold (12.5%) temperatures.

Sensory seeking

Responses to the multiple-choice items showed that autistic adults identified they most commonly seek out music (60%), and different textures (73.5%). Other seeking experiences that some of the autistic adults endorsed included looking at patterns (35%) and bright colours (30%), feeling pressure differences (32.5%), favourite (37.5%) or spicy food flavours (30%), and the scent of fresh air (35%).

Neutral sensory experiences

Responses to multiple-choice items found many of the autistic adults did not have any sensory reactivity differences associated with low contrast images (77.5%) or chewing gum (57.5%). Some of the autistic adults also identified having no sensory reactivity differences associated with looking at bright colours (40%) or patterns (30%), ambient noise (47.5%), memorable (45%) or favourite (32.5%) foods, or the scent of fresh air (40%), pollution (40%), or flowers (30%).

Table 18
Summary of quantitative analysis. Percentage of participants in the multiple-choice responses who identified experiencing sensory reactivity differences to sensory stimuli for hyperreactivity, hyporeactivity and seeking, and in each modality (n = 40).

		Percentage %			
		Hyperreactive	*Hyporeactive*	*Seeking*	*Neutral*
Overall	Yes	93.9	28.6	41.4	-
	No	6.1	71.4	28.6	-
Visual	Bright lights	75.0	5.0	0.0	17.5
	Flashing lights	75.0	0.0	0.0	22.5
	Bright colours	27.5	0.0	30.0	40.0
	Low contrast images	7.5	7.5	7.5	77.5
	Patterns	35.0	2.5	35.0	30.0
Auditory	Lots of conversations	82.5	6.0	2.5	2.5
	Shopping centres	26.0	5.0	5.0	20.0
	Public transport	70.0	7.5	0.0	17.5
	Loud noises	87.5	5.0	2.5	2.5
	Ambient noises	40.0	7.5	10.0	47.5
	High pitch noises	77.5	2.5	2.5	12.5
	Music	75.0	0.0	60.0	15.0
Tactile	Pressure differences	47.5	5.0	32.5	17.5
	Clothing,	75.0	0.0	15.0	15.0
	Different textures	62.5	0.0	73.5	12.5
Interoception	Cold temperatures	42.5	12.5	7.5	27.5
	Hot temperatures	55.0	15.0	2.5	20.0
	Changes in the weather	47.5	10.0	2.5	35.0
	Physical pain	35.0	30.0	5.0	25.0
Gustatory	Spicy food	37.5	10.0	30.0	25.0
	Food temperatures	32.5	5.0	10.0	42.5
	Food textures	65.0	2.5	17.5	22.5
	Favourite foods	22.5	5.0	37.5	32.5
	Memorable foods	20.0	2.5	25.0	45.0
	Chewing gum	10.0	0.0	20.0	57.5
Olfactory	Strong scents	65.0	10.0	10.0	15.0
	Perfumes	60.0	10.0	12.5	12.5
	Pollution	45.0	7.5	0.0	40.0
	Flowers	27.5	15.0	20.0	30.0
	Fresh air	12.5	12.5	35.0	40.0

5.5.2 Content analysis

The qualitative data was then analysed using content analysis to create categories of sensory input/contexts that related to sensory reactivity in each modality. Table 19 shows sensory input/contexts associated with sensory reactivity differences in each modality. Example quotes for these categories can be found in the supplementary materials (Appendix 4).

Sensory hyperreactivity

Content analysis found that the autistic adults commonly experience hyperreactivity to bright lights, both artificial and to sunlight, as well as to flashing lights, and busy, cluttered environments. Many also reported being hyperreactive to bright colours and patterns, and motion or moving objects. In the auditory domain, hyperreactivity to loud and/or unexpected sounds was the most reported, such as sirens, alarms, and dogs barking. But also, being hyperreactive in response to busy/chaotic auditory environments and to background noise, especially situations with multiple conversations, were commonly reported. In the tactile domain, many of the autistic adults reported being hyperreactive to touch from other people, especially when it is light or unexpected, as well as to different fabric textures and labels in clothing, being unable to wear some clothing because of this. Some of the autistic adults also reported being hyperreactive to tight clothing, and certain rough textures, such as carpets and feathers, and wet/greasy textures, such as sweat or lotions. Regarding interception, many of the autistic adults reported being hyperreactive to temperature extremes; being too hot or too cold. As for Olfactory, many of the autistic adults reported a range of individualistic food aversions and dietary restrictions due to being hyperreactive to certain food tastes and textures. Lastly, many of the autistic adults reported being hyperreactive to what they referred to as *strong odours*, as well as perfume, scented products, or food odours, which they often find unbearable and could result in them feel nauseated. Some of the autistic adults also reported being hyperreactive to people or animal smells, as well as dirty home odours such as bins/trash.

Sensory hyporeactivity

Experiences of sensory hyporeactivity were less commonly reported. However, content analysis found that some of the autistic adults reported they were hyporeactive to visual search or environmental changes, such as having difficulty finding an item they're looking for and being slow to notice changes or danger in their environment. Additionally, some of the autistic adults described experiences of auditory hyporeactivity in instances when they are hyper-focussed or concentrating on a task. Furthermore, many of the autistic adults reported their experiences of being hyporeactive to pain and consider themselves to have a high pain threshold compared to others. Additionally, the autistic adults also described their experiences of being hyporeactive to temperature and may be slow to notice if they feel too hot or cold, or if they touch something that is very hot or cold. Lastly, some of the autistic adults reported that they can struggle to smell subtle scents that other people report to have noticed.

Sensory seeking

The content analysis found that many of the autistic adults described how they seek out to look at bright colours and patterns for extended periods of time, as well as complex images, such as scenes of nature or artwork. A few also reported that they seek out motion or moving objects, as well as ambient lighting. As for the auditory domain, the autistic adults commonly reported that they seek out music related to their individual music tastes and will often listen to the same song repeatedly. Regarding the tactile domain, many of the autistic adults described how they seek out pressure, such as by wearing tight clothing and getting tight hugs from trusted people, as well as seeking out certain textures, such as those that are soft or fluffy. Additionally, some of the autistic adults seek out the feeling of warm or cold surfaces on their skin. Relating to the gustatory domain, many of the autistic adults reported that they seek out certain food tastes and textures and would sometimes fixate on certain foods. Lastly, many of the autistic adults described how they continually seek out odours that they like, such as food scents, perfume, scented products, and aromatherapy.

Table 19
Summary of content analysis. Number of participants who reported experiences relating to sensory hyperreactivity, hyporeactivity, and seeking, in each modality (n = 49).

		Hyperreactive	***Hyporeactive***	***Seeking***
Visual	Bright lights (e.g., artificial, sunlight)	30	-	-
	Flashing lights	12	-	-
	Cluttered/busy environments	13	-	-
	Bright colours	6	-	10
	Patterns	5	-	9
	Motion/moving objects	5	-	5
	Visual search (e.g., slow to see dangers or changes)	-	7	-
	Complex images (e.g., nature scenes, artwork)	-	-	9
	Ambient lights	-	-	6
Auditory	Loud and/or unexpected sounds	28	-	-
	Busy/chaotic auditory environments	19	-	-
	Background noise	18	-	-
	Sounds others cannot hear	10	-	-
	High pitched noises	6	-	-
	Out of tune sounds	3	-	-
	Repetitive sounds	3	-	-
	No response when distracted/focussed	-	10	-
	Own music	-	-	26
	Ambient sounds (e.g., fans or engines humming)	-	-	3
Tactile	Light and/or unexpected touch from people	29	-	-
	Clothing fabrics and labels	24	-	-
	Tight clothing	9	-	-
	Environmental textures (e.g., carpet, blankets, feathers)	9	-	18
	Wet/greasy textures (e.g., rain, sweat, lotions)	8	-	-
	Pressure (e.g., tight clothing, tight hugs)	-	-	23
	Hot or cold items/surfaces	-	-	10
Interoception	Temperature extremes	17	11	-
	Pain	4	15	-
	Body signals (e.g., hunger, needing the toilet)	-	4	-
Gustatory	Food tastes	18	8	24
	Food textures	16	-	5
Olfactory	Strong odours	31	-	-
	Perfumes	12	-	5
	Food odours	9	-	7
	Scented products	8	-	6
	People and animals	6	-	4
	Dirty home odours (e.g., bins)	6	-	-
	Cigarette smoke	5	-	-
	Pollution	4	-	-
	Subtle odours	-	9	-

5.5.3 Thematic analysis

The iterative approach to thematic analysis led to the development of 4 themes with 11 sub-themes, as depicted in Table 20, that related to sensory reactivity in autistic adults: “Outcomes”, “Tolerance and management”, “Control”, and “The role of other people”.

Table 20
Summary of main themes and sub-themes developed from thematic analysis relating to sensory reactivity in autistic adults

Main theme	Sub-themes
Outcomes	Physical outcomes and responses Feeling overwhelmed and disengaging Mental health
Control	A desire for control and predictability Difficulty with self-control
Tolerance and management	Moderated by mood Soothing sensory input Avoidance Adaptation
The role of other people	Understanding Support

Outcomes

Many of the autistic adults reported the impacts of having sensory reactivity differences. They described how sensory experiences can negatively impact their mental health, highlighting links to anxiety, self-harm, and eating disorders. They also reported negative physical responses in response to aversive aspects of the sensory environment, and how these could affect their physical health. The autistic adults also described how sensory stimuli and environments can become overwhelming, which can make them feel like they have disengaged or ‘shutdown’.

Mental health

Several of the autistic adults reported the impact that sensory experiences can have on their mental health. Difficulties with sensory input was described to impact mood, causing stress and agitation:

> *“Bright lights such as ceiling lights are unbearable and make me feel very stressed.”* SE007

Many of the autistic adults also reported that aversive sensory experiences were a cause for anxiety. They described how a range of experiences across modalities could trigger anxiety, such as loud sounds, unexpected touch, bright or flickering lights, disliked food tastes and textures, and strong scents:

> *“When we had issues with our sewage system that persisted for a couple of weeks the constant smell made me agitated and anxious to the point I was experiencing suicidal ideation.”* SE016

Additionally, some of the participants reported links between sensory seeking experiences and mental health conditions, for instance, self-harming being described as a form of sensory seeking, and strong liking for certain foods being related to eating disorders:

"I was bulimic for a number of years. This was a form of sensory seeking - I always binged on sweet foods and unlike most bulimics was always very present as I was eating the food." SE016

Physical outcomes & responses

Sensory experiences were reported to trigger a range of physical responses that can be intense and overwhelming. Sensory hyperreactivity is often experienced as physical pain, for instance due to sudden loud sounds or unexpected touch, and can induce headaches and nausea, for instance because of strong scents becoming overpowering:

"Smelling a strong smell is like being tortured, time stops and I'm nearly sick." SE008

"I'm easily startled by sound or touch, sounds physically hurt me." SE017

Additionally, difficulty with sensory stimuli had implications for physical health, such as auditory hyperreactivity impacting sleep, restrictive or repetitive eating due to difficulties with taste leading to nutritional imbalances, or medical difficulties due to being hyporeactive to pain:

"I think over the years I learned to dissociate from pain and/or found it difficult to recognise or describe what my pain was. This led to many traumatic medical situations where I couldn't say that I was in pain..." SE038

Feeling overwhelmed and disengaging

Feeling overwhelmed due to sensory input was commonly reported by the autistic adults. Many described overwhelm arising from multi-sensory environments or complex and intense environments. A few of the participants also conveyed that being overwhelmed manifests in disengagement or 'shutdown', and they are no longer able to tolerate the sensory environment:

"I can become overwhelmed in busy, crowded places. Often in these situations I will feel like everything around me is moving faster and feel a kind of disconnect (maybe even dissociation?) from it all." SE037

"… all the loud environmental noise (which may seem like nothing to most people - air conditioning humming, projector buzzing, lights buzzing, plates clinking in a restaurant kitchen), can drive me into a shutdown. And then every sound is utterly overwhelming." SE040

Tolerance and management

Most of the autistic adults reported a range of adaptive and maladaptive strategies that they use to cope with their sensory reactivity differences and the sensory environment. Many of the autistic adults described how they avoid aversive sensory stimuli or environments they struggle to cope with. However, they also described adaptations they make to be able to cope with sensory input in certain situations. Many of the adults also described how they seek soothing sensory input as a coping strategy, due to the calming effects they experience. However, the autistic adults also described how their ability to cope

with sensory input is moderated by their mood, such as when feeling more relaxed, or tired and stressed.

Avoidance

Many of the autistic adults described how they avoid sensory stimuli and environments as a coping strategy. Avoidance was often described as the need to 'run away' and escape from aversive sensory input when it became too difficult to cope with it. Not being able to escape from aversive sensory input or situations was often reported to be distressing. Some of the autistic adults mentioned certain environments they will avoid for sensory reasons:

> *"Not being able to escape with summer becomes a big anxiety thing for me - most other negative sensory things can be fixed by leaving the room or going home, this can't, so it just becomes a constant background factor…'"* SE047

> *"[I] never go into supermarkets because of visual overload…"* SE048

Avoidance was also reported in the form of physical blocking behaviours, such as covering eyes, ear, or nose, or closing eyes or holding breath, in response to visual, auditory, or olfactory stimuli that are difficult to cope with:

> *"In a crowded place I need to put my hands over my ears. I feel sick and can't focus on anything."* SE027

Adaptations

Many of the autistic adults reported different ways they have had to adapt to be able to cope with sensory input in different situations or environments. Several of the adults described tools and strategies that help with their ability to cope, such as using sunglasses to lessen the effects of bright lights or using earplugs or headphones to lessen the impact of loud or busy sound environments, or altering their environments to cope with their sensory difficulties:

> *"Going to grocery-store is the worst. The lights are always very bright and there are so many details to see. I cannot go in there without sunglasses and a baseball cap."* SE032

> *"I am very sensitive to all noise... I turn off everything possible and spend time in my quiet bedroom when life gets too noisy."* SE029

Some of the autistic adults also talked about how their sensory reactivity to certain input has adapted over time, and this has meant they are better able to tolerate some sensory input that they previously struggled with:

> *"I have only been able to tolerate multi-textured food in the past 10 years and still struggle with fruits such as apples as they have an unpredictable texture"* SE007

Soothing sensory input

The majority of the autistic adults reported that they seek soothing sensory input as a way to cope with distressing situations or as a calming strategy when they are distressed. Some of the autistic adults described having 'toolkits' of sensory strategies that they could engage with when feeling distressed:

> *"I always keep a fleecy blanket in my bag to wrap myself tightly in when in distress or just to hold and feel, I lie on my tummy on the floor and ask my husband (over twice my weight) to lie on top of me, love the warm weight of my pet guinea pigs."* SE010

Enjoyable sensory experiences were also reported to be helpful in overshadowing aversive sensory input, for instance listening to music in headphones when in challenging noisy environments or feeling pleasant textures to detract from other input:

> *"I seek comfort in small things (such as nice textures, I currently have a coin that I keep in my pocket to hold when I'm nervous) so that I can filter the sensory environment. It helps distract me from what is happening around me so that when I seek that input, I can avoid more intense or unpleasant inputs."* SE018

Moderated by mood

Several of the autistic adults reported that the extent of their sensory reactivity can depend on their mood and that this can change whether they are hyperreactive or neutrally reactive to certain sensory input. They described how their tolerance for sensory stimuli, such as sounds, touch, or bright lights, can be better if they are feeling more relaxed or rested. But equally, sensory experiences can be more distressing and aversive if already stressed and tired:

> *"Sometimes if I'm relaxed things seem to be neutral. If I've slept well, and have had a relaxed day, I can tolerate most noises and lights well."* SE015

> *"When under stress I am hyperreactive to sound. When not stressed, loud environments make me very tired but I only experience them as in-the-moment unpleasant when stressed or tired."* SE042

Control

Many of the autistic adults reported how control was related to their sensory reactivity and sensory experiences. A desire for predictability and control over sensory stimuli was commonly described to effect how sensory stimuli is experienced. Similarly, the level of control over the sensory input and intensity of the input can affect whether it is perceived as an enjoyable or aversive experience.

A desire for control and predictability

Frequently reported by the autistic adults was a difficulty with unpredictable sensory stimuli. They described how unexpected sensory events can be distressing, such as a sudden siren or being touched

by someone. But also, sensory stimuli that is not always the same can be challenging as the experience can be unpredictable:

> *"Sirens and doorbells make me scared. I cannot concentrate if the noise around me is unpredictable."* SE021

> *"Fruit is the hardest for me because the tastes are so variable, such as one apple to the next."* SE007

The autistic adults also reported how if they are in control of the intensity, then certain sensory experiences can be experienced as tolerable or enjoyable, such as enjoying music as long as they are in control of the volume:

> *"I really like music and listen to it as much as I can during the day including during work and at all times on public transport and when shopping etc. I like being able to have full control of what I hear and how loud it is. I'm very specific in the music I listen to and will sometimes just listen to the same band/album/song for weeks..."* SE022

Difficulty with self-control

Several of the autistic adults also reported a difficulty with self-control when it comes to engaging with enjoyable sensory experiences. Although not all the autistic adults reported this as being a problem for them, some mentioned how this can be disruptive to their lives or a source of embarrassment:

> *"I can easily be completely distracted by certain decorative lighting; I can regularly spend long periods of time in the lighting section of a department store and find it difficult to leave."* SE046

> *"Love being able to touch soft and squashy things. Sometimes [I] have little control and [it] can be embarrassing when I do it inappropriately."* SE027

The role of other people

Many of the autistic adults described how other people play a role in their sensory experiences. Other people were reported to be a source for self-understanding and making sense of the extent of sensory reactivity differences through comparison of their sensory experiences to other people. But also, sensory experiences can be impacted by other people's understanding or misunderstanding of sensory reactivity differences. Furthermore, close relationships were also reported to be a source of support for autistic adults in relation to their sensory reactivity differences.

Understanding

The autistic adults frequently reported their own sensory experiences in comparison to what others experience. This was often in the context of comparing if their experiences of sensory input were more or less than others, or if their tolerance of sensory experiences better or worse than others, as a way of understanding if sensory reactivity was comparative rather than different to others. In some cases,

these comparisons were based on their own perceptions of the behaviour of others, whereas others were based on information of sensory experiences provided by individuals:

> *"The lights in my dance studio flicker when first turned on. I close and cover my eyes to avoid this. Others don't seem to need to do this, though they note mild discomfort."* SE010

> *"When something happens where other people would feel pain I don't react as much and when people ask if everything [is] ok, I'm wondering if it should've hurt or not."* SE033

However, a few of the autistic adults reported how their sensory reactivity differences and their responses to sensory input may be misunderstood by others:

> *"At work the tube lighting is strong, so I go to the bathroom and keep the lights off for 5 mins at a time... I think my colleagues probably assume I have a bowel issue. (I don't...)"* SE015

Support

Some of the autistic adults described how other people, especially significant relationships, were a source of support for sensory reactivity differences. They reported that others can help them navigate environments that they are finding challenging due sensory input, or can help them avoid discomfort or injury, such as if they are hyporeactive to pain or temperature:

> *"My partner will point out that I'm shivering before I've realised I'm feeling very cold. If my body is in pain it takes me time to realise, for example if my partner sits on my foot and it is in an awkward position, he'll notice, and I'll become aware it's painful once it has been pointed out."* SE15

Several of the adults also reported how other people were a source for supporting enjoyable sensory experiences, such as providing sensory input to help when feeling distressed:

> *"My [boyfriend] knows that if I have a meltdown the best help is to squish me as hard as he can until I feel ok again."* SE039

5.5.4 Model of sensory reactivity differences in autistic adults

Due to the interconnected nature of the themes and sub-themes developed in the thematic analysis, we propose a theoretical model depicting autistic adults' experience of sensory reactivity differences (Figure 9). We propose that reactivity differences to sensory input, hyperreactivity, hyporeactivity, or seeking, can have short-term outcomes, including experiencing physical discomfort or becoming overwhelmed or overloaded by input, as well as long-term outcomes for mental and physical health. These outcomes can then feedback to influence reactivity to sensory input. However, there are certain moderators that influence these outcomes for autistic adults, including both personal and external moderators. Personal moderators include the level of control over input and how predictable sensory input is, the level of self-control when engaging with enjoyable sensory input, and the level of personal resources, including current mood and energy levels. External moderators include

management strategies, including avoiding and having the opportunity to escape sensory input, making adaptations to tolerate input, and regulating using soothing sensory input, and also the level of self-understanding, and understanding and support provided by other people.

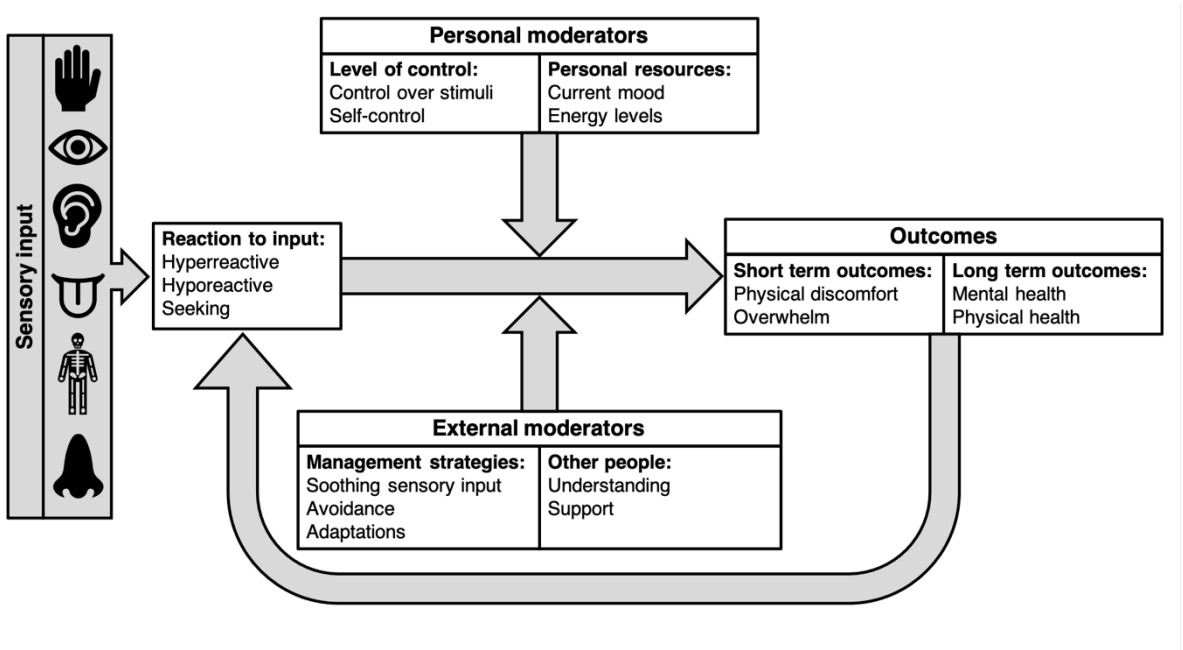

Figure 9
Summary of main themes and sub-themes developed from thematic analysis relating to sensory reactivity in autistic adults

5.6 Discussion

This novel co-produced, mixed-methods study, has provided new and comprehensive insights into the complex sensory experiences of autistic adults. As well as elucidating stimuli and contexts associated with sensory hyperreactivity, hyporeactivity and seeking, across modalities, our results have enhanced understanding of autistic adults' complex sensory experiences and informed the creation of a refined model from these experiences. Importantly, 96% of our sample identified as having sensory reactivity differences, supporting the persistence into adulthood (Crane et al., 2009), and highlighting the importance of researching sensory reactivity in autistic adults. Moreover, our results indicate that cooccurring sensory seeking and hyperreactivity (44.9%) was most experienced, whilst cooccurring sensory seeking and hyporeactivity was least experienced (0%). This supports that sensory seeking may be a strategy to regulate sensory input associated with hyperreactivity (Schulz & Stevenson, 2019), over being a stimulatory strategy associated with hyporeactivity.

5.6.1 Sensory input related to sensory reactivity differences

Our study adopted a novel mixed-methods approach to comprehensively outline sensory stimuli and contexts related to sensory reactivity differences in autistic adults. Although many of the sensory inputs identified, aligned with existing understanding, our results highlight the complexities of sensory reactivity differences across modalities, as well as the individualistic and contextual nature to sensory reactivity in autistic adults.

Our results echo existing research to indicate that sensory hyperreactivity is commonly experienced by autistic adults, with 93.3% of our sample self-identifying as being sensory hyperreactive. In line with previous research in autistic children and adults (Dickie et al., 2009; Robertson & Simmons, 2015; Schoen et al., 2008), we found that autistic adults experience hyperreactivity to a wide range of sensory input. However, our results importantly highlight that some sensory input commonly associated with sensory hyperreactivity are not endorsed by all individuals and are linked with personal preference, especially regarding colours and patterns, music, textures, tactile pressure, food tastes and textures, and scents, which individuals could be hyperreactive towards or seek out depending on their own personal preferences.

Our findings also provide a greater understanding of autistic adults' experiences of sensory hyporeactivity. Sensory hyporeactivity was referred to less than other sensory experiences, with only 28.6% self-identifying as being sensory hyporeactive. Sensory hyporeactivity may become less prominent in adulthood, as sensory hyperreactivity and seeking increases (Liss et al., 2006), alternatively it may be underreported due to difficulties in self-reporting, as hyporeactivity is characterised by not noticing sensory input (Smith & Sharp, 2013). The autistic adults in our study described experiences of auditory hyporeactivity due to inattention. This suggests that hyporeactivity to sensory input may be due to inattention rather than neural processing differences, which could account for the variegated experiences of auditory hyper- and hyporeactivity experienced by an individual (Funabiki et al., 2012).

Lastly, our findings elucidated experiences associated with sensory seeking for autistic adults. Previous research has suggested sensory seeking may diminish with age (Crane et al., 2009; Kern et al., 2007), however, our results found 41.4% of the autistic adults to still engage in a diverse range of seeking behaviours. Specifically, our results provide deeper insight into the wide range of sensory input that autistic adults seek out across modalities. Sensory seeking was commonly individualistic, which is important to consider when using standardised sensory assessments that may not be accurately capturing the extent of an individual's sensory seeking behaviours.

Overall, these findings have important implications for the development and interpretation of sensory assessments and the identification of support needs for autistic adults.

5.6.2 Autistic adults' experiences of sensory reactivity differences

Our results also provide a greater understanding of autistic adults' sensory experiences, a relatively under-researched area, and is the first known to understand sensory experiences related to all areas of sensory reactivity differences, including sensory hyperreactivity, hyporeactivity and seeking. Taking an iterative approach to thematic analysis, we developed themes relating to outcomes, the importance of control, tolerance and management, and the role of other people. Based on the interconnected nature of these themes, we propose a model of sensory reactivity experiences in autistic adults (Figure 3). Although we are not the first to propose a model of sensory reactivity in autistic adults, and some of the findings are in line with these studies (see: Robertson & Simmons, 2015; Smith & Sharp, 2013), our

mixed-methods approach and co-production with the autistic community has led to the development of some novel findings and a unique model, informed by our comprehensive results (see Figure 3).

The autistic adults in our study described a range of outcomes related to their sensory reactivity differences. In our model, we propose that sensory reactivity differences can have short-term outcomes relating to physical responses and overwhelm. Our results importantly highlight autistic adults can become overwhelmed or overloaded due to sensory input and become disengaged with their circumstances or themselves. Sensory overload may result from hyper-focussing differences in autistic people, making it difficult to be able to divert attention away from aversive aspects of the sensory environment (Liss et al., 2006). This may contribute to 'Burnout', in which autistic individuals commonly experience chronic exhaustion and loss of skills, as well as experiencing heightened sensitivity to environmental stimuli and greater difficulty with tolerating or filtering out input (Raymaker et al., 2020).

Furthermore, our results suggest sensory reactivity differences have long-term outcomes relating to mental and physical health. Previous research has indicated that sensory hyperreactivity and hyporeactivity may be a risk factor for mental health conditions, such as anxiety in autistic adults (e.g., Hwang et al., 2019), and eating disorders in autistic women (Brede et al., 2020). However, our findings also suggest that sensory seeking, which is often considered to be an enjoyable experience, may also be associated with mental health conditions, as some autistic adults described links between their sensory seeking behaviours and self-harm and eating disorders. These findings are especially important as mental health conditions, such as anxiety, are disproportionately high in autistic populations (Buck et al., 2014). Moreover, our results highlight the physical impact of sensory reactivity differences. For instance, reduced food intake due to sensitivities towards food tastes or not noticing when hungry, can have consequences for physical health, or excessively listening to loud music can damage hearing.

Similarly to previous work (Robertson & Simmons, 2015), the autistic adults in our study described how they are more able to tolerate sensory input if they have control over the stimuli and it is less unpredictable. However, a novel finding in our study is that some of the autistic adults also described control in terms of their difficulties with self-control, such as finding it hard to disengage with certain enjoyable sensory input. Sensory reactivity differences are part of the diagnostic criterion for autism associated with restricted and repetitive behaviours (DSM-5 American Psychiatric Association, 2013), and research has found sensory seeking to relate to ritualistic/sameness behaviours in autistic children (Boyd et al., 2010). Therefore, our findings suggest these behaviours persist into adulthood.

Although various coping mechanisms and strategies for sensory reactivity differences have previously been shown in qualitative research (Robertson & Simmons, 2015; Smith & Sharp, 2013), we found avoidance, making adaptations, and engaging in soothing sensory strategies to be commonly used coping mechanisms/strategies. The autistic adults in our study emphasised the importance of being able to escape from unbearable sensory input to avoid sensory overload. Avoidance is often considered a maladaptive strategy for anxiety, due to avoidance impacting the ability to regulate arousal, which then increases and maintains anxiety, leading to more avoidance (Green et al., 2012; Joosten & Bundy,

2010; Lidstone et al., 2014; Mazurek et al., 2013). However, it may be an essential strategy for autistic individuals. Our results provide additional insights into the extensive use of adaptive strategies used by autistic adults, such as using earplugs/headphones to tolerate noisy environments, or sunglasses in bright environments. Furthermore, the autistic adults in our study also described how they engage with soothing sensory input as a regulation strategy. Our findings suggest that autistic adults also sensory seek across modalities, engaging with personally preferred scents, textures, and visuals that are experienced as soothing and enjoyable. Additionally, in line with previous work (Robertson & Simmons, 2015; Smith & Sharp, 2013), our results show listening to chosen music is a common strategy found to be soothing. Music has been identified as a common interest of autistic adults, and engagement with significant or 'special' interests is related to greater subjective wellbeing (Grove et al., 2018).

5.6.3 Limitations and future directions

Although a key strength of our study was the online survey approach, facilitating the potential for a diverse range of perspectives and experiences from geographically dispersed populations, online research has some potential limitations. For instance, we were unable to provide support for individuals who may have struggled with the open-ended questions within the questionnaire. Although we encouraged respondents to seek support, this may have restricted participation in this study, especially for those without access to support, or individuals with higher support needs or intellectual disability (ID). Although 4% of our participants reported to have cooccurring ID, this is not representative of the autistic population, within which around 50-55% have cooccurring ID (Charman et al., 2011; Loomes et al., 2017). Autism research often underrepresents individuals with ID (Russell et al., 2019), and therefore future research should endeavour to understand the sensory experiences of these individuals.

5.6.4 Conclusion

Our study demonstrates that sensory reactivity differences are prominent in autistic adults, and that they are complex, individual, interconnected, and experienced across a range of modalities. We propose a theoretical model of sensory reactivity differences informed by the experiences of autistic adults. Crucially, it highlights key moderating factors that may reduce the long-term impact of sensory reactivity differences on physical and mental health. Future work could be informed by our model and aim to understand more about the positive and negative impacts of the identified moderators of sensory reactivity differences. Our findings have important implications for support services and future research that aims to reduce the impact of sensory reactivity differences for autistic adults.

5.6.5 Acknowledgements

Special thanks to the autistic adults who participated in this study and those who provided feedback in the development of this project. Especially, to Aimee Fletcher, Jack Welch, Charlie Murphy, and Hannah Steel for providing feedback on the findings and interpretations. Additionally, thanks to Anthony Haffey and Autism Berkshire for helping with recruitment.

Chapter 6. General discussion

The four studies presented in this thesis expand understanding of the links between sensory reactivity differences and anxiety in autistic people.

The primary research question for this thesis was:

1) Are sensory reactivity differences, including hyperreactivity, hyporeactivity, and seeking, differentially related to anxiety symptomology in autistic children and adults?

The secondary research questions for this thesis were:

2) Is IU a mediating factor in the relationship between sensory reactivity differences and anxiety symptomology in autistic children and adults

3) What are autistic adults' experiences of sensory reactivity differences?

The first research question was addressed by the studies in Chapters 2, 3, and 4, the second research question was addressed by the studies in Chapters 3 and 4, and the final research question was addressed by the study in Chapter 5.

6.1 Sensory reactivity differences and anxiety symptomology

The studies in this thesis have advanced understanding of the associations between sensory reactivity differences and anxiety symptomology in autistic children and adults. This was examined in autistic children aged 3 – 14 years (Chapter 2), in preschool-aged autistic children aged 3 – 5 years (Chapter 3), and in autistic adults aged 18 years+ (Chapter 4). Overall, significant associations between sensory hyperreactivity, hyporeactivity, and seeking and anxiety symptomology were found across the studies. Although a differential relationship was not always found across studies, significant associations were consistently found between sensory reactivity differences and separation anxiety in autistic children and adults. It is important to note that phobia/physical injury fears and OCD were not measured in the adult studies (Chapter 4). Table 21 summarises the key associations found across these studies.

Table 21
*Summary of results showing the significant relationships between sensory reactivity differences and anxiety symptomologies in autistic children and adults. Negative associations are indicated by *, otherwise relationships are positive.*

	Preschool-age children ***Chapter 3***	**Children** ***Chapter 2***	**Adults** ***Chapter 4*** *Study 1*	*Study 2*
Sensory hyperreactivity	Total anxiety	Total anxiety	Total anxiety	Total anxiety
	GAD			GAD
	Separation anxiety	Separation anxiety	Separation anxiety	Separation anxiety
	Social anxiety			Social anxiety
	Physical injury fears	Physical injury fears		
	OCD			
Hyperreactivity controlling for AQ	Separation anxiety	Phobia/ physical injury fears		
Sensory Hyporeactivity			Separation anxiety	
Hyporeactivity controlling for AQ		Total anxiety*		
		Social anxiety*		
Sensory Seeking				Total anxiety
				GAD
				Separation anxiety
				Social anxiety
Seeking controlling for AQ				

Note. GAD: Generalised anxiety disorder; OCD: Obsessive-compulsive disorder; AQ: Autism traits

6.1.1 Sensory hyperreactivity and anxiety

A significant association between sensory hyperreactivity and total anxiety was robustly found in children and adults across all four of the studies. As well as this link being found in the quantitative

studies in this thesis (Chapters 2, 3, and 4), the mixed-methods study in Chapter 5 also supports that anxiety is an outcome of sensory hyperreactivity from the perspective of autistic adults. This is in line with previous work in which an association between sensory hyperreactivity and anxiety has consistently been found in autistic individuals across the lifespan (e.g., Green et al., 2012; Hwang et al., 2019; Wigham et al., 2015).

There has been some indication that sensory hyperreactivity may be implicated in specific anxiety symptomology, such as separation anxiety and specific phobia, (Black et al., 2017), GAD (Bitsika et al., 2019), and social anxiety (Pickard et al., 2020). However, this had not yet been extensively explored and no known studies have examined this in young children or adults. The results of the quantitative studies in this thesis did not find a clear association between sensory hyperreactivity and specific anxiety symptomology. However, they consistently indicated a link between sensory hyperreactivity and separation anxiety in autistic children, as well as adults, whilst also finding significant links between sensory hyperreactivity and GAD, social anxiety, phobia/physical injury fears, and OCD. In preschool-age children (Chapter 3), sensory hyperreactivity was not found to be differentially related to anxiety symptomology until controlling for autism traits, which then showed sensory hyperreactivity to be significantly related to just separation anxiety. In children with an older age range (Chapter 2), sensory hyperreactivity was found to be significantly related to separation anxiety and physical injury fears, and subsequently to just phobia/physical injury fears when controlling for autism traits. In adults (Chapter 4), Study 1 found sensory hyperreactivity to be significantly related to separation anxiety, whilst Study 2 found sensory hyperreactivity to be significantly related to all anxiety symptomologies. Broader autism traits were not found to be implicated in either of the adult studies, however this was likely due to the use of the short AQ-10 in this study which provided a comparatively limited range of scores. The approach to control for autism traits was taken to remove variance that may be explained by broader autism traits, and to limit inflated findings due to diagnostic or construct overlap. As proposed by South and Rodgers (2017) from their review on anxiety in autism, there may be a range of additional factors that are related to anxiety in autistic individuals, such as RRB's, IU, and alexithymia/emotion recognition. RRB's especially have commonly been found to be associated with both sensory hyperreactivity and anxiety in autistic individuals (Boulter et al., 2014; Hwang et al., 2019; Neil et al., 2016; Wigham et al., 2015). Overall, the findings in this thesis suggest that it is important to consider broader autism traits when examining the links between sensory hyperreactivity and anxiety symptomology.

Although not conclusive from the results in this thesis, the consistent link found between sensory hyperreactivity, and separation anxiety may indicate that sensory hyperreactivity is an important risk factor for separation anxiety. This may be because family members often step in to help reduce anxiety experienced by autistic individuals (Robertson et al., 2018). Additionally, autistic individuals often rely on other people for support with strategies that are associated with both sensory hyperreactivity and anxiety (Robertson et al., 2018; Smith & Sharp, 2013). This is also apparent from the results of the mixed-methods study in Chapter 5, in which support and understanding from others was suggested to be an important mediating factor for long term impacts, such as anxiety, due to sensory reactivity

differences. Thus, autistic individuals who experience sensory hyperreactivity or anxiety may develop a strong reliance on close relationships, which can increase worries and anxiety at the prospect of becoming separated. However, it is also important to consider that some difficulties related to autism and additional cooccurring conditions mean that some individuals will have greater support needs. Thus, reasonable distress about becoming separated may be appropriate, whilst disproportionate anxiety given the needs of an individual, would be indicative of clinical separation anxiety (Kerns et al., 2017). Furthermore, although traditional separation symptoms are present in autistic individuals, overall presentations may differ from the general population. Separation anxiety may be more related to relying on significant others to mediate interaction with the world rather concerns relating to and separation from significant others (Rodgers et al., 2016). Thus, more research is needed to understand how separation anxiety in autistic individuals compares to separation anxiety in the general population.

6.1.2 Sensory hyporeactivity and anxiety

Although the studies in this thesis found a significant link between sensory hyporeactivity and anxiety symptomology, this varied across the studies. The study in preschool-age children (Chapter 3) did not find a link between sensory hyporeactivity and anxiety. The study in children with an older age range (Chapter 2) did not initially find an association between sensory hyporeactivity and anxiety, but when controlling for autism traits, it was negatively related to total anxiety and social anxiety. Whereas in adults (Chapter 4), Study 1 found sensory hyporeactivity to be significantly related to separation anxiety, although it was not a significant predictor, whilst Study 2 did not find sensory hyporeactivity to be significant related to anxiety. Inconsistent results have also been found in previous research, with some finding sensory hyporeactivity to be related to anxiety in autistic children and adults (Glod et al., 2019; Hwang et al., 2019), and other research in children not finding a link (Pfeiffer et al., 2005; Wigham et al., 2015). Thus, it remains difficult to draw conclusions as to the role of sensory hyporeactivity and anxiety in autistic individuals. It may be that sensory hyporeactivity becomes a source of anxiety later in adulthood. As Study 1 found a significant association between sensory hyporeactivity and separation anxiety, although this was better predicted by sensory hyperreactivity, it may be that parents and caregivers support attenuation to sensory input that has not been noticed. As highlighted in the mixed-methods study in Chapter 5, other people can be a source of support to avoid injury if hyporeactive to the sensory environment. However, increased independence in adulthood may mean reduced support from others for sensory hyporeactivity, subsequently increasing worry and anxiety associated with becoming separated from significant others. Alternatively, it may be that sensory hyporeactivity is indirectly related to anxiety through RRB's (Wigham et al., 2015). Otherwise, previous research has suggested there is often cooccurrence between anxiety and depression, and sensory hyperreactivity and hyporeactivity in individuals (Baranek et al., 2006; Nimmo-Smith et al., 2020; Pollack, 2005). Thus, it may be that sensory hyporeactivity is indirectly associated to anxiety due to sensory hyperreactivity or cooccurring anxiety and depression symptoms. To elucidate this, future research is still need that could understand the indirect relationships between sensory reactivity differences as well as the wider factors that may account for the differential links between sensory hyporeactivity and anxiety.

6.1.3 Sensory seeking and anxiety

As for sensory seeking, the studies in this thesis primarily support that it is not associated with anxiety in autistic children, as no link was found at preschool-age (Chapter 3), or the older age range (Chapter 2). This is in line with previous research that has not found a link between sensory seeking and anxiety in autistic children (Lidstone et al., 2014). As for autistic adults (Chapter 4), Study 1 did not find a significant association between sensory seeking and anxiety, which is in line with work conducted with non-autistic adults (Engel-Yeger & Dunn, 2011; Levit-Binnun et al., 2014). However, Study 2 was the first known to find a significant link between sensory seeking and anxiety, including GAD, separation anxiety, and social anxiety in autistic adults. This may be due to the much greater sample size in Study 2 that could suggest the other studies comparatively lacked power to find a significant association, or, because this study was the only one in this thesis to include the extended SPSI, which has additional items relating to interoceptive, vestibular/proprioceptive, gustatory, and olfactory domains. This could suggest that sensory seeking associated with these domains is more implicated in anxiety than auditory, tactile, and visual domains alone. Interestingly, the study in Chapter 5 study indicated that along with music and deep pressure, the autistic adults identified that they commonly seek out food tastes, which may suggest that the significant link between sensory seeking and anxiety in Study 2 of Chapter 4 was influenced by the inclusion of the gustatory domain. Alternatively, it may be that vestibular and proprioceptive behaviours, such as swinging or spinning, crossover with behaviours associated with RRBs, which have been found to be associated with anxiety in autistic individuals (Hwang et al., 2019; Wigham et al., 2015). However, as discussed in Chapter 4, it may be that sensory seeking is indirectly connected to anxiety via sensory hyperreactivity and is a strategy used by autistic adults to regulate or control sensory input that is aversive (Lidstone et al., 2014). This is also supported by the mixed-methods study in Chapter 5, which found autistic adults most commonly experience cooccurring sensory hyperreactivity and seeking. Furthermore, they described their experiences of seeking out soothing sensory input as a management strategy to ease feelings of stress or anxiety, but also to regulate sensory input in aversive environments, such as listening to music in noisy contexts. The soothing influence of certain sensory input has also been described by autistic adults in previous qualitative research (Robertson & Simmons, 2015; Smith & Sharp, 2013). Furthermore, the study in Chapter 5 also indicated that sensory seeking was perceived to be implicated in other mental health difficulties, such as self-harm and eating disorders. Therefore, the role of sensory seeking in anxiety and wider mental health conditions should be examined in future research, to understand the role of different domains and the parameters under which sensory seeking can be a strategy to alleviate anxiety induced by sensory hyperreactivity.

6.1.4 Considering the replication of findings

There may be multiple explanations for the differences across the studies in this thesis. Research has found varying factor structures in anxiety symptomology across studies (Glod et al., 2017; Jitlina et al., 2017; Magiati et al., 2017; Zainal et al., 2014), which is likely due to the large heterogeneity in autism (Vasa & Mazurek, 2015) and may account for the varied findings across the samples in our studies. Thus, there are likely to be additional cooccurring factors not assessed within the scope of this thesis,

that are linked to the development and maintenance of certain anxiety symptomology and may have differed between groups, for instance alexithymia, which has been found to be related to social anxiety (Pickard et al., 2020), or intellectual disability, which has been found to be associated more profoundly with specific phobia (Kerns et al., 2020). Additionally, as there are few measures of sensory reactivity and anxiety that can be used across age groups, different measures were used across the studies. For instance, the study in Chapter 3 was the only study to combine the SPSI questionnaire with the SAND sensory observation, and the adult study was the only one to include the SCAARED questionnaire for anxiety. Furthermore, trajectories may change and not be stable across the lifespan for anxiety (Bystritsky et al., 2013) and also sensory reactivity differences. Anxiety conditions also vary in their age of onset, for instance, phobia and separation anxiety symptoms are thought to establish earliest (Beesdo et al., 2009). Additionally, puberty has also been suggested to be a time where there is a reorganisation of sensory regions of the brain, including the amygdala, hippocampus, and visual cortex (Hebbard et al., 2003; Nuñez et al., 2003; Romeo & Sisk, 2001), which may also alter sensory reactivity across development. Therefore, there are multiple factors that may lead to varying associations between sensory reactivity differences and anxiety across the lifespan.

6.2 The role of intolerance of uncertainty

The studies in this thesis have also advanced understanding of IU and how it may be an important transdiagnostic factor in the relationship between sensory reactivity differences and anxiety symptomology in autistic children and adults. This was examined in autistic preschool-age children age 3 – 5 years (Chapter 3), and in autistic adults age 18 years+ (Chapter 4). Table 22 summarises the key associations found across these studies.

Table 22
Summary of results showing the significant positive relationships between intolerance of uncertainty, sensory reactivity differences and anxiety symptomologies in autistic children and adults.

	Preschool-age children	**Adults**
IU correlations	Sensory hyperreactivity	Sensory hyperreactivity
		Sensory hyporeactivity
		Sensory seeking
	Total anxiety	Total anxiety
	GAD	GAD
	Separation anxiety	Separation anxiety
	Social anxiety	Social anxiety
	Physical injury fears	
	OCD	
IU mediation	Hyper → IU → Anxiety	Hyper → IU → Anxiety
	Hyper → Anxiety → IU	Hyper → Anxiety → IU

Note. GAD: Generalised anxiety disorder; OCD: Obsessive-compulsive disorder; IU: Intolerance of uncertainty; Hyper: Sensory hyperreactivity.

These studies were the first to examine links between IU and sensory seeking, and how IU is implicated in the relationships between sensory reactivity differences and certain anxiety symptomology. In line with previous research, these studies found IU to be associated with sensory hyperreactivity and anxiety in autistic children and adults (Hwang et al., 2019; Neil et al., 2016; Wigham et al., 2015), and to sensory hyporeactivity and anxiety in autistic adults (Hwang et al., 2019). However, the study in Chapter 4 was the first to also indicate that IU may be related to sensory seeking and anxiety in autistic adults, although it was not found to be a mediator in the relationship between sensory seeking and anxiety. This may mean that sensory seeking is related to IU and anxiety in a different way than sensory hyperreactivity, perhaps due to the interconnection between sensory seeking and hyperreactivity or associated with RRBs, which was not examined in this thesis. Alternatively, this unique finding may also be due to differences across studies as described in the previous section (6.1).

The study in Chapter 3 suggests that sensory hyperreactivity cross-sectionally predicts both anxiety and IU in preschool-age autistic children, and that anxiety and IU are also both mediators. Additionally, this was similarly replicated in the study in Chapter 4, but with anxiety only partially mediating the relationship between sensory hyperreactivity and IU. Finding sensory hyperreactivity to consistently be a predictor of anxiety reflects previous longitudinal research which found sensory hyperreactivity to emerge earlier and predict anxiety in autistic toddlers (Green et al., 2012). However, the findings in this thesis are the first to suggest that IU is also an important early construct that is interrelated with the development/maintenance of anxiety in autism, and that anxiety may also mediate the relationships between sensory hyperreactivity and IU. Furthermore, the mixed-methods study in Chapter 5 supports that the predictability and level of control over, sensory input, is an important factor that can limit or exacerbate the experience of sensory input, moderating both short-term and long-term outcomes of sensory reactivity differences, especially hyperreactivity. Thus, from the perspective of autistic adults, a need for predictability and control, which are characteristic of IU, is implicated in whether sensory reactivity differences lead to outcomes such as anxiety. Interestingly, the correlational results in both preschool-age autistic children and adults suggest that IU is not differentially related to anxiety symptomology. Previous research has highlighted that IU is an important construct in GAD and social anxiety in non-autistic samples (Boelen & Reijntjes, 2009; Dugas & Ladouceur, 2000; Holaway et al., 2006), and social anxiety in autistic children and adolescents (Pickard et al., 2020). However, the results of this thesis suggest that IU is not differentially related to anxiety symptomology. This supports that it is an important transdiagnostic factor that can be targeted in interventions for autistic individuals across the lifespan.

Taken together, the findings in this thesis support previous research (see: South & Rodgers, 2017) to suggest that IU may be a central factor in the relationship between sensory hyperreactivity and anxiety and autism. Sensory input can often be unpredictable and will not always be associated with a specific object or situation. The perceived unpredictability of sensory input can also be enhanced by altered sensory interpretation in autism (Fiser et al., 2010; Pellicano & Burr, 2012). IU is also associated with alerting in attentional networks, and therefore individuals with greater IU may be more hypervigilant and likely to process uncertain information as threatening (Dugas et al., 2005; Fergus & Carleton, 2016).

Therefore, greater negative bias, hypervigilance, and avoidance enhances anxiety through context conditioning (Green & Ben-Sasson, 2010; Grillon, 2008).

6.3 Lived experiences of sensory reactivity

The final study of this thesis (Chapter 5) advances understanding of autistic adults' experiences of sensory reactivity differences and wider factors associated with these. Of upmost importance, is that this mixed-methods study, co-produced with members of the autistic community, conveys the lived experiences of autistic people alongside the other studies in this thesis. This approach importantly facilitated a more holistic exploration of autistic sensory experiences that could reveal unique insights into the impact of sensory reactivity differences.

Although the studies in this thesis aimed to unpick the specific links between the certain types of sensory reactivity and anxiety, it is important to consider that lived experiences are not this simplistic and discrete, and sensory reactivity differences are often experienced by individuals in varying patterns, and across time and contexts (Baranek et al., 2006; Lidstone et al., 2014). Therefore, the final mixed-methods study in this thesis provided enhanced perspective into the complexity of sensory input associated with sensory reactivity differences in autistic adults, as well as autistic adults' experiences of sensory reactivity differences. As well as the results aligning with the findings of the quantitative studies, from the perspectives of autistic individuals, this study also informed the development of an enhanced theoretical model of sensory experiences (Figure 9, section 5.5.4). This importantly highlights the wider context of additional factors that could also be influential in the relationships between sensory reactivity and anxiety, as well as other outcomes. Lastly, the results of this study do support the individual and contextual nature of sensory reactivity differences, and the links to different sensory input. This highlights that the overall findings of this thesis should be considered from a dimensional rather than a categorical perspective.

This study also provided additional perspectives of sensory hyporeactivity and seeking. Firstly, it found that sensory hyporeactivity may have an attentional component to it. Therefore, it may be linked to inattention as opposed to neural processing differences, which could account for varied responses of hyper and hyporeactivity in an individual (Funabiki et al., 2012). As the studies in this thesis found inconsistent links between sensory hyporeactivity and anxiety, understanding the impact of individual differences in attention could be an important consideration for future research. Additionally, the final study also highlighted how sensory seeking may not always be positive. Although sensory seeking can be enjoyable and linked to relaxation and soothing experiences, it may also have detrimental impacts, such as to mental or physical health. As the other studies in this thesis inconsistently found links between sensory seeking and anxiety, future research could therefore differentiate positive and negative sensory seeking experiences to understand if these have differential links with anxiety.

6.4 Limitations and future directions

Although limitations for each study were outlined in the corresponding chapters, there are some overarching limitations associated with this thesis. A key strength of this thesis is the examination of

sensory reactivity differences and anxiety in under researched age groups, notably preschool-age children, and adults. Additionally, the study with preschool-age children (Chapter 3), included participants with few-to-no words and possible cooccurring intellectual disability. However, the general approach taken for this thesis was to recruit diverse, heterogenous samples based on age, rather than specific sub-groups. Therefore, this means that some subgroups, such as those with cooccurring intellectual disability, have been underrepresented across the studies. Although IQ tests were conducted in the child studies (Chapters 2 and 3) through face-to-face testing, the adult studies (Chapters 4 and 5) were conducted online, and IQ was not assessed. IQ has not been found to be related to sensory reactivity differences (Sanz-Cervera et al., 2015; Siper et al., 2017; Tavassoli et al., 2014). However, recent research has found that prevalence rates of anxiety conditions differ between autistic people with and without cooccurring intellectual disability (Kerns et al., 2020). But this group is often neglected in research, despite this being of high importance due to the high cooccurrence in autism (Cascio et al., 2021; Loomes et al., 2017; Russell et al., 2019). Therefore, it is especially important that future research further understands if the links between sensory reactivity differences and anxiety are different in autistic people with and without cooccurring intellectual disability.

As it was beyond the scope of this thesis, the effect of sex/gender was not examined across the studies in this thesis. Research has suggested that there may be sex differences in presentations of autism, for instance females have been found to present with higher sensory reactivity differences and less RRBs and socio-communication differences compared to males (Lai et al., 2011; Lai & Szatmari, 2020). Furthermore, research has also shown that the prevalence of anxiety is different across groups, with higher rates of anxiety found to be present in females compared to males (Gotham et al., 2015). However, although sex has traditionally been considered a binary construct, its components can be dimensional or multicategory (Joel & McCarthy, 2017). Furthermore, the development of autistic women has been suggested to be shaped by social conditioning and gendered expectations, beyond sex-related biological mechanisms (Lai & Szatmari, 2020). In general, gender fluidity is more common in autistic groups (Stagg & Vincent, 2019; Strang et al., 2018, 2020; Walsh et al., 2018), as autistic people may feel less pressure to conform to societal expectations (Strang et al., 2018), and in the adult samples in Chapters 4 and 5, multiple participants were recruited that did not identify to fit within the gender binary. Therefore, although it is important to understand subgroup differences to improve anxiety interventions for autistic individuals, it could be argued that considering sex or gender as a binary construct in autism research may not always be appropriate.

Additionally, it has been argued that it is important to conduct research using a range of different types of assessments that capture different perspectives (Spain et al., 2018; White et al., 2009). Therefore, it is a strength of the studies in this thesis that measures to gain different perspectives were used where possible, such as using the Dominique Interactive self-report in autistic children (Chapter 2) and the SAND observational assessment in preschool-age autistic children (Chapter 3). Additionally, where questionnaires were used, approaches were consistently taken to limit possible inflated results due to possible overlap, such as controlling for autism traits and applying Bonferroni corrections for more conservative significance levels. Although, it is important to note that this approach could mean that

associations were missed that may be of clinical importance. However, the adult study in Chapter 4 only included questionnaire measures and the child studies in Chapters 2 and 3 still heavily relied on questionnaire measures, as additional observations and psychophysiological assessments were not found to be reliable. It is also important to note that adaptations were made to the scoring and administration of questionnaire measures in Chapters 2 and 4. Although this approach was necessary, this could have affected the psychometric properties of these measures. Therefore, the measurement challenges are a key limitation across the studies in this thesis. Although there are more objective assessments of both sensory reactivity and anxiety that have been designed or adapted for use in autistic individuals, as outlined in the introduction, these were not suitable for the studies and/or participants included in this thesis. The need for suitable measures that can be used with autistic individuals has recently been highlighted as an important next step in research (Gotham et al., 2020), especially for autistic individuals with cooccurring intellectual disability (Flynn et al., 2017). Since the conception of the studies in this thesis, additional measures have been published, which could be used in future research, such as the Paediatric Anxiety Rating Scale modified for autism spectrum disorder (Maddox et al., 2020), and the Anxiety Scale for Autism – Adults (Rodgers et al., 2020).

Lastly, although the studies in this thesis approached clinical constructs from a diagnostic category approach in line the with DSM (DSM-5 American Psychiatric Association, 2013), aligning with the current diagnostic system, there is some debate as to whether a dimensional approach should be adopted in research to cut across dimensional categories. Currently, the categories of symptoms that make up distinct disorders provide a straightforward means of classification and diagnosis across a variety of contexts. However, there is a lot of heterogeneity in diagnostic groups due to the varied ways individuals can qualify for a disorder (Allsopp et al., 2019; Olbert et al., 2014). Additionally, as discussed throughout this thesis, there is cooccurrence and overlap in conditions (Allsopp et al., 2019), and there may be common dimensions that are currently being overlooked. Due to the limitations of the current diagnostic system, there has been a shift towards encouraging research to adopt a dimensional approach. The Research Domain Criteria (RDoC) framework introduced by the National Institute for Mental Health proposes measuring basic dimensions of functioning across the full range of human behaviour from what is typical to atypical (Insel et al., 2010). Although there are challenges to research using this framework, as it does not currently align with the diagnostic systems, a dimensional approach could be considered for future work.

6.5 Implications

Despite the limitations, the findings in the studies in this thesis have important implications. Firstly, the findings enhance understanding of autism related factors, specifically sensory reactivity differences and IU, that relate to anxiety symptomology across the lifespan. This is important as clinical professionals can misunderstand or lack knowledge of how anxiety can present differently in autistic individuals (Camm-Crosbie et al., 2019; Crane et al., 2019; Kerns et al., 2017; Maddox et al., 2020), but accurate assessment and identification of anxiety is important for autistic individuals to be given access to appropriate interventions (Kerns et al., 2020). Secondly, the findings improve understanding of how sensory reactivity differences, including sensory seeking and hyporeactivity, may relate to certain

anxiety symptomology. Thus, understanding an autistic individual's sensory profile has important implications for treatment approaches. Due to the heterogeneity, there is no one-size-fits-all approach to treating anxiety in autistic individuals (Gotham et al., 2020). So, it is important to determine if anxiety symptomologies should be approached differently in treatment (Wood et al., 2015), especially considering individual differences in sensory reactivity and IU.

6.6 Conclusion

This thesis investigated the relationships between sensory reactivity differences and anxiety symptomology in autistic children and adults, also examining the role of IU, and elucidating more about the sensory experiences of autistic adults. The findings robustly support that sensory hyperreactivity is related to anxiety symptomology, such as separation anxiety, in autistic individuals, and that IU is an associated transdiagnostic factor. However, there was mixed results as to the links between both sensory hyporeactivity and seeking, and anxiety, and therefore it is difficult to draw conclusions and further research is needed. To accompany these studies, sensory experiences were also explored from the perspectives of autistic adults, which provided enhanced insights of the complexity and impact of sensory reactivity differences and informed the development of a refined model of wider associated factors, which could lead the way for future directions.

The results provide further evidence to support that sensory reactivity differences are associated with anxiety in autistic people. Future research should aim to understand wider factors that may also be implicated in this relationship. Furthermore, with the recent and upcoming developments of anxiety assessments suitable for use in different subgroups of autistic individuals, future work should aim to replicate findings using a multidisciplinary approach to examine risk factors for anxiety in subgroups. Understanding the risk factors for anxiety in autism has important implications for the development and efficacy of interventions, and consequently, the quality of life of autistic children and adults.

Bibliography

21andsensory, E. (2020). 21andsensory [Instagram]. *21andsensory*. https://www.instagram.com/21andsensory/?hl=en

Achenbach, T. M., & Ruffle, T. M. (2000). The Child Behavior Checklist and Related Forms for Assessing Behavioral/Emotional Problems and Competencies. *Pediatrics in Review*, *21*(8), 265–271. https://doi.org/10.1542/pir.21-8-265

Allison, C., Auyeung, B., & Baron-Cohen, S. (2012). Toward Brief "Red Flags" for Autism Screening: The Short Autism Spectrum Quotient and the Short Quantitative Checklist in 1,000 Cases and 3,000 Controls. *Journal of the American Academy of Child & Adolescent Psychiatry*, *51*(2), 202-212.e7. https://doi.org/10.1016/j.jaac.2011.11.003

Allsopp, K., Read, J., Corcoran, R., & Kinderman, P. (2019). Heterogeneity in psychiatric diagnostic classification. *Psychiatry Research*, *279*, 15–22. https://doi.org/10.1016/j.psychres.2019.07.005

Amos, G. A., Byrne, G., Chouinard, P. A., & Godber, T. (2019). Autism Traits, Sensory Over-Responsivity, Anxiety, and Stress: A Test of Explanatory Models. *Journal of Autism and Developmental Disorders*, *49*(1), 98–112. https://doi.org/10.1007/s10803-018-3695-6

Angulo, M., Rooks, B. T., Gill, M., Goldstein, T., Sakolsky, D., Goldstein, B., Monk, K., Hickey, M. B., Diler, R. S., Hafeman, D., Merranko, J., Axelson, D., & Birmaher, B. (2017). Psychometrics of the screen for adult anxiety related disorders (SCAARED)- A new scale for the assessment of DSM-5 anxiety disorders. *Psychiatry Research*, *253*, 84–90. https://doi.org/10.1016/j.psychres.2017.02.034

Auyeung, B., Baron-Cohen, S., Wheelwright, S., & Allison, C. (2008). The Autism Spectrum Quotient: Children's Version (AQ-Child). *Journal of Autism and Developmental Disorders*, *38*(7), 1230–1240. https://doi.org/10.1007/s10803-007-0504-z

Ayres, A. J. (1972). *Sensory integration and learning disorders.* WPS.

Baranek, G. T. (1999). *Sensory Processing Assessment*. University of North Carolina.

Baranek, G. T., David, F. J., Poe, M. D., Stone, W. L., & Watson, L. R. (2006). Sensory Experiences Questionnaire: Discriminating sensory features in young children with autism, developmental delays, and typical development: SEQ. *Journal of Child Psychology and Psychiatry*, *47*(6), 591–601. https://doi.org/10.1111/j.1469-7610.2005.01546.x

Baranek, G. T., Watson, L. R., Boyd, B. A., Poe, M. D., David, F. J., & McGuire, L. (2013). Hyporesponsiveness to social and nonsocial sensory stimuli in children with autism, children with developmental delays, and typically developing children. *Development and Psychopathology*, *25*(2), 307–320. https://doi.org/10.1017/S0954579412001071

Barlow, D. H. (2000). Unraveling the mysteries of anxiety and its disorders from the perspective of emotion theory. *American Psychologist*, *55*(11), 1247–1263. https://doi.org/10.1037/0003-066X.55.11.1247

Beesdo, K., Knappe, S., & Pine, D. S. (2009). Anxiety and Anxiety Disorders in Children and Adolescents: Developmental Issues and Implications for DSM-V. *Psychiatric Clinics of North America*, *32*(3), 483–524. https://doi.org/10.1016/j.psc.2009.06.002

Bellini, S. (2006). The Development of Social Anxiety in Adolescents With Autism Spectrum Disorders. *Focus on Autism and Other Developmental Disabilities*, *21*(3), 138–145. https://doi.org/10.1177/10883576060210030201

Ben-Sasson, A., Carter, A. S., & Briggs-Gowan, M. J. (2009). Sensory Over-Responsivity in Elementary School: Prevalence and Social-Emotional Correlates. *Journal of Abnormal Child Psychology*, *37*(5), 705–716. https://doi.org/10.1007/s10802-008-9295-8

Ben-Sasson, A., Cermak, S. A., Orsmond, G. I., Carter, A. S., & Fogg, L. (2007). Can we differentiate sensory over-responsivity from anxiety symptoms in toddlers? Perspectives of occupational therapists and psychologists. *Infant Mental Health Journal*, *28*(5), 536–558. https://doi.org/10.1002/imhj.20152

Ben-Sasson, A., Cermak, S. A., Orsmond, G. I., Tager-Flusberg, H., Carter, A. S., Kadlec, M. B., & Dunn, W. (2007). Extreme Sensory Modulation Behaviors in Toddlers With Autism Spectrum Disorders. *American Journal of Occupational Therapy*, *61*(5), 584–592. https://doi.org/10.5014/ajot.61.5.584

Ben-Sasson, A., Cermak, S. A., Orsmond, G. I., Tager-Flusberg, H., Kadlec, M. B., & Carter, A. S. (2008). Sensory clusters of toddlers with autism spectrum disorders: Differences in affective symptoms. *Journal of Child Psychology and Psychiatry*, *49*(8), 817–825. https://doi.org/10.1111/j.1469-7610.2008.01899.x

Birmaher, B., Khetarpal, S., Brent, D., Cully, M., Balach, L., Kaufman, J., & Neer, S. M. (1997). The Screen for Child Anxiety Related Emotional Disorders (SCARED): Scale Construction and

Psychometric Characteristics. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(4), 545–553. https://doi.org/10.1097/00004583-199704000-00018

Bishop, S. J. (2007). Neurocognitive mechanisms of anxiety: An integrative account. *Trends in Cognitive Sciences*, *11*(7), 307–316. https://doi.org/10.1016/j.tics.2007.05.008

Bitsika, V., Arnold, W. A., & Sharpley, C. F. (2019). The Role of Sensory Features in Mediating Associations Between Autism Symptoms and Anxiety in Boys with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*. https://doi.org/10.1007/s10803-019-03917-1

Black, K. R., Stevenson, R. A., Segers, M., Ncube, B. L., Sun, S. Z., Philipp-Muller, A., Bebko, J. M., Barense, M. D., & Ferber, S. (2017). Linking Anxiety and Insistence on Sameness in Autistic Children: The Role of Sensory Hypersensitivity. *Journal of Autism and Developmental Disorders*, *47*(8), 2459–2470. https://doi.org/10.1007/s10803-017-3161-x

Boelen, P. A., & Reijntjes, A. (2009). Intolerance of uncertainty and social anxiety. *Journal of Anxiety Disorders*, *23*(1), 130–135. https://doi.org/10.1016/j.janxdis.2008.04.007

Booth, T., Murray, A. L., McKenzie, K., Kuenssberg, R., O'Donnell, M., & Burnett, H. (2013). Brief Report: An Evaluation of the AQ-10 as a Brief Screening Instrument for ASD in Adults. *Journal of Autism and Developmental Disorders*, *43*(12), 2997–3000. https://doi.org/10.1007/s10803-013-1844-5

Boswell, J. F., Thompson-Hollands, J., Farchione, T. J., & Barlow, D. H. (2013). Intolerance of Uncertainty: A Common Factor in the Treatment of Emotional Disorders: Intolerance of Uncertainty. *Journal of Clinical Psychology*, *69*(6), 630–645. https://doi.org/10.1002/jclp.21965

Boulter, C., Freeston, M., South, M., & Rodgers, J. (2014). Intolerance of Uncertainty as a Framework for Understanding Anxiety in Children and Adolescents with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, *44*(6), 1391–1402. https://doi.org/10.1007/s10803-013-2001-x

Boyd, B. A., Baranek, G. T., Sideris, J., Poe, M. D., Watson, L. R., Patten, E., & Miller, H. (2010). Sensory features and repetitive behaviors in children with autism and developmental delays. *Autism Research*, *3*(2), 78–87. https://doi.org/10.1002/aur.124

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Braun, V., Clarke, V., Boulton, E., Davey, L., & McEvoy, C. (2020). The online survey as a qualitative research tool. *International Journal of Social Research Methodology*, 1–14. https://doi.org/10.1080/13645579.2020.1805550

Braun, V., Clarke, V., & Gray, D. (2017). Innovations in Qualitative Methods. In B. Gough (Ed.), *The Palgrave Handbook of Critical Social Psychology* (pp. 243–266). Palgrave Macmillan UK. https://doi.org/10.1057/978-1-137-51018-1_13

Brede, J., Babb, C., Jones, C., Elliott, M., Zanker, C., Tchanturia, K., Serpell, L., Fox, J., & Mandy, W. (2020). "For Me, the Anorexia is Just a Symptom, and the Cause is the Autism": Investigating Restrictive Eating Disorders in Autistic Women. *Journal of Autism and Developmental Disorders*. https://doi.org/10.1007/s10803-020-04479-3

Brown, C., Tollefson, N., Dunn, W., Cromwell, R., & Filion, D. (2001). The Adult Sensory Profile: Measuring Patterns of Sensory Processing. *American Journal of Occupational Therapy*, *55*(1), 75–82. https://doi.org/10.5014/ajot.55.1.75

Brugha, T., Cooper, S. A., McManus, S., Purdon, S., Smith, J., Scott, F. J., Spiers, N., & Tyrer, F. (2012). *Estimating the prevalence of autism spectrum conditions in adults: Extending the 2007 adult psychiatric morbidity survey*. NHS Information Centre.

Buck, T. R., Viskochil, J., Farley, M., Coon, H., McMahon, W. M., Morgan, J., & Bilder, D. A. (2014). Psychiatric Comorbidity and Medication Use in Adults with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *44*(12), 3063–3071. https://doi.org/10.1007/s10803-014-2170-2

Buhr, K., & Dugas, M. J. (2002). The intolerance of uncertainty scale: Psychometric properties of the English version. *Behaviour Research and Therapy*, *40*(8), 931–945. https://doi.org/10.1016/S0005-7967(01)00092-4

Buhr, K., & Dugas, M. J. (2006). Investigating the construct validity of intolerance of uncertainty and its unique relationship with worry. *Journal of Anxiety Disorders*, *20*(2), 222–236. https://doi.org/10.1016/j.janxdis.2004.12.004

Burns, C. O., Dixon, D. R., Novack, M., & Granpeesheh, D. (2017). A Systematic Review of Assessments for Sensory Processing Abnormalities in Autism Spectrum Disorder. *Review Journal of Autism and Developmental Disorders*, *4*(3), 209–224. https://doi.org/10.1007/s40489-017-0109-1

Bystritsky, A., Khalsa, S. S., Cameron, M. E., & Schiffman, J. (2013). Current diagnosis and treatment of anxiety disorders. *P & T: A Peer-Reviewed Journal for Formulary Management*, *38*(1), 30–57.

Camm-Crosbie, L., Bradley, L., Shaw, R., Baron-Cohen, S., & Cassidy, S. (2019). 'People like me don't get support': Autistic adults' experiences of support and treatment for mental health difficulties, self-injury and suicidality. *Autism*, *23*(6), 1431–1441. https://doi.org/10.1177/1362361318816053

Carleton, R. N., Mulvogue, M. K., Thibodeau, M. A., McCabe, R. E., Antony, M. M., & Asmundson, G. J. G. (2012). Increasingly certain about uncertainty: Intolerance of uncertainty across anxiety and depression. *Journal of Anxiety Disorders*, *26*(3), 468–479. https://doi.org/10.1016/j.janxdis.2012.01.011

Carpenter, K. L. H., Baranek, G. T., Copeland, W. E., Compton, S., Zucker, N., Dawson, G., & Egger, H. L. (2018). Sensory Over-Responsivity: An Early Risk Factor for Anxiety and Behavioral Challenges in Young Children. *Journal of Abnormal Child Psychology*. https://doi.org/10.1007/s10802-018-0502-y

Cascio, M. A., Weiss, J. A., & Racine, E. (2021). Making Autism Research Inclusive by Attending to Intersectionality: A Review of the Research Ethics Literature. *Review Journal of Autism and Developmental Disorders*, *8*(1), 22–36. https://doi.org/10.1007/s40489-020-00204-z

Castleberry, A. (2012). *NVivo 10 [software program]* (Version 10) [Computer software]. QSR International.

Cavanagh, S. (1997). Content analysis: Concepts, methods and applications: Content analysis is a flexible methodology that is particularly useful to nurse researchers, asserts Stephen Cavanagh. *Nurse Researcher*, *4*(3), 5–16. https://doi.org/10.7748/nr.4.3.5.s2

Chamak, B., Bonniau, B., Jaunay, E., & Cohen, D. (2008). What Can We Learn about Autism from Autistic Persons? *Psychotherapy and Psychosomatics*, *77*(5), 271–279. https://doi.org/10.1159/000140086

Chamberlain, P. D., Rodgers, J., Crowley, M. J., White, S. E., Freeston, M. H., & South, M. (2013). A potentiated startle study of uncertainty and contextual anxiety in adolescents diagnosed with autism spectrum disorder. *Molecular Autism*, *4*(1), 31. https://doi.org/10.1186/2040-2392-4-31

Charman, T., Pickles, A., Simonoff, E., Chandler, S., Loucas, T., & Baird, G. (2011). IQ in children with autism spectrum disorders: Data from the Special Needs and Autism Project (SNAP). *Psychological Medicine*, *41*(3), 619–627. https://doi.org/10.1017/S0033291710000991

Chiarotti, F., & Venerosi, A. (2020). Epidemiology of Autism Spectrum Disorders: A Review of Worldwide Prevalence Estimates Since 2014. *Brain Sciences*, *10*(5), 274. https://doi.org/10.3390/brainsci10050274

Crane, L., Adams, F., Harper, G., Welch, J., & Pellicano, E. (2019). 'Something needs to change': Mental health experiences of young autistic adults in England. *Autism*, *23*(2), 477–493. https://doi.org/10.1177/1362361318757048

Crane, L., Goddard, L., & Pring, L. (2009). Sensory processing in adults with autism spectrum disorders. *Autism*, *13*(3), 215–228. https://doi.org/10.1177/1362361309103794

Crompton, C. J., Sharp, M., Axbey, H., Fletcher-Watson, S., Flynn, E. G., & Ropar, D. (2020). Neurotype-Matching, but Not Being Autistic, Influences Self and Observer Ratings of Interpersonal Rapport. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.586171

Dar, R., Kahn, D. T., & Carmeli, R. (2012). The relationship between sensory processing, childhood rituals and obsessive–compulsive symptoms. *Journal of Behavior Therapy and Experimental Psychiatry*, *43*(1), 679–684. https://doi.org/10.1016/j.jbtep.2011.09.008

de Bruin, E. I., Ferdinand, R. F., Meester, S., de Nijs, P. F. A., & Verheij, F. (2007). High Rates of Psychiatric Co-Morbidity in PDD-NOS. *Journal of Autism and Developmental Disorders*, *37*(5), 877–886. https://doi.org/10.1007/s10803-006-0215-x

Dellapiazza, F., Vernhet, C., Blanc, N., Miot, S., Schmidt, R., & Baghdadli, A. (2018). Links between sensory processing, adaptive behaviours, and attention in children with autism spectrum disorder: A systematic review. *Psychiatry Research*, *270*, 78–88. https://doi.org/10.1016/j.psychres.2018.09.023

Dickie, V. A., Baranek, G. T., Schultz, B., Watson, L. R., & McComish, C. S. (2009). Parent reports of sensory experiences of preschool children with and without autism: A qualitative study. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association*, *63*(2), 172–181.

Driscoll, K., Schonberg, M., Stark, M. F., Carter, A. S., & Hirshfeld-Becker, D. (2020). Family-Centered Cognitive Behavioral Therapy for Anxiety in Very Young Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *50*(11), 3905–3920. https://doi.org/10.1007/s10803-020-04446-y

DSM-5 American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders 5 (DSM-5)*. Arlington: American Psychiatric Publishing.

DSM-IV American Psychiatric Association. (1994). *Diagnostic and Statistical Manual of Mental Disorders-IV (DSM-IV)*. Arlington: American Psychiatric Publishing.

Dugas, M. J., Brillon, P., Savard, P., Turcotte, J., Gaudet, A., Ladouceur, R., Leblanc, R., & Gervais, N. J. (2010). A Randomized Clinical Trial of Cognitive-Behavioral Therapy and Applied Relaxation for Adults With Generalized Anxiety Disorder. *Behavior Therapy*, *41*(1), 46–58. https://doi.org/10.1016/j.beth.2008.12.004

Dugas, M. J., Gagnon, F., Ladouceur, R., & Freeston, M. H. (1998). Generalized anxiety disorder: A preliminary test of a conceptual model. *Behaviour Research and Therapy*, *36*(2), 215–226. https://doi.org/10.1016/S0005-7967(97)00070-3

Dugas, M. J., Hedayati, M., Karavidas, A., Buhr, K., Francis, K., & Phillips, N. A. (2005). Intolerance of Uncertainty and Information Processing: Evidence of Biased Recall and Interpretations. *Cognitive Therapy and Research*, *29*(1), 57–70. https://doi.org/10.1007/s10608-005-1648-9

Dugas, M. J., & Ladouceur, R. (2000). Treatment of Gad: Targeting Intolerance of Uncertainty in Two Types of Worry. *Behavior Modification*, *24*(5), 635–657. https://doi.org/10.1177/0145445500245002

Dunn, O. J., & Clark, V. (1969). Correlation Coefficients Measured on the Same Individuals. *Journal of the American Statistical Association*, *64*(325), 366–377. https://doi.org/10.1080/01621459.1969.10500981

Dunn, W. (1999). *Sensory profile* (Vol. 555). San Antonio, TX: Pscyhological Corporation.

Edgington, L., Hill, V., & Pellicano, E. (2016). The design and implementation of a CBT-based intervention for sensory processing difficulties in adolescents on the autism spectrum. *Research in Developmental Disabilities*, *59*, 221–233. https://doi.org/10.1016/j.ridd.2016.09.004

Edwards, S. L., Rapee, R. M., Kennedy, S. J., & Spence, S. H. (2010). The Assessment of Anxiety Symptoms in Preschool-Aged Children: The Revised Preschool Anxiety Scale. *Journal of Clinical Child & Adolescent Psychology*, *39*(3), 400–409. https://doi.org/10.1080/15374411003691701

Elliott, C. D., Murray, D. J., & Pearson, L. S. (1983). *British ability scales*. nfer-nelson.

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*(1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Elwin, M., Ek, L., Schröder, A., & Kjellin, L. (2012). Autobiographical Accounts of Sensing in Asperger Syndrome and High-Functioning Autism. *Archives of Psychiatric Nursing*, *26*(5), 420–429. https://doi.org/10.1016/j.apnu.2011.10.003

Engel-Yeger, B., & Dunn, W. (2011). The Relationship between Sensory Processing Difficulties and Anxiety Level of Healthy Adults. *British Journal of Occupational Therapy*, *74*(5), 210–216. https://doi.org/10.4276/030802211X13046730116407

Factor, R. S., Ryan, S. M., Farley, J. P., Ollendick, T. H., & Scarpa, A. (2017). Does the Presence of Anxiety and ADHD Symptoms Add to Social Impairment in Children with Autism Spectrum Disorder? *Journal of Autism and Developmental Disorders*, *47*(4), 1122–1134. https://doi.org/10.1007/s10803-016-3025-9

Fergus, T. A., & Carleton, R. N. (2016). Intolerance of uncertainty and attentional networks: Unique associations with alerting. *Journal of Anxiety Disorders*, *41*, 59–64. https://doi.org/10.1016/j.janxdis.2016.03.010

Ferrão, Y. A., Shavitt, R. G., Prado, H., Fontenelle, L. F., Malavazzi, D. M., de Mathis, M. A., Hounie, A. G., Miguel, E. C., & do Rosário, M. C. (2012). Sensory phenomena associated with repetitive behaviors in obsessive-compulsive disorder: An exploratory study of 1001 patients. *Psychiatry Research*, *197*(3), 253–258. https://doi.org/10.1016/j.psychres.2011.09.017

Fiser, J., Berkes, P., Orbán, G., & Lengyel, M. (2010). Statistically optimal perception and learning: From behavior to neural representations. *Trends in Cognitive Sciences*, *14*(3), 119–130. https://doi.org/10.1016/j.tics.2010.01.003

Fletcher-Watson, S., Adams, J., Brook, K., Charman, T., Crane, L., Cusack, J., Leekam, S., Milton, D., Parr, J. R., & Pellicano, E. (2018). Making the future together: Shaping autism research

through meaningful participation. *Autism*, 136236131878672. https://doi.org/10.1177/1362361318786721

Flynn, S., Vereenooghe, L., Hastings, R. P., Adams, D., Cooper, S.-A., Gore, N., Hatton, C., Hood, K., Jahoda, A., Langdon, P. E., McNamara, R., Oliver, C., Roy, A., Totsika, V., & Waite, J. (2017). Measurement tools for mental health problems and mental well-being in people with severe or profound intellectual disabilities: A systematic review. *Clinical Psychology Review*, *57*, 32–44. https://doi.org/10.1016/j.cpr.2017.08.006

Forsyth, A. S., & Trevarrow, R. (2018). Sensory strategies in adult mental health: A qualitative exploration of staff perspectives following the introduction of a sensory room on a male adult acute ward. *International Journal of Mental Health Nursing*, *27*(6), 1689–1697. https://doi.org/10.1111/inm.12466

Freeston, M. H., Rhéaume, J., Letarte, H., Dugas, M. J., & Ladouceur, R. (1994). Why do people worry? *Personality and Individual Differences*, *17*(6), 791–802. https://doi.org/10.1016/0191-8869(94)90048-5

Frith, H. (2000). Focusing on Sex: Using Focus Groups in Sex Research. *Sexualities*, *3*(3), 275–297. https://doi.org/10.1177/136346000003003001

Funabiki, Y., Murai, T., & Toichi, M. (2012). Cortical activation during attention to sound in autism spectrum disorders. *Research in Developmental Disabilities*, *33*(2), 518–524. https://doi.org/10.1016/j.ridd.2011.10.016

Galiana-Simal, A., Vela-Romero, M., Romero-Vela, V. M., Oliver-Tercero, N., García-Olmo, V., Benito-Castellanos, P. J., Muñoz-Martinez, V., & Beato-Fernandez, L. (2020). Sensory processing disorder: Key points of a frequent alteration in neurodevelopmental disorders. *Cogent Medicine*, *7*(1). https://doi.org/10.1080/2331205X.2020.1736829

Gernsbacher, M. A. (2017). Editorial Perspective: The use of person-first language in scholarly writing may accentuate stigma. *Journal of Child Psychology and Psychiatry*, *58*(7), 859–861. https://doi.org/10.1111/jcpp.12706

Ghandour, R. M., Sherman, L. J., Vladutiu, C. J., Ali, M. M., Lynch, S. E., Bitsko, R. H., & Blumberg, S. J. (2019). Prevalence and Treatment of Depression, Anxiety, and Conduct Problems in US Children. *The Journal of Pediatrics*, *206*, 256-267.e3. https://doi.org/10.1016/j.jpeds.2018.09.021

Gjevik, E., Eldevik, S., Fjæran-Granum, T., & Sponheim, E. (2011). Kiddie-SADS Reveals High Rates of DSM-IV Disorders in Children and Adolescents with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, *41*(6), 761–769. https://doi.org/10.1007/s10803-010-1095-7

Glod, M., Creswell, C., Waite, P., Jamieson, R., McConachie, H., Don South, M., & Rodgers, J. (2017). Comparisons of the Factor Structure and Measurement Invariance of the Spence Children's Anxiety Scale—Parent Version in Children with Autism Spectrum Disorder and Typically Developing Anxious Children. *Journal of Autism and Developmental Disorders*, *47*(12), 3834–3846. https://doi.org/10.1007/s10803-017-3118-0

Glod, M., Riby, D. M., Honey, E., & Rodgers, J. (2015). Psychological Correlates of Sensory Processing Patterns in Individuals with Autism Spectrum Disorder: A Systematic Review. *Review Journal of Autism and Developmental Disorders*, *2*(2), 199–221. https://doi.org/10.1007/s40489-015-0047-8

Glod, M., Riby, D. M., & Rodgers, J. (2019). Short report: Relationships between sensory processing, repetitive behaviors, anxiety, and intolerance of uncertainty in autism spectrum disorder and Williams syndrome. *Autism Research*, *12*(5), 759–765. https://doi.org/10.1002/aur.2096

Gotham, K., Brunwasser, S. M., & Lord, C. (2015). Depressive and Anxiety Symptom Trajectories From School Age Through Young Adulthood in Samples With Autism Spectrum Disorder and Developmental Delay. *Journal of the American Academy of Child & Adolescent Psychiatry*, *54*(5), 369-376.e3. https://doi.org/10.1016/j.jaac.2015.02.005

Gotham, K., Cassidy, S., & Weiss, J. (2020). Mental health across the lifespan. *Autism*, *24*(4), 805–808. https://doi.org/10.1177/1362361320912132

Green, S. A., & Ben-Sasson, A. (2010). Anxiety Disorders and Sensory Over-Responsivity in Children with Autism Spectrum Disorders: Is There a Causal Relationship? *Journal of Autism and Developmental Disorders*, *40*(12), 1495–1504. https://doi.org/10.1007/s10803-010-1007-x

Green, S. A., Ben-Sasson, A., Soto, T. W., & Carter, A. S. (2012). Anxiety and Sensory Over-Responsivity in Toddlers with Autism Spectrum Disorders: Bidirectional Effects Across Time. *Journal of Autism and Developmental Disorders*, *42*(6), 1112–1119. https://doi.org/10.1007/s10803-011-1361-3

Green, S. A., Hernandez, L., Tottenham, N., Krasileva, K., Bookheimer, S. Y., & Dapretto, M. (2015). Neurobiology of Sensory Overresponsivity in Youth With Autism Spectrum Disorders. *JAMA Psychiatry*, *72*(8), 778. https://doi.org/10.1001/jamapsychiatry.2015.0737

Green, S. A., Rudie, J. D., Colich, N. L., Wood, J. J., Shirinyan, D., Hernandez, L., Tottenham, N., Dapretto, M., & Bookheimer, S. Y. (2013). Overreactive Brain Responses to Sensory Stimuli in Youth With Autism Spectrum Disorders. *Journal of the American Academy of Child & Adolescent Psychiatry*, *52*(11), 1158–1172. https://doi.org/10.1016/j.jaac.2013.08.004

Grillon, C. (2008). Models and mechanisms of anxiety: Evidence from startle studies. *Psychopharmacology*, *199*(3), 421–437. https://doi.org/10.1007/s00213-007-1019-1

Grove, R., Hoekstra, R. A., Wierda, M., & Begeer, S. (2018). Special interests and subjective wellbeing in autistic adults: Special interests and wellbeing in autism. *Autism Research*, *11*(5), 766–775. https://doi.org/10.1002/aur.1931

Hallett, V., Mueller, J., Breese, L., Hollett, M., Beresford, B., Irvine, A., Pickles, A., Slonims, V., Scott, S., Charman, T., & Simonoff, E. (2021). Introducing 'Predictive Parenting': A Feasibility Study of a New Group Parenting Intervention Targeting Emotional and Behavioral Difficulties in Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *51*(1), 323–333. https://doi.org/10.1007/s10803-020-04442-2

Hallett, V., Ronald, A., Colvert, E., Ames, C., Woodhouse, E., Lietz, S., Garnett, T., Gillan, N., Rijsdijk, F., Scahill, L., Bolton, P., & Happé, F. (2013). Exploring anxiety symptoms in a large-scale twin study of children with autism spectrum disorders, their co-twins and controls. *Journal of Child Psychology and Psychiatry*, *54*(11), 1176–1185. https://doi.org/10.1111/jcpp.12068

Hebbard, P. C., King, R. R., Malsbury, C. W., & Harley, C. W. (2003). Two organizational effects of pubertal testosterone in male rats: Transient social memory and a shift away from long-term potentiation following a tetanus in hippocampal CA1. *Experimental Neurology*, *182*(2), 470–475. https://doi.org/10.1016/S0014-4886(03)00119-5

Herry, C., Bach, D. R., Esposito, F., Di Salle, F., Perrig, W. J., Scheffler, K., Luthi, A., & Seifritz, E. (2007). Processing of Temporal Unpredictability in Human and Animal Amygdala. *Journal of Neuroscience*, *27*(22), 5958–5966. https://doi.org/10.1523/JNEUROSCI.5218-06.2007

Hilton, C. L., Harper, J. D., Kueker, R. H., Lang, A. R., Abbacchi, A. M., Todorov, A., & LaVesser, P. D. (2010). Sensory Responsiveness as a Predictor of Social Severity in Children with High

Functioning Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, *40*(8), 937–945. https://doi.org/10.1007/s10803-010-0944-8

Hodgson, A. R., Freeston, M. H., Honey, E., & Rodgers, J. (2017). Facing the Unknown: Intolerance of Uncertainty in Children with Autism Spectrum Disorder. *Journal of Applied Research in Intellectual Disabilities*, *30*(2), 336–344. https://doi.org/10.1111/jar.12245

Holaway, R. M., Heimberg, R. G., & Coles, M. E. (2006). A comparison of intolerance of uncertainty in analogue obsessive-compulsive disorder and generalized anxiety disorder. *Journal of Anxiety Disorders*, *20*(2), 158–174. https://doi.org/10.1016/j.janxdis.2005.01.002

Holm, S. (1979). A Simple Sequentially Rejective Multiple Test Procedure. *Scandinavian Journal of Statistics*, 65–70.

Horder, J., Wilson, C. E., Mendez, M. A., & Murphy, D. G. (2014). Autistic Traits and Abnormal Sensory Experiences in Adults. *Journal of Autism and Developmental Disorders*, *44*(6), 1461–1469. https://doi.org/10.1007/s10803-013-2012-7

Hwang, Y. I. (Jane), Arnold, S., Srasuebkul, P., & Trollor, J. (2019). Understanding anxiety in adults on the autism spectrum: An investigation of its relationship with intolerance of uncertainty, sensory sensitivities and repetitive behaviours. *Autism*, 136236131986890. https://doi.org/10.1177/1362361319868907

IBIS network, Estes, A., Zwaigenbaum, L., Gu, H., St. John, T., Paterson, S., Elison, J. T., Hazlett, H., Botteron, K., Dager, S. R., Schultz, R. T., Kostopoulos, P., Evans, A., Dawson, G., Eliason, J., Alvarez, S., & Piven, J. (2015). Behavioral, cognitive, and adaptive development in infants with autism spectrum disorder in the first 2 years of life. *Journal of Neurodevelopmental Disorders*, *7*(1), 24. https://doi.org/10.1186/s11689-015-9117-6

IBM Corp. (2020). *IBM SPSS Statistics for Mac* (27.0) [Computer software].

Insel, T., Cuthbert, B., Garvey, M., Heinssen, R., Pine, D. S., Quinn, K., Sanislow, C., & Wang, P. (2010). Research Domain Criteria (RDoC): Toward a New Classification Framework for Research on Mental Disorders. *American Journal of Psychiatry*, *167*(7), 748–751. https://doi.org/10.1176/appi.ajp.2010.09091379

JASP team. (2020). *JASP (Version 0.14) [Computer software]*. https://jasp-stats.org/

Jenkinson, R., Milne, E., & Thompson, A. (2020). The relationship between intolerance of uncertainty and anxiety in autism: A systematic literature review and meta-analysis. *Autism*, *24*(8), 1933–1944. https://doi.org/10.1177/1362361320932437

Jitlina, K., Zumbo, B., Mirenda, P., Ford, L., Bennett, T., Georgiades, S., Waddell, C., Smith, I. M., Volden, J., Duku, E., Zwaigenbaum, L., Szatmari, P., Vaillancourt, T., & Elsabbagh, M. (2017). Psychometric Properties of the Spence Children's Anxiety Scale: Parent Report in Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *47*(12), 3847–3856. https://doi.org/10.1007/s10803-017-3110-8

Joel, D., & McCarthy, M. M. (2017). Incorporating Sex As a Biological Variable in Neuropsychiatric Research: Where Are We Now and Where Should We Be? *Neuropsychopharmacology*, *42*(2), 379–385. https://doi.org/10.1038/npp.2016.79

Jones, R. S. P., Quigney, C., & Huws, J. C. (2003). First-hand accounts of sensory perceptual experiences in autism: A qualitative analysis. *Journal of Intellectual & Developmental Disability*, *28*(2), 112–121. https://doi.org/10.1080/1366825031000147058

Joosten, A. V., & Bundy, A. C. (2010). Sensory processing and stereotypical and repetitive behaviour in children with autism and intellectual disability: SENSORY PROCESSING IN AUTISM. *Australian Occupational Therapy Journal*, *57*(6), 366–372. https://doi.org/10.1111/j.1440-1630.2009.00835.x

Kapp, S. K., Gillespie-Lynch, K., Sherman, L. E., & Hutman, T. (2013). Deficit, difference, or both? Autism and neurodiversity. *Developmental Psychology*, *49*(1), 59–71. https://doi.org/10.1037/a0028353

Kenny, L., Hattersley, C., Molins, B., Buckley, C., Povey, C., & Pellicano, E. (2016). Which terms should be used to describe autism? Perspectives from the UK autism community. *Autism*, *20*(4), 442–462. https://doi.org/10.1177/1362361315588200

Kern, J. K., Trivedi, M. H., Grannemann, B. D., Garver, C. R., Johnson, D. G., Andrews, A. A., Savla, J. S., Mehta, J. A., & Schroeder, J. L. (2007). Sensory correlations in autism. *Autism*, *11*(2), 123–134. https://doi.org/10.1177/1362361307075702

Kerns, C. M., & Kendall, P. C. (2012). The Presentation and Classification of Anxiety in Autism Spectrum Disorder. *Clinical Psychology: Science and Practice*, *19*(4), 323–347. https://doi.org/10.1111/cpsp.12009

Kerns, C. M., Kendall, P. C., Berry, L., Souders, M. C., Franklin, M. E., Schultz, R. T., Miller, J., & Herrington, J. (2014). Traditional and Atypical Presentations of Anxiety in Youth with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *44*(11), 2851–2861. https://doi.org/10.1007/s10803-014-2141-7

Kerns, C. M., Renno, P., Kendall, P. C., Wood, J. J., & Storch, E. A. (2017). Anxiety Disorders Interview Schedule–Autism Addendum: Reliability and Validity in Children With Autism Spectrum Disorder. *Journal of Clinical Child & Adolescent Psychology*, *46*(1), 88–100. https://doi.org/10.1080/15374416.2016.1233501

Kerns, C. M., Winder-Patel, B., Iosif, A. M., Nordahl, C. W., Heath, B., Solomon, M., & Amaral, D. G. (2020). Clinically Significant Anxiety in Children with Autism Spectrum Disorder and Varied Intellectual Functioning. *Journal of Clinical Child & Adolescent Psychology*, 1–16. https://doi.org/10.1080/15374416.2019.1703712

Kim, S. H., & Lord, C. (2012). Combining information from multiple sources for the diagnosis of autism spectrum disorders for toddlers and young preschoolers from 12 to 47 months of age: Combining information for the diagnosis of ASD for toddlers and young preschoolers. *Journal of Child Psychology and Psychiatry*, *53*(2), 143–151. https://doi.org/10.1111/j.1469-7610.2011.02458.x

Knapp, M., Romeo, R., & Beecham, J. (2007). *The economic consequences of autism in the UK* [Electronic resource]. Foundation for People with Learning Disabilities. http://www.lse.edu/collections/pressAndInformationOffice/PDF/EconomicCostsofAutism.pdf

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology* (Fourth Edition). SAGE.

Lai, M.-C., Lombardo, M. V., Pasco, G., Ruigrok, A. N. V., Wheelwright, S. J., Sadek, S. A., Chakrabarti, B., MRC AIMS Consortium, & Baron-Cohen, S. (2011). A Behavioral Comparison of Male and Female Adults with High Functioning Autism Spectrum Conditions. *PLoS ONE*, *6*(6), e20835. https://doi.org/10.1371/journal.pone.0020835

Lai, M.-C., & Szatmari, P. (2020). Sex and gender impacts on the behavioural presentation and recognition of autism: *Current Opinion in Psychiatry*, *33*(2), 117–123. https://doi.org/10.1097/YCO.0000000000000575

Lane, A. E., Dennis, S. J., & Geraghty, M. E. (2011). Brief Report: Further Evidence of Sensory Subtypes in Autism. *Journal of Autism and Developmental Disorders*, *41*(6), 826–831. https://doi.org/10.1007/s10803-010-1103-y

Lane, A. E., Molloy, C. A., & Bishop, S. L. (2014). Classification of Children With Autism Spectrum Disorder by Sensory Subtype: A Case for Sensory-Based Phenotypes: Sensory phenotypes in autism. *Autism Research*, *7*(3), 322–333. https://doi.org/10.1002/aur.1368

Lane, A. E., Young, R. L., Baker, A. E. Z., & Angley, M. T. (2010). Sensory Processing Subtypes in Autism: Association with Adaptive Behavior. *Journal of Autism and Developmental Disorders*, *40*(1), 112–122. https://doi.org/10.1007/s10803-009-0840-2

Lane, S. J. (2002). Sensory modulation. In A. C. Bundy, S. J. Lane, & E. A. Murray (Eds.), *Sensory integration: Theory and practice* (2nd ed., pp. 101–122). F. A. Davis.

Lau, B. Y., Leong, R., Uljarevic, M., Lerh, J. W., Rodgers, J., Hollocks, M. J., South, M., McConachie, H., Ozsivadjian, A., Van Hecke, A., Libove, R., Hardan, A., Leekam, S., Simonoff, E., & Magiati, I. (2020). Anxiety in young people with autism spectrum disorder: Common and autism-related anxiety experiences and their associations with individual characteristics. *Autism*, *24*(5), 1111–1126. https://doi.org/10.1177/1362361319886246

Leekam, S. R., Nieto, C., Libby, S. J., Wing, L., & Gould, J. (2007). Describing the Sensory Abnormalities of Children and Adults with Autism. *Journal of Autism and Developmental Disorders*, *37*(5), 894–910. https://doi.org/10.1007/s10803-006-0218-7

Levit-Binnun, N., Szepsenwol, O., Stern-Ellran, K., & Engel-Yeger, B. (2014). The relationship between sensory responsiveness profiles, attachment orientations, and anxiety symptoms: Sensory responsiveness, attachment, and anxiety. *Australian Journal of Psychology*, *66*(4), 233–240. https://doi.org/10.1111/ajpy.12064

Leyfer, O. T., Folstein, S. E., Bacalman, S., Davis, N. O., Dinh, E., Morgan, J., Tager-Flusberg, H., & Lainhart, J. E. (2006a). Comorbid Psychiatric Disorders in Children with Autism: Interview Development and Rates of Disorders. *Journal of Autism and Developmental Disorders*, *36*(7), 849–861. https://doi.org/10.1007/s10803-006-0123-0

Leyfer, O. T., Folstein, S. E., Bacalman, S., Davis, N. O., Dinh, E., Morgan, J., Tager-Flusberg, H., & Lainhart, J. E. (2006b). Comorbid Psychiatric Disorders in Children with Autism: Interview

Development and Rates of Disorders. *Journal of Autism and Developmental Disorders*, *36*(7), 849–861. https://doi.org/10.1007/s10803-006-0123-0

Lidstone, J., Uljarević, M., Sullivan, J., Rodgers, J., McConachie, H., Freeston, M., Le Couteur, A., Prior, M., & Leekam, S. (2014). Relations among restricted and repetitive behaviors, anxiety and sensory features in children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *8*(2), 82–92. https://doi.org/10.1016/j.rasd.2013.10.001

Liss, M., Mailloux, J., & Erchull, M. J. (2008). The relationships between sensory processing sensitivity, alexithymia, autism, depression, and anxiety. *Personality and Individual Differences*, *45*(3), 255–259. https://doi.org/10.1016/j.paid.2008.04.009

Liss, M., Saulnier, C., Fein, D., & Kinsbourne, M. (2006). Sensory and attention abnormalities in autistic spectrum disorders. *Autism*, *10*(2), 155–172. https://doi.org/10.1177/1362361306062021

Liss, M., Timmel, L., Baxley, K., & Killingsworth, P. (2005). Sensory processing sensitivity and its relation to parental bonding, anxiety, and depression. *Personality and Individual Differences*, *39*(8), 1429–1439. https://doi.org/10.1016/j.paid.2005.05.007

Lombardo, M. V., Lai, M.-C., & Baron-Cohen, S. (2019). Big data approaches to decomposing heterogeneity across the autism spectrum. *Molecular Psychiatry*, *24*(10), 1435–1450. https://doi.org/10.1038/s41380-018-0321-0

Loomes, R., Hull, L., & Mandy, W. P. L. (2017). What Is the Male-to-Female Ratio in Autism Spectrum Disorder? A Systematic Review and Meta-Analysis. *Journal of the American Academy of Child & Adolescent Psychiatry*, *56*(6), 466–474. https://doi.org/10.1016/j.jaac.2017.03.013

Lord, C., Rutter, M., DiLavore, P., Risi, S., Gotham, K., & Bishop, S. (2012). *Autism diagnostic observation schedule* (2nd ed.). Western Psychological Services.

MacLennan, K., Roach, L., & Tavassoli, T. (2020). The Relationship Between Sensory Reactivity Differences and Anxiety Subtypes in Autistic Children. *Autism Research*, *13*(5), 785–795. https://doi.org/10.1002/aur.2259

MacLennan, K., Rossow, T., & Tavassoli, T. (2021). The relationship between sensory reactivity, intolerance of uncertainty and anxiety subtypes in preschool-age autistic children. *Autism*, 136236132110161. https://doi.org/10.1177/13623613211016110

Maddox, B. B., Crabbe, S., Beidas, R. S., Brookman-Frazee, L., Cannuscio, C. C., Miller, J. S., Nicolaidis, C., & Mandell, D. S. (2020). “I wouldn’t know where to start”: Perspectives from clinicians, agency leaders, and autistic adults on improving community mental health services for autistic adults. *Autism*, *24*(4), 919–930. https://doi.org/10.1177/1362361319882227

Maddox, B. B., Lecavalier, L., Miller, J. S., Pritchett, J., Hollway, J., White, S. W., Gillespie, S., Evans, A. N., Schultz, R. T., Herrington, J. D., Bearss, K., & Scahill, L. (2020). Reliability and validity of the Pediatric Anxiety Rating Scale modified for autism spectrum disorder. *Autism*, *24*(7), 1773–1782. https://doi.org/10.1177/1362361320922682

Maenner, M. J., Shaw, K. A., Baio, J., EdS1, Washington, A., Patrick, M., DiRienzo, M., Christensen, D. L., Wiggins, L. D., Pettygrove, S., Andrews, J. G., Lopez, M., Hudson, A., Baroud, T., Schwenk, Y., White, T., Rosenberg, C. R., Lee, L.-C., Harrington, R. A., … Dietz, P. M. (2020). Prevalence of Autism Spectrum Disorder Among Children Aged 8 Years—Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2016. *MMWR. Surveillance Summaries*, *69*(4), 1–12. https://doi.org/10.15585/mmwr.ss6904a1

Magiati, I., Lerh, J. W., Hollocks, M. J., Uljarevic, M., Rodgers, J., McConachie, H., Ozsivadjian, A., South, M., Van Hecke, A., Hardan, A., Libove, R., Leekam, S., & Simonoff, E. (2017). The measurement properties of the spence children’s anxiety scale-parent version in a large international pooled sample of young people with autism spectrum disorder: Measurement properties of the SCAS-P in ASD. *Autism Research*, *10*(10), 1629–1652. https://doi.org/10.1002/aur.1809

March, J. S., Parker, J. D. A., Sullivan, K., Stallings, P., & Conners, C. K. (1997). The Multidimensional Anxiety Scale for Children (MASC): Factor Structure, Reliability, and Validity. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(4), 554–565. https://doi.org/10.1097/00004583-199704000-00019

Mason, D., Mackintosh, J., McConachie, H., Rodgers, J., Finch, T., & Parr, J. R. (2019). Quality of life for older autistic people: The impact of mental health difficulties. *Research in Autism Spectrum Disorders*, *63*, 13–22. https://doi.org/10.1016/j.rasd.2019.02.007

Mayes, S. D., Calhoun, S. L., Aggarwal, R., Baker, C., Mathapati, S., Molitoris, S., & Mayes, R. D. (2013). Unusual fears in children with autism. *Research in Autism Spectrum Disorders*, *7*(1), 151–158. https://doi.org/10.1016/j.rasd.2012.08.002

Mazurek, M. O., Vasa, R. A., Kalb, L. G., Kanne, S. M., Rosenberg, D., Keefer, A., Murray, D. S., Freedman, B., & Lowery, L. A. (2013). Anxiety, Sensory Over-Responsivity, and Gastrointestinal Problems in Children with Autism Spectrum Disorders. *Journal of Abnormal Child Psychology*, *41*(1), 165–176. https://doi.org/10.1007/s10802-012-9668-x

McEvoy, P. M., & Mahoney, A. E. J. (2012). To Be Sure, To Be Sure: Intolerance of Uncertainty Mediates Symptoms of Various Anxiety Disorders and Depression. *Behavior Therapy*, *43*(3), 533–545. https://doi.org/10.1016/j.beth.2011.02.007

Miller, L. J., Anzalone, M. E., Lane, S. J., Cermak, S. A., & Osten, E. T. (2007). Concept evolution in sensory integration: A proposed nosology for diagnosis. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association*, *61*(2), 135–140. https://doi.org/10.5014/ajot.61.2.135

Miller, L. J., Nielsen, D. M., & Schoen, S. A. (2012). Attention deficit hyperactivity disorder and sensory modulation disorder: A comparison of behavior and physiology. *Research in Developmental Disabilities*, *33*(3), 804–818. https://doi.org/10.1016/j.ridd.2011.12.005

Miller-Kuhaneck, H., Henry, D. A., Glennon, T. J., & Mu, K. (2007). Development of the Sensory Processing Measure-School: Initial Studies of Reliability and Validity. *American Journal of Occupational Therapy*, *61*(2), 170–175. https://doi.org/10.5014/ajot.61.2.170

Mukaddes, N. M., & Fateh, R. (2010). High rates of psychiatric co-morbidity in individuals with Asperger's disorder. *The World Journal of Biological Psychiatry*, *11*(2–2), 486–492. https://doi.org/10.3109/15622970902789130

Mulligan, S., Schoen, S. A., Miller, L. J., Valdez, A., & Magalhaes, D. (2019). The Sensory Processing 3-Dimensions Scale: Initial Studies of Reliability and Item Analyses. *The Open Journal of Occupational Therapy*, *7*(1). https://doi.org/10.15453/2168-6408.1505

Muskett, A., Radtke, S., White, S., & Ollendick, T. (2019). Autism Spectrum Disorder and Specific Phobia: The Role of Sensory Sensitivity: Brief Review. *Review Journal of Autism and Developmental Disorders*. https://doi.org/10.1007/s40489-019-00159-w

Nauta, M. H., Scholing, A., Rapee, R. M., Abbott, M., Spence, S. H., & Waters, A. (2004). A parent-report measure of children's anxiety: Psychometric properties and comparison with child-report in a clinic and normal sample. *Behaviour Research and Therapy*, *42*(7), 813–839. https://doi.org/10.1016/S0005-7967(03)00200-6

Neal, J. A., Edelmann, R. J., & Glachan, M. (2002). Behavioural inhibition and symptoms of anxiety and depression: Is there a specific relationship with social phobia? *British Journal of Clinical Psychology*, *41*(4), 361–374. https://doi.org/10.1348/014466502760387489

Neil, L., Green, D., & Pellicano, E. (2017). The Psychometric Properties of a New Measure of Sensory Behaviors in Autistic Children. *Journal of Autism and Developmental Disorders*, *47*(4), 1261–1268. https://doi.org/10.1007/s10803-016-3018-8

Neil, L., Olsson, N. C., & Pellicano, E. (2016). The Relationship Between Intolerance of Uncertainty, Sensory Sensitivities, and Anxiety in Autistic and Typically Developing Children. *Journal of Autism and Developmental Disorders*, *46*(6), 1962–1973. https://doi.org/10.1007/s10803-016-2721-9

Nimmo-Smith, V., Heuvelman, H., Dalman, C., Lundberg, M., Idring, S., Carpenter, P., Magnusson, C., & Rai, D. (2020). Anxiety Disorders in Adults with Autism Spectrum Disorder: A Population-Based Study. *Journal of Autism and Developmental Disorders*, *50*(1), 308–318. https://doi.org/10.1007/s10803-019-04234-3

Nuñez, J. L., Huppenbauer, C. B., McAbee, M. D., Juraska, J. M., & DonCarlos, L. L. (2003). Androgen receptor expression in the developing male and female rat visual and prefrontal cortex: Androgen Receptors in Developing Cerebral Cortex. *Journal of Neurobiology*, *56*(3), 293–302. https://doi.org/10.1002/neu.10236

Olbert, C. M., Gala, G. J., & Tupler, L. A. (2014). Quantifying heterogeneity attributable to polythetic diagnostic criteria: Theoretical framework and empirical application. *Journal of Abnormal Psychology*, *123*(2), 452–462. https://doi.org/10.1037/a0036068

Ozsivadjian, A., Knott, F., & Magiati, I. (2012). Parent and child perspectives on the nature of anxiety in children and young people with autism spectrum disorders: A focus group study. *Autism*, *16*(2), 107–121. https://doi.org/10.1177/1362361311431703

Pellicano, E. (2013). Sensory Symptoms in Autism: A Blooming, Buzzing Confusion? *Child Development Perspectives*, *7*(3), 143–148. https://doi.org/10.1111/cdep.12031

Pellicano, E., & Burr, D. (2012). When the world becomes 'too real': A Bayesian explanation of autistic perception. *Trends in Cognitive Sciences*, *16*(10), 504–510. https://doi.org/10.1016/j.tics.2012.08.009

Pellicano, E., Dinsmore, A., & Charman, T. (2013). *A Future Made Together: Shaping autism research in the UK.* London: Institute of Education.

Pfeiffer, B., Kinnealey, M., Reed, C., & Herzberg, G. (2005). Sensory modulation and affective disorders in children and adolescents with Asperger's disorder. *The American Journal of Occupational Therapy: Official Publication of the American Occupational Therapy Association*, *59*(3), 335–345.

Pickard, H., Hirsch, C., Simonoff, E., & Happé, F. (2020). Exploring the cognitive, emotional and sensory correlates of social anxiety in autistic and neurotypical adolescents. *Journal of Child Psychology and Psychiatry*. https://doi.org/10.1111/jcpp.13214

Pollack, M. H. (2005). Comorbid anxiety and depression. *The Journal of Clinical Psychiatry*, *66 Suppl 8*, 22–29.

Postorino, V., Kerns, C. M., Vivanti, G., Bradshaw, J., Siracusano, M., & Mazzone, L. (2017). Anxiety Disorders and Obsessive-Compulsive Disorder in Individuals with Autism Spectrum Disorder. *Current Psychiatry Reports*, *19*(12). https://doi.org/10.1007/s11920-017-0846-y

Rapee, R. M., Kennedy, S. J., Ingram, M., Edwards, S. L., & Sweeney, L. (2010). Altering the Trajectory of Anxiety in At-Risk Young Children. *American Journal of Psychiatry*, *167*(12), 1518–1525. https://doi.org/10.1176/appi.ajp.2010.09111619

Raymaker, D. M., Teo, A. R., Steckler, N. A., Lentz, B., Scharer, M., Delos Santos, A., Kapp, S. K., Hunter, M., Joyce, A., & Nicolaidis, C. (2020). "Having All of Your Internal Resources Exhausted Beyond Measure and Being Left with No Clean-Up Crew": Defining Autistic Burnout. *Autism in Adulthood*, *2*(2), 132–143. https://doi.org/10.1089/aut.2019.0079

Reynolds, S., Lane, S. J., & Gennings, C. (2010). The Moderating Role of Sensory Overresponsivity in HPA Activity: A Pilot Study With Children Diagnosed With ADHD. *Journal of Attention Disorders*, *13*(5), 468–478. https://doi.org/10.1177/1087054708329906

Robertson, A. E., & Simmons, D. R. (2013). The Relationship between Sensory Sensitivity and Autistic Traits in the General Population. *Journal of Autism and Developmental Disorders*, *43*(4), 775–784. https://doi.org/10.1007/s10803-012-1608-7

Robertson, A. E., & Simmons, D. R. (2015). The Sensory Experiences of Adults with Autism Spectrum Disorder: A Qualitative Analysis. *Perception*, *44*(5), 569–586. https://doi.org/10.1068/p7833

Robertson, A. E., Stanfield, A. C., Watt, J., Barry, F., Day, M., Cormack, M., & Melville, C. (2018). The experience and impact of anxiety in autistic adults: A thematic analysis. *Research in Autism Spectrum Disorders*, *46*, 8–18. https://doi.org/10.1016/j.rasd.2017.11.006

Robertson, S. M. (2009). Neurodiversity, Quality of Life, and Autistic Adults: Shifting Research and Professional Focuses onto Real-Life Challenges. *Disability Studies Quarterly*, *30*(1). https://doi.org/10.18061/dsq.v30i1.1069

Rodgers, J., Farquhar, K., Mason, D., Brice, S., Wigham, S., Ingham, B., Freeston, M., & Parr, J. R. (2020). Development and Initial Evaluation of the Anxiety Scale for Autism-Adults. *Autism in Adulthood*, *2*(1), 24–33. https://doi.org/10.1089/aut.2019.0044

Rodgers, J., Herrema, R., Honey, E., & Freeston, M. (2018). Towards a Treatment for Intolerance of Uncertainty for Autistic Adults: A Single Case Experimental Design Study. *Journal of Autism and Developmental Disorders*, *48*(8), 2832–2845. https://doi.org/10.1007/s10803-018-3550-9

Rodgers, J., Hodgson, A., Shields, K., Wright, C., Honey, E., & Freeston, M. (2017). Towards a Treatment for Intolerance of Uncertainty in Young People with Autism Spectrum Disorder: Development of the Coping with Uncertainty in Everyday Situations (CUES©) Programme. *Journal of Autism and Developmental Disorders*, *47*(12), 3959–3966. https://doi.org/10.1007/s10803-016-2924-0

Rodgers, J., Wigham, S., McConachie, H., Freeston, M., Honey, E., & Parr, J. R. (2016). Development of the anxiety scale for children with autism spectrum disorder (ASC-ASD): Measuring anxiety in ASD. *Autism Research*, *9*(11), 1205–1215. https://doi.org/10.1002/aur.1603

Romeo, R. D., & Sisk, C. L. (2001). Pubertal and seasonal plasticity in the amygdala. *Brain Research*, *889*(1–2), 71–77. https://doi.org/10.1016/S0006-8993(00)03111-5

Rossow, T., MacLennan, K., & Tavassoli, T. (2021). The relationship between sensory reactivity differences and mental health symptoms in preschool-age autistic children. *Autism Research*, aur.2525. https://doi.org/10.1002/aur.2525

Russell, E., & Sofronoff, K. (2005). Anxiety and social worries in children with Asperger syndrome. *Australian and New Zealand Journal of Psychiatry*, *39*(7), 633–638. https://doi.org/10.1111/j.1440-1614.2005.01637.x

Russell, G., Mandy, W., Elliott, D., White, R., Pittwood, T., & Ford, T. (2019). Selection bias on intellectual ability in autism research: A cross-sectional review and meta-analysis. *Molecular Autism*, *10*(1). https://doi.org/10.1186/s13229-019-0260-x

Sanchez, A. L., Cornacchio, D., Chou, T., Leyfer, O., Coxe, S., Pincus, D., & Comer, J. S. (2017). Development of a scale to evaluate young children's responses to uncertainty and low environmental structure. *Journal of Anxiety Disorders*, *45*, 17–23. https://doi.org/10.1016/j.janxdis.2016.11.006

Sanz-Cervera, P., Pastor-Cerezuela, G., Fernández-Andrés, M.-I., & Tárraga-Mínguez, R. (2015). Sensory processing in children with Autism Spectrum Disorder: Relationship with non-verbal IQ, autism severity and Attention Deficit/Hyperactivity Disorder symptomatology. *Research in Developmental Disabilities*, *45–46*, 188–201. https://doi.org/10.1016/j.ridd.2015.07.031

Schaaf, R. C., Dumont, R. L., Arbesman, M., & May-Benson, T. A. (2017). Efficacy of Occupational Therapy Using Ayres Sensory Integration ®: A Systematic Review. *American Journal of Occupational Therapy*, *72*(1), 7201190010p1. https://doi.org/10.5014/ajot.2018.028431

Schoen, S. A., Lane, S. J., Mailloux, Z., May-Benson, T., Parham, L. D., Smith Roley, S., & Schaaf, R. C. (2019). A systematic review of ayres sensory integration intervention for children with autism. *Autism Research*, *12*(1), 6–19. https://doi.org/10.1002/aur.2046

Schoen, S. A., Miller, L. J., & Green, K. E. (2008). Pilot Study of the Sensory Over-Responsivity Scales: Assessment and Inventory. *American Journal of Occupational Therapy*, *62*(4), 393–406. https://doi.org/10.5014/ajot.62.4.393

Schoen, S. A., Miller, L. J., & Sullivan, J. (2017). The development and psychometric properties of the Sensory Processing Scale Inventory: A report measure of sensory modulation. *Journal of Intellectual & Developmental Disability*, *42*(1), 12–21. https://doi.org/10.3109/13668250.2016.1195490

Schulz, S. E., & Stevenson, R. A. (2019). Sensory hypersensitivity predicts repetitive behaviours in autistic and typically-developing children. *Autism*, *23*(4), 1028–1041. https://doi.org/10.1177/1362361318774559

Simonoff, E., Pickles, A., Charman, T., Chandler, S., Loucas, T., & Baird, G. (2008). Psychiatric Disorders in Children With Autism Spectrum Disorders: Prevalence, Comorbidity, and Associated Factors in a Population-Derived Sample. *Journal of the American Academy of*

Child & Adolescent Psychiatry, *47*(8), 921–929. https://doi.org/10.1097/CHI.0b013e318179964f

Siper, P. M., Kolevzon, A., Wang, A. T., Buxbaum, J. D., & Tavassoli, T. (2017). A clinician-administered observation and corresponding caregiver interview capturing DSM-5 sensory reactivity symptoms in children with ASD: Sensory assessment for neurodevelopmental disorders. *Autism Research*, *10*(6), 1133–1140. https://doi.org/10.1002/aur.1750

Sivik, T. (1993). Alexithymia and hypersensitivity to touch and palpation. *Integrative Physiological and Behavioral Science*, *28*(2), 130–136. https://doi.org/10.1007/BF02691215

Smith, R. S., & Sharp, J. (2013). Fascination and Isolation: A Grounded Theory Exploration of Unusual Sensory Experiences in Adults with Asperger Syndrome. *Journal of Autism and Developmental Disorders*, *43*(4), 891–910. https://doi.org/10.1007/s10803-012-1633-6

Song, M.-K., Lin, F.-C., Ward, S. E., & Fine, J. P. (2013). Composite Variables: When and How. *Nursing Research*, *62*(1), 45–49. https://doi.org/10.1097/NNR.0b013e3182741948

South, M., & Rodgers, J. (2017). Sensory, Emotional and Cognitive Contributions to Anxiety in Autism Spectrum Disorders. *Frontiers in Human Neuroscience*, *11*. https://doi.org/10.3389/fnhum.2017.00020

Spain, D., Sin, J., Linder, K. B., McMahon, J., & Happé, F. (2018). Social anxiety in autism spectrum disorder: A systematic review. *Research in Autism Spectrum Disorders*, *52*, 51–68. https://doi.org/10.1016/j.rasd.2018.04.007

Spence, S. H. (1998). A measure of anxiety symptoms among children. *Behaviour Research and Therapy*, *36*(5), 545–566. https://doi.org/10.1016/S0005-7967(98)00034-5

Spence, S. H., Barrett, P. M., & Turner, C. M. (2003). Psychometric properties of the Spence Children's Anxiety Scale with young adolescents. *Journal of Anxiety Disorders*, *17*(6), 605–625. https://doi.org/10.1016/S0887-6185(02)00236-0

Srivastava, P., & Hopwood, N. (2009). A Practical Iterative Framework for Qualitative Data Analysis. *International Journal of Qualitative Methods*, *8*(1), 76–84. https://doi.org/10.1177/160940690900800107

Stagg, S. D., & Vincent, J. (2019). Autistic traits in individuals self-defining as transgender or nonbinary. *European Psychiatry*, *61*, 17–22. https://doi.org/10.1016/j.eurpsy.2019.06.003

Steiger, J. H. (1980). Tests for comparing elements of a correlation matrix. *Psychological Bulletin*, *87*(2), 245–251. https://doi.org/10.1037/0033-2909.87.2.245

Strang, J. F., Powers, M. D., Knauss, M., Sibarium, E., Leibowitz, S. F., Kenworthy, L., Sadikova, E., Wyss, S., Willing, L., Caplan, R., Pervez, N., Nowak, J., Gohari, D., Gomez-Lobo, V., Call, D., & Anthony, L. G. (2018). "They Thought It Was an Obsession": Trajectories and Perspectives of Autistic Transgender and Gender-Diverse Adolescents. *Journal of Autism and Developmental Disorders*, *48*(12), 4039–4055. https://doi.org/10.1007/s10803-018-3723-6

Strang, J. F., van der Miesen, A. I., Caplan, R., Hughes, C., daVanport, S., & Lai, M.-C. (2020). Both sex- and gender-related factors should be considered in autism research and clinical practice. *Autism*, *24*(3), 539–543. https://doi.org/10.1177/1362361320913192

Syu, Y.-C., Huang, P.-C., Wang, T.-Y., Chang, Y.-C., & Lin, L.-Y. (2020). Relationship Among Sensory Over-Responsivity, Problem Behaviors, and Anxiety in Emerging Adults with Autism Spectrum Disorder. *Neuropsychiatric Disease and Treatment*, *Volume 16*, 2181–2190. https://doi.org/10.2147/NDT.S270308

Syu, Y.-C., & Lin, L.-Y. (2018). Sensory Overresponsivity, Loneliness, and Anxiety in Taiwanese Adults with Autism Spectrum Disorder. *Occupational Therapy International*, *2018*, 1–7. https://doi.org/10.1155/2018/9165978

Tavassoli, T., Bellesheim, K., Siper, P. M., Wang, A. T., Halpern, D., Gorenstein, M., Grodberg, D., Kolevzon, A., & Buxbaum, J. D. (2016). Measuring Sensory Reactivity in Autism Spectrum Disorder: Application and Simplification of a Clinician-Administered Sensory Observation Scale. *Journal of Autism and Developmental Disorders*, *46*(1), 287–293. https://doi.org/10.1007/s10803-015-2578-3

Tavassoli, T., Hoekstra, R. A., & Baron-Cohen, S. (2014). The Sensory Perception Quotient (SPQ): Development and validation of a new sensory questionnaire for adults with and without autism. *Molecular Autism*, *5*(1), 29. https://doi.org/10.1186/2040-2392-5-29

Tavassoli, T., Miller, L. J., Schoen, S. A., Nielsen, D. M., & Baron-Cohen, S. (2014). Sensory over-responsivity in adults with autism spectrum conditions. *Autism*, *18*(4). https://doi.org/10.1177/1362361313477246

Toerien, M., & Wilkinson, S. (2004). Exploring the depilation norm: A qualitative questionnaire study of women's body hair removal. *Qualitative Research in Psychology*, *1*(1), 69–92. https://doi.org/10.1191/1478088704qp006oa

Toscano, R., Baillie, A. J., Lyneham, H. J., Kelly, A., Kidd, T., & Hudson, J. L. (2020). Assessment of anxiety in children and adolescents: A comparative study on the validity and reliability of the Spence Children's Anxiety Scale in children and adolescents with anxiety and Autism Spectrum Disorder. *Journal of Affective Disorders*, *260*, 569–576. https://doi.org/10.1016/j.jad.2019.09.055

Turner-Brown, L. M., Baranek, G. T., Reznick, J. S., Watson, L. R., & Crais, E. R. (2013). The First Year Inventory: A longitudinal follow-up of 12-month-old to 3-year-old children. *Autism*, *17*(5), 527–540. https://doi.org/10.1177/1362361312439633

Uljarević, M., Lane, A., Kelly, A., & Leekam, S. (2016). Sensory subtypes and anxiety in older children and adolescents with autism spectrum disorder: Sensory Subtypes and Anxiety in Autism. *Autism Research*, *9*(10), 1073–1078. https://doi.org/10.1002/aur.1602

Uljarević, M., Richdale, A. L., McConachie, H., Hedley, D., Cai, R. Y., Merrick, H., Parr, J. R., & Le Couteur, A. (2018). The Hospital Anxiety and Depression scale: Factor structure and psychometric properties in older adolescents and young adults with autism spectrum disorder: Hospital anxiety and depression scale in ASD. *Autism Research*, *11*(2), 258–269. https://doi.org/10.1002/aur.1872

Valla, J. P., Kovess, V., Chan Chee, C., Berthiaume, C., Vantalon, V., Piquet, C., Gras-Vincendon, A., Martin, C., & Alles-Jardel, M. (2002). A French study of the Dominic Interactive. *Social Psychiatry and Psychiatric Epidemiology*, *37*(9), 441–448. https://doi.org/10.1007/s00127-002-0575-2

van Steensel, F. J. A., Bögels, S. M., & Dirksen, C. D. (2012). Anxiety and Quality of Life: Clinically Anxious Children With and Without Autism Spectrum Disorders Compared. *Journal of Clinical Child & Adolescent Psychology*, *41*(6), 731–738. https://doi.org/10.1080/15374416.2012.698725

van Steensel, F. J. A., Bögels, S. M., & Perrin, S. (2011). Anxiety Disorders in Children and Adolescents with Autistic Spectrum Disorders: A Meta-Analysis. *Clinical Child and Family Psychology Review*, *14*(3), 302–317. https://doi.org/10.1007/s10567-011-0097-0

van Steensel, F. J., Deutschman, A. A., & Bögels, S. M. (2013). Examining the Screen for Child Anxiety-Related Emotional Disorder-71 as an assessment tool for anxiety in children with high-functioning autism spectrum disorders. *Autism*, *17*(6), 681–692. https://doi.org/10.1177/1362361312455875

Vasa, R. A., Keefer, A., McDonald, R. G., Hunsche, M. C., & Kerns, C. M. (2020). A Scoping Review of Anxiety in Young Children with Autism Spectrum Disorder. *Autism Research*. https://doi.org/10.1002/aur.2395

Vasa, R. A., Kreiser, N. L., Keefer, A., Singh, V., & Mostofsky, S. H. (2018). Relationships between autism spectrum disorder and intolerance of uncertainty: Relationships between IU and ASD. *Autism Research*, *11*(4), 636–644. https://doi.org/10.1002/aur.1916

Vasa, R. A., & Mazurek, M. O. (2015). An update on anxiety in youth with autism spectrum disorders: *Current Opinion in Psychiatry*, *28*(2), 83–90. https://doi.org/10.1097/YCO.0000000000000133

Vasa, R. A., Mazurek, M. O., Mahajan, R., Bennett, A. E., Bernal, M. P., Nozzolillo, A. A., Arnold, L. E., & Coury, D. L. (2016). Assessment and Treatment of Anxiety in Youth With Autism Spectrum Disorders. *PEDIATRICS*, *137*(Supplement), S115–S123. https://doi.org/10.1542/peds.2015-2851J

Walsh, R. J., Krabbendam, L., Dewinter, J., & Begeer, S. (2018). Brief Report: Gender Identity Differences in Autistic Adults: Associations with Perceptual and Socio-cognitive Profiles. *Journal of Autism and Developmental Disorders*, *48*(12), 4070–4078. https://doi.org/10.1007/s10803-018-3702-y

Wechsler, D., & Naglieri, J. A. (2006). *Wechsler nonverbal scale of ability: WNV*. TX: PsychCorp.

White, S. W., Oswald, D., Ollendick, T., & Scahill, L. (2009). Anxiety in children and adolescents with autism spectrum disorders. *Clinical Psychology Review*, *29*(3), 216–229. https://doi.org/10.1016/j.cpr.2009.01.003

Wigham, S., Rodgers, J., South, M., McConachie, H., & Freeston, M. (2015). The Interplay Between Sensory Processing Abnormalities, Intolerance of Uncertainty, Anxiety and Restricted and Repetitive Behaviours in Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *45*(4), 943–952. https://doi.org/10.1007/s10803-014-2248-x

Wood, J. J., Ehrenreich-May, J., Alessandri, M., Fujii, C., Renno, P., Laugeson, E., Piacentini, J. C., De Nadai, A. S., Arnold, E., Lewin, A. B., Murphy, T. K., & Storch, E. A. (2015). Cognitive

Behavioral Therapy for Early Adolescents With Autism Spectrum Disorders and Clinical Anxiety: A Randomized, Controlled Trial. *Behavior Therapy*, *46*(1), 7–19. https://doi.org/10.1016/j.beth.2014.01.002

Woodbury-Smith, M. R., Robinson, J., Wheelwright, S., & Baron-Cohen, S. (2005). Screening Adults for Asperger Syndrome Using the AQ: A Preliminary Study of its Diagnostic Validity in Clinical Practice. *Journal of Autism and Developmental Disorders*, *35*(3), 331–335. https://doi.org/10.1007/s10803-005-3300-7

Yap, M. B. H., Morgan, A. J., Cairns, K., Jorm, A. F., Hetrick, S. E., & Merry, S. (2016). Parents in prevention: A meta-analysis of randomized controlled trials of parenting interventions to prevent internalizing problems in children from birth to age 18. *Clinical Psychology Review*, *50*, 138–158. https://doi.org/10.1016/j.cpr.2016.10.003

Zainal, H., Magiati, I., Tan, J. W.-L., Sung, M., Fung, D. S. S., & Howlin, P. (2014). A Preliminary Investigation of the Spence Children's Anxiety Parent Scale as a Screening Tool for Anxiety in Young People with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, *44*(8), 1982–1994. https://doi.org/10.1007/s10803-014-2075-0

Zigmond, A. S., & Snaith, R. P. (1983). The Hospital Anxiety and Depression Scale. *Acta Psychiatrica Scandinavica*, *67*(6), 361–370. https://doi.org/10.1111/j.1600-0447.1983.tb09716.x

Appendices

Appendix 1: Spearman's partial correlation table for section 3.5.2.

Supplementary table
Spearman's partial correlations between sensory reactivity differences (SPSI and SAND composite z-scores), anxiety (PAS), and intolerance of uncertainty (RULES), controlling for autism traits (AQ).

	Hyperreactivity	Hyporeactivity	Seeking	IU
Total anxiety	**.403* (.006)**	-.186 (.220)	-.046 (.763)	**.707** (.000)**
GAD	**.271 (.072)**	-.199 (.190)	-.038 (.803)	**.681** (.000)**
Social anxiety	**.348 (.019)**	-.236 (.118)	-.026 (.867)	**.570** (.000)**
OCD	**.287 (.056)**	-.078 (.610)	.092 (.549)	**.585** (.000)**
Physical injury fears	**.318 (.033)**	-.288 (.055)	-.214 (.158)	**.438** (.000)**
Separation anxiety	**.371* (.010)**	-.197 (.196)	-.032 (.833)	**.653** (.000)**
IU	**.429* (.004)**	-.050 (.749)	-.022 (.888)	-

*. Correlation is significant at the $p \leq 0.01$ level (2-tailed) after a Bonferroni correction
**. Correlation is significant at the $p < 0.001$ level (2-tailed)
Significant correlations prior to Bonferroni correction are indicated in bold without being flagged
Note. GAD: Generalised anxiety symptoms; OCD: Obsessive-compulsive symptoms; IU: Intolerance of Uncertainty; ADOS-2: Autism Diagnostic Observation Schedule-2

Appendix 2: Mediation statistics table for section 4.5.2

Supplementary table

Mediation analyses between sensory hyperreactivity and seeking (SPSI), anxiety (SCAARED), and intolerance of uncertainty (IUS).

Predictor	Mediator	Outcome	Total effect					Direct effect					Indirect effect				
			B	*se*	LL	UL	*p*	*B*	*se*	LL	UL	*p*	*B*	*se*	LL	UL	*p*
Hyper	IU	Anxiety	.033	.006	**.019**	**.047**	**<.001***	.009	.006	-.004	.021	.130	.024	.004	**.016**	**.034**	**<.001***
Seeking	IU	Anxiety	.018	.009	**-.002**	**.036**	**.048**	.016	.008	**.002**	**.033**	**.038**	.002	.004	-.008	.010	.729
Hyper	Anxiety	IU	.046	.006	**.034**	**.057**	**<.001***	.030	.005	**.020**	**.041**	**<.001***	.016	.003	**.009**	**.022**	**<.001***
Seeking	Anxiety	IU	.003	.009	-.014	.020	.729	-.005	.007	-.020	.009	.466	.008	.004	.000	.017	.053

*. Correlation is significant at the Bonferroni corrected $p \leq .013$ (.05/4) level (2-tailed)

Significant correlations prior to Bonferroni correction are indicated in bold without being flagged

Note. Hyper: Sensory hyperreactivity; IU: Intolerance of uncertainty; *se*: standard error; LL and UL: 95 % confidence intervals Lower Limit and Upper Limit. Significant relationships at the $p<0.008$ level after a Bonferroni correction highlighted in bold.

Appendix 3: Semi-structured questionnaire referred to in section 5.4.3

[Information sheet]
[Consent]

Demographic questions

Please complete this questionnaire based on your own experiences. It is not a problem if you require support to complete this questionnaire, but the answers to questions must be your own input.

Age [open text box]

I have a diagnosis of autism or Asperger's [YES / NO] [if NO, send to end of questionnaire]

I have additional diagnoses [select option with space for additional relevant diagnosis]

Gender [open text or options]

Ethnicity [options]

Living situation [city, town, village]

Definition of terms
Throughout this questionnaire, we will ask you about your different sensory experiences using the terms: hyperreactivity, hyporeactivity and seeking behaviour. These are how we define these terms:

Hyperreactivity
Hyperreactivity describes behavioral responses to sensory stimuli that are more extreme than what is observed in typically developing individuals. Someone who is hyperreactive shows aversive behavior towards an ordinary stimulus. Individuals may engage in avoidance behavior (e.g., turning away, covering ears/eyes), use nonverbal cues (e.g., startled facial expression), or verbally express their dislike of a stimulus. For example, individuals who are hyperreactive to sound might hold their hands over their ears in response to ordinary sounds, such as a vacuum cleaner. An individual who is hyperreactive to touch might avoid wearing clothes of certain material or avoid eating food of certain texture. An individual who is visually hyperreactive might squint or turn away from bright ceiling lights. Sensory hyperreactivity can impair daily functioning when certain environments must be avoided or modified due to an overload of sensory stimulation.

Hyporeactivity

Hyporeactivity describes behavioral responses to sensory stimuli that are less than what is observed in typically developing individuals. People who respond less, slower, or do not respond at all are considered hyporeactive to sensory stimuli that others would notice. For example, an individual who is hyporeactive to sound might not notice or be slow to respond to a loud siren. An individual who is hyporeactive to touch might display a high threshold for hot or cold temperatures or pain. An individual who is hyperreactive to visual stimuli might not notice a flashing light or might require frequent prompting to notice items in his or her surroundings. Sensory hyporeactivity can impair daily functioning often due to safety concerns (e.g., slow to respond to a car passing by, failure to notice extreme temperatures or alarms/sirens).

Sensory Seeking

Sensory seeking describes behavioral responses to sensory stimuli that are unusual due to the frequency or intensity of a response to a stimulus. For example, an individual who seeks sounds might put noisemaking objects close to his or her ears. An individual who seeks tactile stimuli might rub textures of interest repeatedly. An individual who seeks visual stimuli might inspect parts of objects close to his or her eyes. Sensory seeking behavior can impair daily functioning when an individual's interest interferes with his or her participation in everyday activities (e.g., socialization, personal care).

General

Do you generally consider yourself sensory **hyperreactive**? [yes/ no]

1a. Describe your experience of being sensory **hyperreactive**. Enter N/A if you have no experiences that are sensory hypersensitive [open text 300 word limit]

Do you generally consider yourself sensory **hyporeactive**? [yes/ no]

2a. Describe your experience of being sensory **hyporeactive**. Enter N/A if you have no experiences that are sensory hyposensitive [open text 300 word limit]

Do you generally consider yourself sensory **seeking**? [yes/ no]

3a. Describe your experience of being sensory **seeking**. Enter N/A if you have no experiences that are sensory seeking [open text 300 word limit]

Describe any **other** or your **neutral** experiences of the sensory environment. Enter N/A if you have no experiences [open text 300 word limit]

Visual

How do you respond to the visual environment? [example options and open text]

Below are some options gathered from what autistic people have told us they are sensory reactive to, please rate how you respond to these areas using the labels hyperreactive, hyporeactive, sensory seeking or neutral [can select multiple options]

	Hyperreactive	Hyporeactive	Seeking	Neutral
Bright lights				
Flickering lights				
Bright colours				
Low contrast images				
Patterns				
Other [please state]				
[additional information]				

Describe your experiences of being **hyperreactive** to the visual environment. You can describe more than one situation. [N/A option] [open text 300 word limit]

Describe your experiences of being **hyporeactive** to the visual environment. You can describe more than one situation. [N/A option] [open text 300 word limit]

Describe your experiences of being **sensory seeking** to the visual environment. You can describe more than one situation. [N/A option] [open text 300 word limit]

Describe your experiences of being **neutral** to the visual environment. You can describe more than one situation. [N/A option] [open text 300 word limit]

Auditory (sound)

How do you respond to sound/the auditory environment? [example options and open text]

Below are some options gathered from what autistic people have told us they are sensory reactive to, please rate how you respond to these areas using the labels hyperreactive, hyporeactive, sensory seeking or neutral [can select multiple options]

	Hyperreactive	Hyporeactive	Seeking	Neutral
Lots of conversations				
Shopping centres				
Public transport				
Loud noises				
Ambient noises				
High pitch noises				
Music				

Other [please state]
[additional information]

Describe your experiences of being **hyperreactive** to the auditory environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **hyporeactive** to the auditory environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **sensory seeking** to the auditory environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **neutral** to the auditory environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Tactile (touch)
How do you respond to touch/the tactile environment? [example options and open text]

Below are some options gathered from what autistic people have told us they are sensory reactive to, please rate how you respond to these areas using the labels hyperreactive, hyporeactive, sensory seeking or neutral [can select multiple options]

	Hyperreactive	Hyporeactive	Seeking	Neutral
Pressure differences				
Clothes				
Food				
Different textures				
Other [please state]				
[additional information]				

Describe your experiences of being **hyperreactive** to touch. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **hyporeactive** to touch. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **sensory seeking** to touch. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **neutral** to touch. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Interoception (changes in your body)

How do you respond interoceptively/changes in the body due to the environment? [example options and open text]

Below are some options gathered from what autistic people have told us they are sensory reactive to, please rate how you respond to these areas using the labels hyperreactive, hyporeactive, sensory seeking or neutral [can select multiple options]

	Hyperreactive	Hyporeactive	Seeking	Neutral
Cold temperatures				
Hot temperatures				
Changes in the weather				
Physically painful incidents				
Other [please state]				
[additional information]				

Describe your experiences of being **hyperreactive** to changes in the body due to the sensory environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **hyporeactive** to changes in the body due to the sensory environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **sensory seeking** to changes in the body due to the sensory environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **neutral** to changes in the body due to the sensory environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Taste

How do you respond to tastes in the environment? [example options and open text]

Below are some options gathered from what autistic people have told us they are sensory reactive to, please rate how you respond to these areas using the labels hyperreactive, hyporeactive, sensory seeking or neutral [can select multiple options]

	Hyperreactive	Hyporeactive	Seeking	Neutral
Spicy foods				
Food temperatures				
Food textures				
Favourite foods				
Memorable foods				
Chewing gum				
Other [please state]				
[additional information]				

Describe your experiences of being **hyperreactive** to tastes. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **hyporeactive** to tastes. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **sensory seeking** to tastes. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **neutral** to tastes. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Smell

How do you respond to smells/scents in your environment? [example options and open text]

Below are some options gathered from what autistic people have told us they are sensory reactive to, please rate how you respond to these areas using the labels hyperreactive, hyporeactive, sensory seeking or neutral [can select multiple options]

	Hyperreactive	Hyporeactive	Seeking	Neutral
Strong scents				
Perfumes				
Specific scents				
Pollution				
Flowers				
Fresh air				

Other [please state]
[additional information]

Describe your experiences of being **hyperreactive** to smells/scents in the environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **hyporeactive** to smells/scents in the environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **sensory seeking** to smells/scents in the environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Describe your experiences of being **neutral** to smells/scents in the environment. You can describe more than one situation and include any exceptions. [N/A option] [open text 300 word limit]

Thank you for taking part in our study. If you have any questions or concerns as a result of your participation, please contact Keren MacLennan: k.r.maclennan@pgr.reading.ac.uk

Appendix 4: Example quotes for the content analysis for section 5.5.2

Supplementary Table

Example quotes from the content analysis for experiences relating to sensory hyperreactivity, hyporeactivity, and seeking, and in each modality (n = 49).

	Hyperreactive	***Hyporeactive***	***Seeking***
Visual	"Sunlight is overwhelming in the summer and I can't stand being out for too long... I also can't stand bright overhead lighting in shops and tend to leave as quickly as possible. Lower overhead lighting is worse and fluorescent is unbearable…" SE029 "A busy visual field causes overload and causes agitation and stimming. I struggle to focus on specific components and take in the entire field, being aware of every movement." SE016	"There are numerous occasions where I was looking for an item which was in plain sight however I it took a long time to find it." SE003	"I can get lost in visual patterns. When I was little one of the churches, we sometimes attended had a patterned coving and I would spend the whole service visually following the infinite line that formed the pattern." SE010
Auditory	"With multiple conversations… my experience is similar to listening to a radio station that then blends into the other one, so you're constantly hearing every other word of the radio station, until at some point the streams completely overlap, but somehow in complete clarity. This, along with all the loud environmental noise (which may seem like nothing to most people - air conditioning humming, projector buzzing, lights buzzing, plates clinking in a restaurant kitchen), can drive me into a shutdown. And then every sound is utterly overwhelming." SE040	"Some sounds make me sleepy and if I'm sleepy or focused I just won't hear things. Like I was reading one time and didn't hear the fire alarm." SE039	"Music calms me down when I'm stressed. Tend to listen to the same song on repeat for hours at a time." SE022
Tactile	"I have to check the texture of fabrics when I'm clothes shopping. Anything rough or crunchy I can't wear. I also need soft and stretchy fabrics." SE038 "I don't like unexpected touch from other people. I prefer firm touch to light touch." SE011 "I'm touch sensitive. I hate other people touching me. My skin crawls, I sweat excessively, and I feel nausea. Especially if it's bare skin. Makes intimacy nigh on impossible." SE030		"It is extremely difficult to provide me with enough, let alone too much, deep pressure. Sometimes I will ask my husband for a tight hug and even the tightest hug he can provide is insufficient to satisfy me. Often, I need him to lie on top of me to provide added pressure." SE046 "Fluffy textures calm me. I have a fluffy blanket in the car to help manage my anxiety on car journeys and one I carry in my bag to calm me on other occasions." SE016
Interoception	"Heat can be utterly unbearable, especially because it interferes with some of my other sensory preferences such as pressure seeking. Even in ordinary warm summer days around 20C, my functioning is impaired, and I feel discomfort. During a true 'heatwave' I can be essentially in a permanent state of shutdown. This sensitivity extends to hot water, as I have an immediate recoil tendency upon entering water even approaching scalding hot." SE046	"I have failed to notice broken bones. I went hiking the day after breaking my foot and walked to school the day after focally fracturing my shin." SE024 "I don't notice until 'too late' that I'm too cold [or] too hot" SE015	"In cold weather I make a blanket nest and a hot water bottle on my back and on my stomach." SE030
Gustatory	"I am very particular about tastes. I only like quite bland foods and can't stand any		"I will continuously seek tastes that I enjoy." SE003

	kind of spice. I will find a food unbearably spicy that others say has no spice to it at all. I used to find fizzy drinks too intense when I was younger." SE011		"I eat when I'm not hungry because I want the taste." SE019
Olfactory	"I have had to quit jobs and refuse assignments due to my being hyperreactive to scents… My aversion to strong, unpleasant scents is so strong that it triggers my gag reflex, can make me throw up, makes me cry, and makes me escape the environment. I have tried but have no control over it. Changing nappies for my kids was challenging. Usually my husband did it. If my kids vomited, the smell made me vomit." SE031	"Often I can't smell subtle smells like flowers or smoke that other people comment on." SE022	"I have a jar of cinnamon in my soothe box, and sawdust because that evokes my pets and makes me calmer… I smell my hands a lot without thinking about it - sometimes it is annoying when they smell of soap. I like it when they smell of yesterday's onions I was chopping." SE10