Distraction, Distress and Diversity: The impact of sensory processing differences on learning and school life for autistic pupils

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Distraction, Distress and Diversity: The impact of sensory processing differences on learning and school life for autistic pupils

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Thesis abstract

The current thesis adopted a mixed-method multi-informant approach to investigate the impact of sensory differences on academic achievement and classroom behaviour for autistic pupils. Study 1 focused on the role of IQ in predicting autistic and neurotypical pupil's academic achievement. Although IQ predicted achievement in both groups, significant IQ-achievement discrepancies were identified, suggesting that factors beyond IQ, might be influencing the achievement of autistic pupils. To explore this possibility, Study 2 asked parents and teachers, if, and how, sensory differences impacted learning and school life for autistic pupils. Sensory differences were perceived to impact learning by causing distraction, distress, anxiety, and limited participation. Factors including predictability, school resources, and staff knowledge minimized sensory disruption. Building on these insights, in Study 3 late-diagnosed autistic females were asked to reflect upon the impact of sensory differences at school. These insights highlighted how sensory differences could exacerbate an already difficult social world. Study 4 used standardized assessment to examine the relationship between sensory processing differences, academic achievement, and classroom behaviour. Although greater sensory differences were associated with greater levels of hyperactivity and poorer peer-relations, unexpectedly Sensitivity was positively related to Reading achievement and accounted for a small but significant amount of variance in scores. Adopting an experimental paradigm, Study 5 examined how the sensory environment impacted the ability of autistic and neurotypical pupils to stay on-task. Children were asked to complete a reading task in a pop-up classroom in four different environmental conditions; Neutral, Audio, Visual, and Audio-visual. Compared to neurotypical pupils, autistic pupils displayed

greater levels of off-task behaviour across all conditions. However, both groups showed greatest levels of off-task behaviour in the Visual and Audio-Visual condition, showing how certain types of sensory inputs have greater or lesser impact on children's ability to focus in a classroom type scenario (irrespective of diagnosis). Framed within a Nordic Model of Disability, these insights have been drawn together to develop a framework for understanding how, and under which circumstances, sensory differences impact the educational outcomes of autistic pupils.

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Declaration

Data presented in Chapter 3 were collected across two independent projects. Elizabeth Jones and Emily McDougal (MCDougal, Riby & Hanley, 2020) both collected data for this project. Both parties were involved in conception of the study, however Elizabeth Jones performed the statistical analysis and drafted the chapter.

Chapter 4 includes one published paper that has appeared as:

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Chapter 5 has been written up for publication as a brief report for submission to a journal.

Statement of copyright

Acknowledgments

First, thank you to my supervisors, Debbie, and Mary, for your support and guidance throughout my PhD. Mary, it seems so long ago that I was sat in your third-year module. I do however vividly remember asking you about the MSc course whilst buying a snack in the Science Site Café. Standing in that queue you encouraged me to apply for 1+3 Studentship. I think it's fair to say I haven't had such a transformational Dairy Milk since. Debbie, your passion for autism research is inspirational. I think most of all, I'm grateful for the resilience and dedication shown by both of you during the last few years. There's been some challenging times, but you've remained supportive and encouraging throughout. I am also very grateful to the ESRC and NINEDTP for funding my studentship [ES/J500082/1] and to all the children, parents, and teachers who took part. This research would not have been possible without you.

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A Note on Language

Throughout this thesis I alternate between identity-first language (i.e., “autistic person”) and person-first language (i.e., “person with autism”). This decision reflects the on-going debate within the autism community about the most appropriate way to talk about individuals with a diagnosis of Autism. Person-first language is said to place an “emphasis on the person’s unique combination of strengths, needs, and experiences (both related and unrelated to their disability)” (Vivanti, 2020; 692). Conversely, identity-first language signals that autism cannot be separated from the individual. That is, identify-first language places autism as a central defining feature to be celebrated (Robertson and Ne’eman, 2008; Vivanti, 2020). Reflecting this, a 2016 UK survey found a preference for the term “autistic" over “person with autism” within the autism community (Kenny et al. 2016). However, to respect the wishes of all members of the community both terms have been used in this thesis. Similar approaches have been adopted in existing published studies (Sedgewick et al., 2016).

Chapter 1: Introduction to sensory processing differences in autism

1.1 Thesis Introduction

It's unusually quiet in year three today. So quiet that only the ticking clock and scraping of a pencil can be heard. It won't last long of course. The spelling test is nearly over and the bell for playtime is due to ring at any moment. "The next word is 'because', Miss Evans announces. Harry sighs, he can never get this one quite right! He knows though, that on one of the classrooms displays there might a clue to help him. "And our 9th word is…", Miss Evans explains. "9th word! We were only on the 7th a minute ago!", Harry shouts. Rosie laughs, Harry always seems to be 'daydreaming'. She, however, knows exactly how to spell Wed-nes-day. Bella too knows how to spell this one but isn't writing anything. All Bella can think about is how scratchy her jumper is and how bright the lights are. And there it is, the bell for break! "Wait! You can't go until you've put your sheets in the middle of the table and collected your snack", Miss Evans shouts. Rosie doesn't have time to wait, she's too excited to get outside and play football on the yard. She runs past Harry, knocking his snack on the floor. "Watch it!", he shouts. Bella covers her ears and quickly makes her way to the reading corner. She much prefers it by here, it's quiet and she can read all of her favourite stories…

Moments like this take place in classrooms up and down the country every day. Indeed, classrooms are often busy, unpredictable, and stimulating spaces, with lots of children learning and playing alongside one another (Barrett et al., 2015). To learn and respond adaptively in this environment, children need to process, organize, and modulate all of this incoming sensory information (Dunn, 1999; Ayers, 1972). This ability is referred to as sensory processing (Dunn, 1999; Ayers, 1972). Between 60-90% of autistic individuals however, experience sensory processing differences (Ben-Sasson et al., 2019). These differences are often referred to *hypersensitivity (e*.g., too much sensory stimulation*)* and *hyposensitivity (*e.g., too little sensory stimulation*)* (Leekam et al., 2007; Kientz & Dunn, 1997; Ben-Sasson et al., 2019). In the extract above, Bella might be thought of as demonstrating hypersensitivity (e.g., finding the classroom lights too bright and her clothes too itchy) whereas Harry might be thought of as experiencing hyposensitivity (e.g., missing the next word on the spelling test). Although sensory processing differences can bring joy to many autistic individuals (Smith & Smith, 2013), they can also have substantial and negative impact on everyday functioning, particularly in unpredictable and multisensory environments (Howe & Stagg, 2016, Donohue et al., 2012). Sensory processing differences may, therefore, be especially prominent and challenging in a busy classroom context (Ashburner, Ziviani & Rodger, 2008; Piller & Pfieffer, 2016). To date however, very little research has considered how these sensory experiences, or the classroom sensory environment itself, impact the learning and behaviour of autistic children (Ashburner, Ziviani & Rodger, 2008, Hanley et al., 2017). This represents a substantial evidence gap in both our theoretical understanding of sensory differences, and also in our applied understanding of how best to support autistic pupils at school.

The core aim of this thesis is to investigate the relationship between sensory processing differences, academic achievement, and classroom behaviour in autistic children. The thesis will adopt a Nordic Relational Model of Disability and explore the impact of a child's sensory differences, the impact of the classroom environment and also consider the interaction between these factors. Central to achieving this aim is the use of a multi-methods approach to allow for multiple perspectives to be captured. To demonstrate why this research and particular approach is needed, the thesis will begin by exploring the evidence for sensory processing differences in Autism Spectrum Disorder (ASD). Chapter 2 will then outline why understanding sensory differences in an educational context is so important, before describing the aims and methodological approach of each empirical chapter.

The current chapter aims to provide a detailed review of sensory processing differences in ASD. First, autism and the concept of sensory processing will be introduced, and the applied and theoretical arguments for focusing on sensory differences in ASD detailed. Next, the nature and severity of sensory differences in autism will be examined. The approaches for investigating sensory differences will be briefly described and Dunn's Sensory Processing Framework introduced (Dunn, 1999). Based on evidence collected via questionnaires and qualitative reports, it will be emphasized that there is substantial variability in the sensory differences experienced by autistic individuals. The final section of this chapter will therefore explore the factors that might account for this variability, focusing on measurement, developmental trajectories, gender, sensory subtypes, and environmental differences.

1.2 Autism Spectrum Disorder

ASD is a lifelong neurodevelopmental condition characterized by differences in social communication and interaction, alongside restricted and repetitive behaviours, and interests (RRBI) (APA, 2013). In addition to these differences, autistic individuals also display a range of strengths including, attention to detail, special skills, and spatial memory (Meilleur, Jelenic, & Mottron, 2014; Fanning et al., 2018). Prevalence estimates suggest that 1% of the UK population are autistic, with 70-75% of autistic individuals also meeting the threshold for an additional neurodevelopmental or psychiatric condition including: anxiety or mood disorder, attention deficit hyperactivity disorder (ADHD), and oppositional defiant disorder (ODD) (Levy et al., 2010; Simonoff et al., 2008). Historically, four times as many males as females have received an ASD diagnosis (Loomes, Hull & Mandy, 2017). However, there is increasing recognition that many females, have been, and continue to be, undiagnosed or misdiagnosed, with more recent estimates suggesting that this sex ratio is closer to three to one (Loomes, et al., 2017). Twin studies have shown that autism has a strong genetic basis, such that concordance rates (likelihood of both twins being autistic) are much greater in monozygotic twins compared to dizygotic twins (Rosenberg et al., 2009; Hallmayer et al., 2011). Autism cannot be attributed to a mutation on a single gene and instead is thought to reflect the action of hundreds of common genetic variants (Miles, 2011; Fletcher-Watson & Happé, 2019). It is because of this that autism is diagnosed based on the set of behaviours, rather than relying on genetic testing (APA, 2013).

Autism, is a heterogeneous condition, meaning that although social difficulties and RRBI are the core behaviours needed for an ASD diagnosis, the presentation and severity of these behaviours vary substantially from person to person (Georgiades, Szatmari & Boyle, 2013). Social and communication difficulties, for instance, can include challenges in social-emotional reciprocity, understanding nonverbal communication cues or developing and maintaining friendship (Fletcher-Watson & Happé, 2019; Thye et al., 2018; APA, 2013). This heterogeneity means that while one autistic child might seem disinterested in their classmates, another autistic child might be eager but unsure how to make friends, whereas another autistic child might develop friendships based on shared interests (Fletcher-Watson & Happé, 2019). RRBI are also variable and can include behaviours such as repetitive motor movements, insistence on sameness, and restricted and fixated interests (APA, 2013). This could include behaviours as varied as lining up toys, spinning and flapping, or demonstrating an in-depth knowledge and fascination with a particular topic.

In the DSM-5, sensory processing differences were introduced as a subcategory of RRBI (APA, 2013). Sensory differences can include hypersensitivity (e.g., responding adversely to a specific sound or texture), hyposensitivity (e.g., apparent indifference to pain/temperature) and unusual interests in sensory aspects of the environment (e.g., excessive smelling or touching of objects) (APA, 2013). Again, the presentation and severity of sensory differences is also highly variable. Whereas one autistic child might become upset by a loud school bell, another autistic child might not notice the cold and neglect to wear their coat on the schoolyard (Cascio et al., 2016, Dunn et al., 2016). Although sensory processing differences were documented in the early writings of autism, to date, much of the behavioural research has focused on the social and RRBI aspects of ASD (Happé

& Frith, 2020; Thye et al., 2018). To build a comprehensive understanding of ASD however, sensory differences also need to be considered, alongside their interaction with the social and other RRBI components of the condition (Uljarevic et al., 2017; Pellicano, 2013). To illustrate why this is the case, the following section will introduce sensory processing before presenting several arguments as to why focusing on sensory differences is important for both our applied and theoretical understanding of ASD.

1.3 The Sensory World

Our senses provide the information needed to organize and process incoming information from the world around us (Dunn, 1997). There are seven sensory systems: visual, auditory, olfactory (smell), gustatory (taste), tactile (touch), vestibular and proprioceptive. Sensory processing is the mechanism by which the central nervous system receives input from the senses and integrates this information to produce an appropriate and adaptive behavioural response (Dunn, 1997; Robertson & Baron-Cohen, 2017). For most individuals this process is automatic (Dionne-Dostie et al., 2015). For instance, when we hear someone talking to us (auditory stimuli), we interpret this information as speech and tend to respond by turning our head to listen. Likewise, when we are standing on a bus or a train and it starts to move (vestibular stimuli) we automatically shift our weight, so we do not fall. Both of these examples reflect unimodal sensory processing (Dionnie-Dostie et al., 2015). However, to experience a coherent and unified percept of the world, we also need to integrate and bind information across multiple sensory domains (Calvert, Spence & Stein, 2004). This is referred to as multisensory processing. An example of multisensory processing is integrating the sound of a car (auditory information) and sight of a car (visual information) when deciding if it's safe to a cross a road. Both unimodal and multisensory processing are therefore critical in guiding how we respond and interact with the world around us (Koziol, Budding & Chidekel, 2011; Dunn, 1999; Ayers, 1972). Sensory processing has thus been proposed to have a central role in child development (Ayers, 1972, Dunn, 1999; Williams & Shellenberger, 1996). As illustrated in Figure 1.1, several researchers have proposed a hierarchical structure in which sensory processing influences the development of higher-order processes including perceptual motor planning and cognition (Koziol, Budding & Chidekel, 2011; Williams & Shellenberger, 1996).

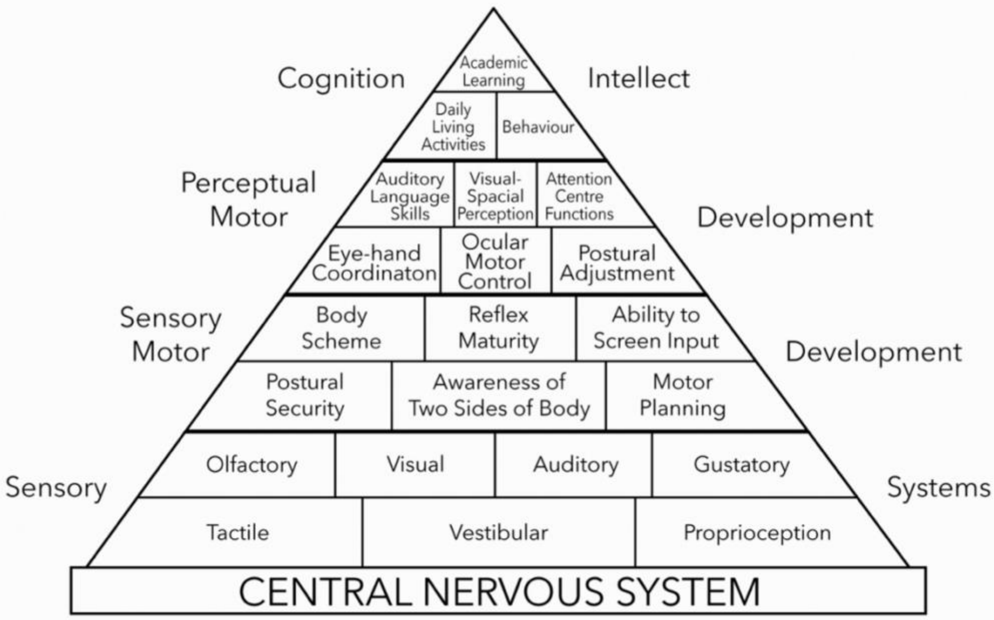


Figure 1.1 Williams & Shellenberger (1996): Pyramid of Learning

Within this framework, appropriate sensory processing allows an infant to explore and respond adaptatively to their surroundings, enabling them to learn new motor skills, regulate attention and engage in positive social experiences (Williams & Shallenberger, 1996). It follows therefore, that differences in sensory processing early in life could impact a range of behaviours and cognitive functions that are critical for day-to-day living (Dunn, 1999; Ayers, 1972). This is turn could also impact upon wider life outcomes, including health, employment, and, as reviewed in Chapter 2, education (Dunn, 1999). There is, therefore, a need to understand the nature and severity of sensory differences and explore the extent to which these differences impact wider outcomes.

1.4 Why focus on sensory differences in ASD?

It should be noted that sensory differences have been reported in other neurodevelopmental conditions such as dyslexia and ADHD. However, the prevalence and impact of these differences appear to be particularly high in ASD (Dellapiazza et al., 2020). Indeed, one of the key reasons for focusing on sensory differences in ASD is that it has been identified as a key research priority by the autistic community (Fletcher-Watson & Happé, 2019). In 2016, Autistica and the James Lind Alliance conducted a survey with autistic individuals from a range of ages, abilities, and backgrounds, to explore what topics and research questions were most important to the autistic community. Findings from this survey led to 10 community research priorities being published; two of which are central to this thesis. The first being “How can sensory processing in autism be better understood?” and the second “Which environments/supports are most appropriate in terms of achieving the best educational /life/social skills outcomes in autistic people?” (Fletcher-Watson & Happé, 2019). Focusing on sensory differences is therefore vital for meeting the needs of the autistic community. Meeting this need is important because sensory processing differences can have far-ranging and often negative impacts (Dunn et al., 2016). Indeed, supporting the hierarchical structure proposed by Williams and Shallenberger (1996), sensory processing differences have been associated with difficulties in daily living (Jasmin, 2009), social play (Kuhaneck & Britner, 2013), anxiety (Green et al., 2012) sleep problems (Reynolds, Lane & Thacker, 2012), and education (see this followed up in Chapter 2). Understanding sensory processing differences more comprehensively and identifying the environments in which these differences are most challenging, is therefore vital for improving outcomes for autistic individuals (Uljarevic et al., 2017).

Alongside applied impacts, there are also theoretical reasons for focusing on sensory differences in ASD. Foremost, exploring the nature and development of sensory differences may help in providing a more unified account of ASD by bridging the gap between the social and RRBI components of the condition (Pellicano, 2013; Thye et al., 2018). To date, much of the behavioural research on RRBI and social experiences in autism has been siloed (Happé & Frith, 2020). This means that the more prevailing theories of autism share the limitation of being unable to account for all aspects of the condition (Happé & Frith, 2020). This issue can be highlighted by considering the Theory of Mind (ToM) account of ASD (Baron-Cohen, Leslie & Frith, 1985). Theory of mind is the ability to understand that others have beliefs, desires, information, and intentions that may differ from our own. According to this hypothesis, autistic individuals have 'deficits' or 'impairments' in ToM, which prevents them from inferring the mental states and perspectives of others (Baron-Cohen, Leslie & Frith, 1985). This theory was developed in large from a series of studies that used false-belief tasks to assess if children with and without neurodevelopmental conditions could infer the mental state of various characters (Baron-Cohen, 2000). Findings from these studies showed that while 85% of neurotypical children and 86% of children with Down

Syndrome were able to infer the correct mental state, and therefore demonstrate ToM abilities, 80% of autistic children failed (Baron-Cohen, Leslie & Frith, 1985). There have however, been several challenges to this theory (Gernsbacher & Yergeau, 2019). Foremost, there is strong evidence that some autistic children can pass this task, meaning that theory lacks universality (Gernsbacher & Yergeau, 2019; Fletcher-Watson & Happé, 2019). Second, linguistic ability has been shown to influence false-belief tasks, raising doubt over which abilities this task measures (Gernsbacher & Yergeau, 2019; Fletcher-Watson & Happé, 2019). Third, while ToM may be able to account for some of the social difficulties faced by autistic individuals, it certainly does not explain RRBI and sensory differences, which are also central to the autistic experience (Thye et al., 2018; Brundson & Happé, 2014). Conversely, theories that have focused on RRBI are unable to account for the social and sensory experiences in ASD. Highlighting this is the Weak Central Coherence account of autism (Frith & Happé, 1994). According to this theory, autistic individuals have a bias for local processing rather than global processing. Behaviourally, this means that although autistic individuals may show strengths in attention to detail, they may often miss the 'bigger picture' or gist of a situation (Frith & Happé, 1994). Again, however this theory lacks universality as not all autistic individuals show this local processing bias (Happé, 2005). Likewise, this theory cannot readily account for heterogeneity in the sensory and social experiences reported in ASD (Uljarevic et al., 2017). The inability of a single theory to account for all aspects of autism has led to the suggestion that perhaps multiple accounts are needed to explain the multiple components of the disorder; an idea known as 'fractionation' (Happé, Ronald & Plomin, 2006; Brundson & Happé, 2014).

One reason to focus on sensory differences, however, is that research in this domain may be able to offer a more unified understanding of autism by providing insights into how social and RRBI experiences interact with one another across development (Thye et al., 2018). Indeed, some researchers have argued that the relationship between sensory and social behaviours in ASD is stronger than suggested in traditional models, and may in fact, be bidirectional and inter-dependent (Ronconi, Molteni & Casartelli, 2016; Gilga, 2014; Thye et al., 2018). This to some extent supports the hierarchical structure proposed by Williams and Shellenberger (1996) and highlights the need to understand autism from a developmental trajectory perspective (Happé & Frith, 2020). Importantly, both hyper- and hyposensitivities have the potential to influence social behaviours in ASD (Thye et al., 2018; Kuhaneck & Britner, 2013; Brock et al., 2012). For example, a child with auditory hypersensitivities may become overwhelmed when playing with noisy children on the school yard and might head back inside to escape to a quieter environment. In contrast, a child with hyposensitivity might miss the opportunity for play due to not noticing the noisy children on the other side of the school yard. Both situations can result in the child having less opportunities to practice and develop their socio-communicative skills (Thye et al., 2018). Over time, this may result in less successful interactions, which could lead to further withdrawal and fewer opportunities to develop socio-communicative skills (Thye et al., 2018; Brock et al., 2012). In recognition of this potential inter-dependence, several theories have now begun to integrate sensory and social features in their account of autism (Thye et al., 2018).

One such theory is the Temporal Binding Hypothesis (Brock et al., 2002). When receiving incoming sensory information from the world around us, we are more likely to integrate stimuli that occur together in close temporal proximity (McGurk & MacDonald, 1976; Shams et al., 2000). Autistic individuals however are proposed to have an extended 'temporal binding window', meaning that stimuli occurring in more distal temporal proximity are bound together (Wallace & Stevenson, 2014; Foss-Feig et al., 2010). This is an issue because it creates the risk of unrelated stimuli becoming bound together, which in turn could create a 'fuzzier', unpredictable world (Foss-Feig et al., 2010). Across development, this could lead to important social cues being missed or not integrated (Brock et al., 2002). For instance, if other unrelated stimuli are being integrated, this might mean that important social cues such as concurrent lip movement (visual information) and voice of a parent (auditory stimuli), are less salient and therefore less likely to influence behaviour (Brock et al., 2002). Alongside impacting social responses, it is also proposed that an extended temporal binding window may potentially lead to a preference for RRBI, as these behaviours could offer some certainty and control in an otherwise unpredictable world (Johnson et al., 2015). While this theory of course does not explain all aspects of sensory processing (particularly the co-occurrence of hypersensitivity and hyposensitivity), it does illustrate how sensory differences can interact with social and RRBI experiences and offers a more unified perspective on autism than that seen in ToM and WCC (Thye et al., 2018).

Lastly, research on sensory differences can highlight why we need to shift our conceptualisation of autism from a medical model of a disability to a social-relational framework. Within a medical model of disability, autism is viewed as a “devastating developmental disorder” (Happé, 1999; 216). Critically, differences in social behaviour or RRBI are viewed as ‘deficits’, that reside entirely within the individual (Kapp, 2019; Goodley & Runswick-Cole, 2012). That is, there is a complete disregard of how wider societal and environmental factors influence the behaviour and experiences of autistic individuals (Goodley & Runswick-Cole, 2012; Milton, 2012). ToM in particular is very much engrained within this framework as it identifies autistic cognition as the single cause of social difficulties (Kapp, 2019). Within this framework, autism is viewed as a disorder that needs to be ‘cured’ and so many interventions aim to modify behaviour to fit neurotypical norms (Waltz, 2018; Kapp, 2019).

Focusing on sensory differences can help shift this narrative by highlighting the importance of environmental factors in shaping behaviour (Goodley & Runswick-Cole, 2012). Indeed, the Nordic Relational Model of Disability defines disability as a mismatch between the persons capabilities and the functional demands of the environment. Disability is thus relative to the environment and also situational (Gustavsson et al., 2005). A blind individual is not disabled when speaking on the phone but may experience disability when placed in an environment that has not been adjusted to meet his or her need, for example not having access to braille books (Tossebro, 2014). In the case of sensory processing differences, a child with hypersensitivity might be comfortable at home but may experience ‘disability’ and distress when placed in unpredictable environments with significant sensory inputs such as bright lights and noisy children (Goodley & Runswick-Cole, 2012; Wendelborg & Tøssebro, 2010; Tøssebro, 2014). Approaching sensory differences from a Nordic Relational Model of Disability as opposed to a Medical Model of

Disability, means that sensory differences are no longer seen as a ‘deficit’ that needs to be cured, but are instead something to be celebrated, supported, and understood in relation to the environment (Tøssebro, 2014). Consequently, interventions are not focused on changing the child but are instead focused on creating a match between the environment and an individual’s sensory needs. It is for this reason that this thesis will explore the impact of a child’s sensory differences, the impact of the classroom environment and also consider the interaction between these factors, when aiming to understand how sensory differences impact the educational outcomes of autistic pupils. Taken together, the evidence presented above emphasizes that there are both applied and theoretical reasons for focusing on sensory processing differences in ASD. Having presented this evidence, the following section will explore the nature and severity of these sensory differences.

1.5 What is the nature of sensory differences in ASD?

An estimated 90% of autistic individuals are thought to experience sensory processing differences (Ben-Sasson et al., 2019). These differences can be experienced across modalities, across both directions of responsivity (hyper/hypo-responsivity), and across the lifespan (Leekam et al., 2007; Kientz & Dunn, 1997; Ben-Sasson et al., 2019). Sensory differences can be analysed at multiple levels of explanation using a multitude of different methods (Schauder & Bennetto, 2016). For instance, a researcher aiming to understand sensory differences at a neural level might use functional fMRI (Schauder & Bennetto, 2016). This was the approach taken by Kaiser et al. (2016) who investigated neural responses to touch in a group of 38 autistic (ages 6-20 years, M=12.41) and neurotypical (ages 5.5-17 years, M=12.66) individuals, matched for age and cognitive ability. In this study, participants were brushed with a 7cm watercolour brush for 6 seconds on either their right palm or forearm whilst undergoing fMRI scanning. Compared to the neurotypical group, the autistic group evidenced an increased response in the primary somatosensory cortex and the insula, which was interpreted by the authors as evidence of hypersensitivity to non-social touch in ASD (Kaiser et al., 2016). This differs from the approach taken by researchers aiming to understand sensory differences at the perceptual level of explanation. Highlighting this is the work of O'Riordan and Passetti (2006) who asked 12 autistic (M=8.7years) and 12 neurotypical children (M=8.7 years) to complete a range of auditory and tactile discrimination tasks. In one auditory task, participants were presented with two alternating tones and asked to identify the point at which the two tones became identical. Relative to neurotypical children, autistic children identified the two tones as identical significantly later in the sequence. This, therefore, was interpreted as evidence for enhanced auditory discrimination skills in ASD compared to NT (O'Riordan & Passetti, 2006). Researchers have also examined sensory differences from a physiological level of explanation. For instance, Keith, Jamieson and Bennetto (2019) examined how classroom noise and task complexity impacted autonomic arousal in a group of autistic and neurotypical adolescents between the ages of 12 and 17 years old. It was found that when completing the more demanding cognitive task in a noise condition, autistic adolescents demonstrated continuous increases in heart rate, which was at the detriment to task performance (Keith, et al., 2019). Importantly, this pattern was not seen in the neurotypical group. Thus, suggesting that auditory input might be especially stressful for autistic children (Keith et al., 2019). Although the above literature illustrates that there are several approaches to examining sensory differences in ASD, the focus of this thesis will be on understanding sensory differences at the observable symptom level. Taking this approach is vital as it allows for multiple informants to report on the nature and severity of sensory differences across different contexts and is thus in line with the Nordic Relational Model of Disability.

1.6 Dunn's Sensory Processing Framework

Questionnaires have been used widely to understand sensory differences at the observable symptom level. Although a scoping review undertaken by DuBois et al. (2017), found that between 1987 and 2017, 11 different questionnaires had been used to assess sensory processing differences in ASD, the most commonly used measure was the Sensory Profile Questionnaire (Dunn, 1997; 2014). The Sensory Profile Questionnaire was developed on the basis of Dunn's Sensory Processing Framework. This framework is presented in Figure 1.2. Within this framework, sensory processing is characterized by four behavioural patterns that are distinguishable on two dimensions: neurological threshold and behavioural response (Dunn, 1997; 2014). Neurological threshold describes the amount of stimulation needed for a Central Nervous System (CNS response). For individuals with a low neurological threshold, the CNS requires minimal sensory stimulation to produce a response, whereas for individuals with a high neurological threshold, much greater stimulation is needed for a comparable response to be generated (Dunn,1997;2014). These contrasting profiles are often referred to as hypersensitivity (low neurological threshold) and hyposensitivity (high neurological threshold) (Dunn, 1997; 2014). Behavioural response, as the second dimension, describes the approach taken by an individual to manage their neurological threshold. An individual with an active behavioural response will attempt to increase or decrease the levels of sensory stimulation, by for example covering their ears or making noise (Dunn, 1997;2014). In contrast, an individual with a passive behavioural response might do little to modify the levels of sensory input but might still struggle with the impact of the stimulation (Dunn, 1997; 2014).

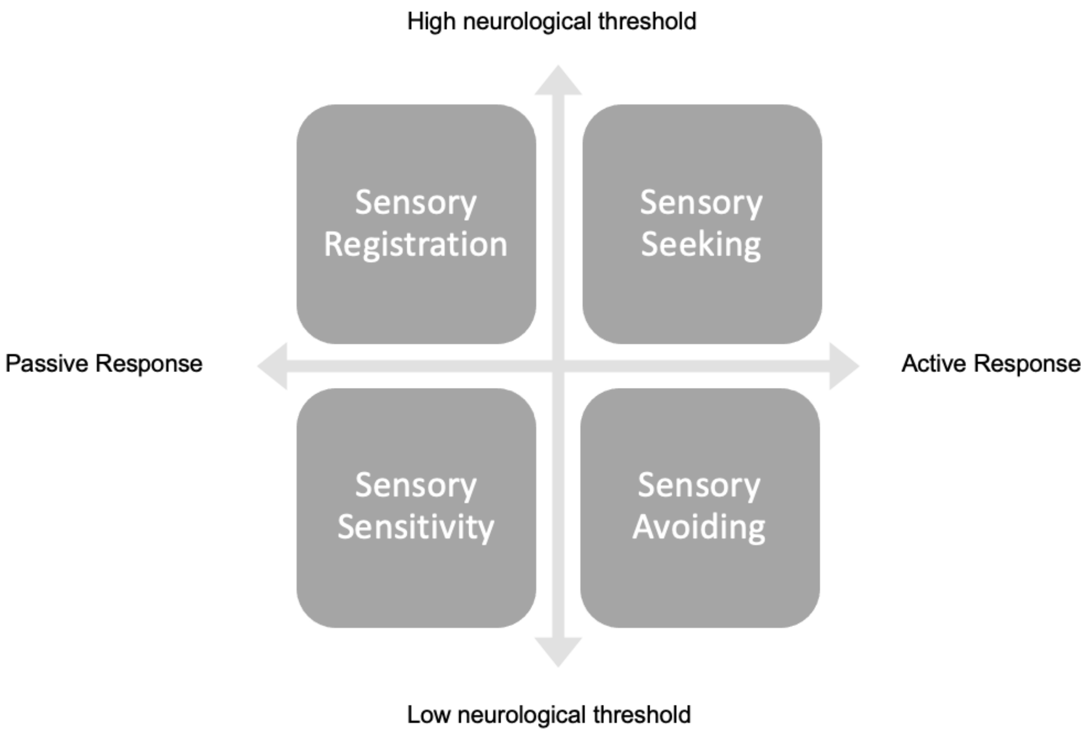


Figure 1.2 Dunn Sensory Processing Framework

The interaction between these two dimensions results in four distinct behavioural patterns, as seen in Figure 1.2 (Dunn, 1997; 2014). Critically, Dunn proposes that each of these patterns is associated with unique strengths and difficulties, which could be important when thinking about achievement and behaviour in class. The first pattern of Sensory Seeking is defined by a high neurological threshold (hypo-reactivity) and a tendency to engage in more active behavioural responses. In class, a child with high levels of sensory seeking might be identified by behaviours such as making noises while working, chewing things, and touching furniture or people. All of these behaviours might represent strategies by the child to increase their levels of sensory stimulation to meet their high neurological levels (Dunn, 1997; 2014). An important feature of this sensory pattern is that in general, sensory experiences are perceived as enjoyable, meaning that some children might wish to share their sensory experiences with others (Dunn, 1997; 2014).

This is very different to that seen in Sensory Avoiding; a profile defined by a low neurological threshold (hyper-reactivity) and an active behavioural response (Dunn, 1997; 2014). Sensory Avoiders are suggested to prefer environments that are familiar and contain predictable sensory input. This can lead to a strong preference for routines and rituals, which might also look like RRBI (Dunn, 1997; 2014). For instance, a child might need to be awoken in a certain way, eat a specific cereal, and watch a particular television show when getting ready for school. Behaviourally, parents and teachers might describe a child with high levels of sensory avoidance as withdrawn or disruptive, as both approaches can be used as strategies to avoid encountering new activities and unfamiliar sensory input (Dunn, 1997; 2014).

Conversely, individuals with high levels of Sensory Sensitivity have a low neurological threshold (hyper-reactivity) alongside a tendency to engage in more passive behavioural responses (Dunn, 1997; 2014). Dunn suggests that individuals with this profile react more quickly and more intensively to the sensory environment compared to others. For example, a child with this pattern might be the first to notice the sound of other pupils coming down the corridor. While this high level of awareness might be advantageous in terms of attention and ability to discriminate, it can also lead to distractibility and hyperactivity (Dunn, 1997; 2014).

This stands in contrast to that seen in Sensory Registration; a profile defined by a high neurological threshold (hypo-reactivity) and a passive behavioural response. Individuals with this pattern tend to miss more sensory cues than others. For example, a child with this profile might miss the teacher calling his/her name. However, Dunn (1997; 2014) suggests that one benefit of this profile is that it can allow individuals to be comfortable across a wider range of sensory environments compared to Sensory Avoiders and Sensory Sensitivity. Moreover, it is suggested that individuals with high levels of Sensory Registration might be better placed to focus on tasks of interests in distracting environments due to not detecting cues that might be distracting to others (e.g., the noise of pupils coming down the corridor). This is particularly relevant for Chapter 7 of this thesis which examines how different patterns of sensory processing impact the ability of children to stay on-task in different classroom sensory environments (Neutral, Audio, Visual and Audio-Visual Stimuli). A summary of Dunn's Sensory Quadrants is provided below in Table 1.1.

Table 1.1 Summary of Dunn's Sensory Quadrant

Sensory Quadrant	Profile	Behavioural Response	Characteristics
Sensory Seeking	Hypo-responsivity	Active	• Tendency for sensory experiences to be perceived as enjoyable. • May attempt to increase levels of sensory stimulation.
Sensory Avoiding	Hyper-reactivity	Active	• Strong preference for familiar and predictable sensory input. • May appear withdrawn or disruptive.
Sensory Sensitivity	Hyper-reactivity	Passive	• May react more quickly and more intensively to the environment compared to others. • High level of awareness that can also lead to distractibility.
Sensory Registration	Hypo-responsivity	Passive	• Tendency to miss sensory cues • Likely to be comfortable across a wider range of sensory environments.

Based on this framework, one of key measures to have been developed is the Sensory Profile Questionnaire (Dunn, 1997; 2014). Several variants of this questionnaire exist, including the Short Sensory Profile, Adolescent/Adult Sensory Profile, Child Sensory Profile, and the School Companion Sensory Profile (Dunn, 1997; Dunn, 2014). All questionnaires, however, ask the participant/caregiver how frequently they, or their child, respond to a sensory event on a five-point Likert Scale. For example, "*is distracted when there is a lot of noise around"* and "*bumps into things, failing to notice objects or people in the way*" (Dunn, 2014). The questionnaire can be scored to provide quadrant scores (Seeking, Avoiding, Sensitivity and Registration), sensory systems scores (General Processing, Auditory, Visual, Touch, Movement, Body Position and Oral Sensory) and also behavioural responses (Conduct Associated with Sensory Processing, Social Emotional Responses and Attentional Responses). In addition, to these three sections, the School Companion Sensory Profile 2 contains four factor scores (Need for External Support, Awareness and Attention, Tolerance, and Availability for Learning) that reflect the pupil's learning characteristics (Dunn, 2014). This thesis will use the School Companion Sensory Profile 2 as a measure of sensory processing, with further methodological details provided in Chapter 6.

Studies using the Sensory Profile as a measure of sensory processing have shown that autistic individuals tend to demonstrate greater frequency of sensory differences compared to non-autistic individuals (Dunn et al., 2016; Schauder & Bennetto, 2016; Wiggins, 2009). Highlighting this are the findings of Kientz and Dunn (1997) who asked the caregivers of 32 autistic children (ages 3 to 13 years old) and the caregivers of 64 non-autistic children to complete the Sensory Profile. It was found that autistic children achieved significantly different scores from non-autistic children on 85% of the items on the Sensory Profile and this occurred in both directions of hypersensitivity and hyposensitivity (Kientz & Dunn, 1997). Therefore, indicating that no single pattern of responsivity is characteristic of autism. Supporting this finding is the work of Brown, Leo, and Austin (2008) who compared the sensory processing scores of 26 autistic (ages 5-8 years) and 26 neurotypical children (matched for age and cognitive ability) on the Sensory Profile Questionnaire. Again, it was found that autistic children had significantly lower scores (indicative of greater sensory differences) on eight out of the nine sensory system scores and all four quadrant scores. Importantly, the findings of Kern et al. (2007) highlight that sensory processing differences can be experienced across the lifespan and are not limited in childhood. Indeed, when using a wider age (6-57 years), Kern et al. (2007) also found that autistic individuals achieved significantly lower scores compared to non-autistic individuals across all sections of the Sensory Profile. Taken together, these studies emphasize that autistic individuals tend to experience greater frequency and severity of sensory differences compared to non-autistic individuals. Moreover, it is clear that sensory differences are not restricted to a particular modality or direction of responsivity. Instead, sensory processing in ASD appears to be characterized by heterogeneity and variability in the types of sensory differences experienced (Rogers & Ozonoff, 2005; Uljarevic et al., 2017).

Emphasizing this are the findings of Crane, Goddard and Pring (2009) who examined patterns of sensory processing both within, and between, autistic and neurotypical groups. In this study, 18 autistic adults (ages 18-65) and 18 age-matched neurotypical adults were asked to complete the Adult/Adolescent Sensory Profile, alongside measures of IQ and autistic traits. In terms of differences between groups, findings are in line with Kern et al. (2007), such that autistic adults evidenced significantly greater differences on all quadrants compared to neurotypical adults. To examine variability within the ASD group, researchers undertook multiple case series analysis to identify which participants were scoring in the extreme 5% of scores in each of the quadrants. Critically, it was found that different participants were achieving extreme scores in each of the quadrants. This emphasizes that while autistic individuals may experience similarly severe sensory differences, the exact nature of these differences varies substantially from person to person (Crane, Goddard, & Pring, 2009).

This variability might explain why there has been such mixed findings with regards to how sensory processing differences in ASD compare to those seen in other neurodevelopmental conditions (Dellapiazza et al., 2020; Ben-Sasson et al., 2019). For example, using the Sensory Experiences Questionnaire, Baranek et al. (2006) found that hyposensitivity best discriminated very young autistic children from neurotypical children, and children with pervasive developmental delay, developmental disabilities, and other developmental delays (ages 5-80 months). However, findings from McCormick et al. (2016) seem to suggest that differences between groups are being driven by differences within particular sensory modalities rather than a global hyper/hypo differences. Indeed, in a sample of 29 ASD, 26 Developmental Disability (DD) and 24 neurotypical children (ages 2-8 years), significant differences between the two clinical groups were found only on the smell/taste and auditory filtering subscales (McCormick et al., 2016). More recently, Ben-Sasson et al. (2019) conducted a meta-analysis of 55 questionnaire studies to understand if a particular pattern of sensory processing best distinguished ASD from typical developmental and other neurodevelopmental conditions. Across these studies, effect sizes were large and significant for Sensory Overresponding (1.28), Sensory Under-responding (1.38) and Seeking (0.66) when comparing autistic children to neurotypical children (Ben-Sasson et al., 2019). However, when comparing autistic children to other developmental disorders, effect sizes were significant for Sensory Overresponding (0.54), significant but low for Seeking (0.49) and non-significant for Sensory Under-responding (0.22). It seems therefore that Sensory Over-Responding (Hypersensitivity) might best distinguish ASD from typical development and other developmental disorders and this is irrespective of age (Ben-Sasson et al., 2019).

Nevertheless, it should be considered that hypersensitivity is perhaps easier to self-report and also for caregivers/teachers to report on (Dickie et al., 2009). Indeed, the very nature of hyposensitivity means that individuals are often unaware that they have missed sensory input, e.g., a teacher calling their name. It is also possible that behaviours linked to hypersensitivity (e.g., covering ears when hearing a loud noise) are more overt and noticeable than behaviours linked to hyposensitivity, making it easier for caregivers to report (Dickie et al., 2009). It is because of this that a range of perspectives are needed to understand the nature and impact of sensory differences in ASD, and this is why a multi-informant approach has been adopted in this thesis.

This thesis has also adopted a mixed-method approach including both qualitative and quantitative evidence. While the literature discussed above provides strong evidence that autistic individuals process and respond differently to sensory stimuli, these studies tell us little about the lived experience that accompanies these differences (Dickie et al., 2009). Indeed, by asking participants (or their caregivers) to answer closed questions on observable behaviours, we restrict our understanding of sensory differences to a pre-defined framework (often the Sensory Profile) and neglect the rich and often complex experiences of autistic individuals (Hughes, 2014; Howe & Stagg, 2016). Emphasizing this are the findings of Robertson and Simmons (2015) who asked six autistic adults in a focus group to reflect on physical reactions to sensory information, enjoyable or distressing aspects of sensory stimuli and sensitivity to the sensory environment. A variety of stimuli were noted as causing distress including bright lights, low frequency sounds, cleaning products and non-branded food. However, one consensus that was reached was that the ability to control a stimulus determined whether that stimulus was perceiving as distressing or enjoyable. One participant explained, "*if they have control over the sensory input, then it's much less distressing and I find that's quite true with touch*." (Robertson & Simmons, 2015; 576). Importantly, when participants felt they had agency, many were able to interact with the stimuli in positive ways, for example listening to music of their choice (Robertson & Simmons, 2015). This is an important finding as the idea that autistic individuals can enjoy interacting with sensory stimuli is largely absent from the questionnaire literature and is one of the key reasons why a mixed-method approach has been adopted in this thesis (see this followed up in Chapter 5 where the experiences of late-diagnosed autistic females are explored).

Qualitative work with autistic children also emphasizes the diversity and richness of sensory differences experienced (Kirby, Dickie & Baranek, 2015; Ashburner et al., 2013). This can be highlighted by Kirby, Dickie and Baranek (2015) who undertook semi-structured interviews with 12 autistic children (ages 4-13 years) to explore sensory differences from their perspective. Children shared both positive and negative sensory experiences, for example one child described hearing a buzzer at a basketball game and "*started to have panic, Ahh, like the panic that my brain is going in, like what should I, what I do? It's kind of like bouncing off the walls in, um, my head, like what should I do*?" (Kirkby, Dickie & Baranek, 2015; 322). Children also reported using a range of strategies to manage sensory experiences, including avoiding situations, increasing control and predictability and self-talk. For instance, one child who was bothered by the sounds of toilets flushing stated "*I took deep breaths, I was like, 'K, that was it, no more flushing*." (Kirkby, Dickie &

Baranek, 2015; 322). Findings therefore illustrate that there are overlaps when comparing child and adult reports, particularly in terms of strategies used to manage difficult sensory experiences (Kirkby, Dickie & Baranek, 2015; Robertson & Simmons, 2015). Both studies also highlight the rich and varied sensory differences experienced by autistic individuals and emphasize the need for both qualitative and quantitative evidence when considering the impact of sensory processing differences in the classroom.

In summary, the literature indicates significant sensory processing differences in ASD, albeit with considerable heterogeneity in presentation (Uljarevic et al., 2017). As will be discussed further in Chapter 2, understanding, and embracing this heterogeneity is vital when attempting to understand potential impacts on learning. This is because different patterns of sensory processing might relate to different strengths and challenges in the classroom (Ashburner et al., 2008). Heterogeneity also means that different approaches might be needed when thinking how best to adapt the classroom environment to meet the sensory needs of pupils. The following section will therefore consider the different factors that might be underlying the heterogeneity observed in the literature.

1.7 What might underlie this heterogeneity?

1.7.1 Measurement

Measurement is an important consideration when thinking about heterogeneity in sensory processing differences (Hughes, 2014). As discussed above, a scoping review undertaken by DuBois et al. (2017) found that 11 different questionnaires had been used to assess sensory processing differences in ASD between 1987 and 2017. While some questionnaires were designed to evaluate sensory differences in the general population (e.g., *AASP* and *Sensory Processing Questionnaire)*, others were designed specifically to identify sensory processing features in ASD (e.g., *Glasgow Sensory Questionnaire* and *Sensory Reactivity in Autism Spectrum)* (DuBois et al., 2017). Importantly, this could lead to different types of sensory differences being captured. For instance, DuBois et al. (2017) argue that questionnaires normed on the general population may not capture sensory seeking behaviours that are typical in ASD. This, therefore, could lead to the frequency and severity of sensory seeking behaviours being underreported (DuBois et al., 2017). Likewise, there are differences across questionnaires regarding which sensory modalities (e.g., visual, and auditory) are measured (Yeung & Thomacos, 2020). Questionnaires also differ in the extent to which items confound social and attention differences with sensory issues. For instance, compared to the Sensory Experiences Questionnaire, the Short Sensory Profile contains many more confounding items such as "I do not get jokes as quickly as others" which touches on important social interaction issues (DuBois et al., 2017; Hughes, 2014). This again, could lead to different estimates with regard to the severity and frequency of sensory differences being reported (Baranek et al., 2006).

In addition to variation across questionnaires, the observed heterogeneity may also reflect differences in how informants perceive and report sensory processing (Yeung & Thomacos, 2020). Self-report for example, allows autistic individuals to reflect on unobservable differences e.g., introspection. Parents and teachers however are limited to that which is observable, and these reports might be influenced by factors such as knowledge of sensory processing differences, expectations of children's behaviour and the environments in which they have observed the child (e.g., teachers only observing differences within the classroom context compared to parents observing differences across a range of environments) (Yeung & Thomacos, 2020). These measurement differences mean that a range of perspectives (e.g., teachers, parent, autistic individuals) gathered through a range of tools (questionnaires, qualitative surveys, observations) are needed to understand how sensory differences impact educational outcomes (Uljarevic et al., 2017).

1.7.2 Developmental Trajectories

A second explanation for the observed heterogeneity is that the way in which some autistic children process or respond to sensory stimuli may change over time (Schaaf & Lane, 2015). This could be underpinned by both biological changes such as a maturing nervous system and also changes in the types of sensory environments that children are exposed to (Schaaf & Lane, 2015). For example, transitioning from primary to secondary school, or transitioning from mainstream to special schools, or vis versa. Although an early meta-analysis of fourteen cross-sectional studies conducted by Ben-Sasson et al. (2009) suggested that sensory symptoms increase early in childhood and then decline after ages 6 to 9 years, more recent evidence suggests that sensory symptoms remain stable throughout childhood (McCormick et al., 2016; Perez Repetto et al., 2017). Emphasizing this trajectory is a study undertaken by McCormick et al. (2016) who asked the parents of 79 children (ASD= 20, DD=26, NT=24) to complete the Short Sensory Profile when the children were approximately ages 2-3, 4-5 and 8-9 years. It was found that both autistic children and children with developmental delay had stable sensory features such that there was no significant change on either total SSP or subscale scores across the three time points. By contrast, neurotypical children evidenced a decrease in sensory symptoms over this period (Perez Repetto et al., 2017). However, one limitation of this study is that it used only the Short Sensory Profile, meaning that it was not possible to capture quadrant scores to assess if these patterns remained stable across development (Perez Repetto et al., 2017; McCormick et al., 2016).

To address these limitations, Perez Repetto et al. (2017) asked the parents of 34 children to complete the Sensory Profile when their child first received an autism diagnosis at ages 3-4 years, and then again at ages 5-6 years once their child had started school. Children also completed the Merill-Palmer Revised Scales of Development and the Preschool Language Scales to understand how cognitive ability and language might moderate developmental changes in sensory processing. At time point 1, mean scores in all sensory quadrants were in the atypical range. Differences were most prevalent for Sensory Seeking, with 58.8% of children achieving scores in the atypical range and lowest for Low Registration, with 41.2% achieving scores in the atypical range (Perez Repetto et al., 2017). In line with the findings of McCormick et al. (2016), sensory differences remained stable across development with no significant difference in mean quadrant scores between the two time points. There was also no significant difference in the percentage of children achieving scores in the atypical range across the four quadrants between the two time points (Perez Repetto et al., 2017). Differences were again most prevalent for Sensory Seeking (52.9% of scores in the atypical range) and lowest for Low Registration (38.2%) and Avoiding (38.2%). Although these findings suggest that sensory differences remain severe and stable across time, it should be considered that children were only tracked over two years, which may not have been long enough to capture the full extent of developmental change (Baranek et al., 2019; Easterbrooks et al., 2020).

Indeed, when tracking children over a longer period, there is some evidence to suggest that sensory differences begin to diminish across childhood (Baranek et al., 2019). Thus, mirroring that seen in neurotypical development. Highlighting this is the work of Baranek et al. (2019) who examined sensory processing differences in 90 children (ASD, n=55, DD, n=35) first when they were between the ages of 2-12 years old (M=5.69 years), and then again three years later (on average) when the children were between 4-14 years old (M=9.00). Caregivers completed the Sensory Experiences Questionnaire and the Sensory Profile at both time points. Replicating a procedure used by Watson et al. (2011), these scores were then adjusted and transformed to create standardized scores reflecting hyperresponsiveness, hypo-responsiveness and sensory seeking. Parents also completed the Social Responsiveness Scale, as a measure of autism symptom severity, and children completed standardized measures of IQ. To examine the extent to which sensory scores at time one predicted time two, researchers undertook correlation and regression analysis, adjusting for covariates such as diagnostic category (ASD, DD), gender, age of child at time one and time elapsed between time one and two (Baranek at el., 2019). Across both groups, correlation coefficients were positive and significant for all three patterns of sensory processing. This, therefore, indicates that there are elements of sensory processing that remain consistent and stable across development. At the same time however, it was found that that the mean score of seeking and hypo-responsiveness was significantly lower in the ASD group at time one compared to time two. Therefore, indicating that differences in these domains had become less severe over time (Baranek et al., 2019).

Collectively, these studies suggest that sensory symptoms remain stable or increase up to middle/late childhood, after which they decrease again into adolescent and adulthood (Ben-Sasson et al., 2009; McCormick et al., 2016; Perez-Repetto et al., 2017). That is, sensory processing appears to follow an inverted U developmental trajectory. Heterogeneity in terms of the severity and presentation of sensory differences may therefore reflect sampling of different age groups (Uljarevic et al., 2017). Acknowledging potential developmental changes is particularly important when thinking how best to meet the sensory needs of children in school because it may suggest the need for different approaches and environmental design at different developmental stages. At the same time, we also need to acknowledge that there are substantial individual differences. This means that we can't just assume that a child will follow a particular developmental trajectory if they're autistic and a particular developmental trajectory if they are neurotypical. A combination of individual differences and developmental change are therefore likely to be exacerbating the variability that we see in the literature.

1.7.3 Sensory Subtypes

A third explanation for the observed heterogeneity is that unique sensory subtypes may exist within the ASD population (Uljarevic et al., 2017). Evidence for this stems from a series of studies conducted by Lane et al (2010; 2011; 2014) who examined if autistic children with similar profiles of sensory processing could be identified using data-driven, model-based cluster analysis. In the largest of these studies, the parents of 228 autistic children (aged between 2-10 years) were first asked to complete the Short Sensory Profile (Lane et al., 2014). Model-based cluster analysis, using the seven factor scores from the Short Sensory Profile was then conducted and four homogenous subtypes were identified. The first cluster was characterized by typical sensory processing (n=84), whereas the second group demonstrated extreme taste/smell sensitivities (n=92). Conversely, the third cluster was characterized by extreme scores in low energy-weak (n=23), while the final group showed differences across all sensory domains (n=29). To investigate if these subtypes were associated with different cognitive and behavioural outcomes, the ADOS, the Mullen Scales of Early Learning and the Stanford Binet 5th Edition were also administered as measures of autism symptom severity and nonverbal IQ (Lane et al., 2014). Critically, it was found that cluster membership was predictive of unique difficulties such that the taste/smell group was strongly associated with communication challenges and the low energy/weak profile related to greater levels of maladaptive behaviours (Lane et al., 2010). Findings therefore suggest that sensory subtypes may exist within the ASD population, with some groups experiencing differences across modalities while other groups experience differences only in specific modalities (Lane et al., 2014). Moreover, it seems that profiles can be differentially associated with a range of behavioural and cognitive outcomes, which could be important when thinking about academic progress and classroom behaviour (Lane et al., 2014).

Nevertheless, there is inconsistency within the literature regarding the exact number and nature of sensory subtypes within ASD (DeBoth & Reynolds, 2017). This can be highlighted by comparing the findings of Lane et al. (2010), to the more recent findings of Simpson et al. (2019). In Simpson et al. (2019) the caregivers of 248 autistic children (between the ages of 4 and 11 years) completed the Short Sensory Profile and then Dirichlet process mixture modelling was applied to explore how many sensory subtypes could be identified. Two subtypes emerged from this analysis (Simpson et al., 2019). The first profile of 'Uniformly Elevated' (N=182) included children who had elevated differences across domains whereas the second subgroup included children who achieved typical scores in Seeking and Registration but elevated scores (indicative of greater differences) on Sensitivity and Avoiding. Therefore, although findings do support the existence of a subtype characterized by a global difference, they offer less support for the other subgroups identified by Lane et al. (2010). However, one potential explanation for this discrepancy is that only 30% of items on the Short Sensory Profile 2 and Sensory Profile match on item description. Moreover, the Avoiding domain on the Short Sensory Profile 2 has no comparable match on the original Short Sensory Profile (Dunn, 1997; 2014). These differences may have made it highly unlikely that comparable subtypes would have been identified. Thus, emphasising the importance of considering which measures are used (Simpson et al., 2019).

Nevertheless, even when accounting for differences between questionnaires, there still appears to be inconsistency with regards to the nature of sensory subtypes within ASD (DeBoth & Reynolds, 2017). Highlighting this is the work of DeBoth and Reynolds (2017) who undertook a systematic review of studies that had undertaken subtyping between 2004-2016 and identified eight studies that met their final inclusion criteria. Across these eight studies, the number of meaningful subtypes identified range from three to five. However, one similarity across these studies was the identification of a subtype that did not demonstrate clinically significant or impairing sensory differences (Lane et al; 2010, 2011;2014; Ausderau et al. 2014, Liss et al., 2006). At the time however, all studies identified a subtype that was characterized by severe and global sensory differences (Lane et al; 2010, 2011; 2014; Ausderau et al., 2014). However, there was not a clear consensus on how best to describe the responses seen in other children (DeBoth & Renolds, 2017). These children demonstrated some sensory differences, but these were not universally severe across modalities. For instance, several studies identified a subgroup demonstrating hyperresponsivity alongside enhanced perception of sensory stimuli (Ausderau et al., 2014), exceptional memory (Liss et al., 2006) and heightened vigilance (Little et al., 2017). By contrast, other studies identified subgroups predominantly characterized hypo-responsiveness and sensory seeking (Ausderau, 2014; Baranek, 2007; Liss, 2006). Despite these inconsistencies, the literature discussed above indicates that meaningful sensory subtypes exist within the ASD population, and that these subtypes may be differentially associated with a range of outcomes, which could be important when thinking about achievement and classroom behaviour (DeBoth & Reynolds, 2017; Butera et al., 2020). The idea of sensory subtypes will be explored further in Chapter 6 of this thesis.

1.7.4 Gender Differences

A fourth possibility is that the nature and severity of sensory differences differs across genders (Lai et al., 2011) Supporting this position are findings from Lai et al. (2011) who used a range of cognitive and behavioural measures to explore similarities and differences between 45 autistic males and 38 autistic females matched for age and IQ. These assessments included the Autism Diagnostic Interview-Revised (ADI-R) (Rutter, Couteur & Lord, 2003) and the ADOS as measures of autism symptom severity, Reading the Mind Eyes Test (Baron-Cohen et al., 2001) as measure of mentalizing and the WASI as a measure of IQ. In terms of similarities, autistic males and females showed comparable mentalizing abilities and also similar levels of co-occurring anxiety, depression, and obsessive-compulsive symptoms. Autistic females however, presented fewer socio-communication difficulties and more lifetime sensory differences (Lai et al., 2011). While some caution is needed due to sensory differences being assessed through the ADI-R, this finding raises the possibility that some of the heterogeneity in reported sensory differences could be due to sex differences between males and females. Alongside identifying causes of heterogeneity, understanding the sensory experiences of autistic females is particular important when thinking about diagnostic criteria and prevalence. Indeed, as indicated at the beginning of this chapter, autistic males outnumber autistic females with a sex ratio of 4.3:1 (Loomes, Hull & Mandy, 2017). Although several different explanations have been proposed for this asymmetry one possibility is that it may reflect a bias in the diagnostic criteria (Hiller, 2014; Lai et al., 2015; Mandy et al., 2012). That is, the diagnostic criteria are largely based upon a male understanding of autism when in-fact there is some evidence suggesting autistic males and females show different behavioural phenotypes (Mandy et al., 2012; Sedgewick et al., 2015; Lai et al., 2015). By not conforming to this male model of autism, some autistic females may fly under the radar and not receive a diagnosis (Giraelli et al., 2010). Chapter 5 of this thesis aims to provide the opportunity for late-diagnosed autistic females to reflect back on the nature and severity of sensory differences at school.

1.7.5 Context

Lastly, it needs to be considered that the environment in which a child is placed can influence both the presentation and severity of sensory symptoms (Tøssebro, 2004, Brown & Dunn, 2010). As discussed above, The Nordic Relational Model Disability (Tøssebro, 2004) provides a useful framework for understanding how and under what circumstances, sensory processing differences affect the day-to-day lives of autistic individuals. Here, 'disability' occurs when there is a mismatch between an individual's functional ability and their environment. In the case of sensory processing differences, a child with hypersensitivity might be comfortable at home but may experience 'disability' and distress when placed in environments with significant sensory inputs such as bright lights and noisy children (Goodley & Runswick-Cole, 2012; Tossebro, 2014).).

Supporting this framework are the findings of Smith and Sharp (2013) who undertook semi-structured interviews using instant messaging with nine autistic adults. Interviews focused on under or over sensitivities to sensory inputs and how these experiences affected day to day life. Participants explained that when they encountered stimuli they perceived to be adverse, they would often feel angry or scared, and would want to escape or attack the stimuli. However, this was not always the case and several factors often determined how strongly the adverse sensory event affected the participant (Smith & Sharp, 2013). For instance, participants explained that multiple inputs were far more stressful than one input. Likewise, ordered, and predictable environments were far less stressful than busy chaotic environments. Notably, participants explained when they were already in a state of stress, they would become more sensitive to adverse sensory events, which in turn would cause greater stress, resulting in a cycle described as the 'Sensory Avalanche'. These findings emphasize that the presentation and severity of sensory differences need not be fixed and instead can vary depending on characteristics such as on the environment (predictable versus chaotic) and emotional state (calm versus anxious) (Smith & Smith, 2013). Questionnaire data also emphasize that the nature of sensory differences can differ across environments (Brown & Dunn, 2010; Fernandez-Andres et al., 2015). Highlighting this is the work of Brown and Dunn, who asked the parents and teachers of 49 children to complete the Sensory Profile and the School Sensory Profile. Correlation analysis was then undertaken on the Seeking and Avoiding scores to understand how similar reports were across the home and classroom contexts. Importantly, moderate positive correlations were found which seems to suggest that while the core issue of sensory processing differences is always present, the environment can moderate the presentation and severity of these differences. That is, sensory differences might become more evident and severe in particular settings such as school. Thus, to capture heterogeneity in sensory differences and understand potential impacts on educational outcomes, reports from multiple informants across multiple settings are needed. This is the approach taken in Chapter 4 of this thesis which asks parents and teachers to consider how sensory differences might impact autistic pupils' academic achievement and classroom behaviour.

1.8 Summary

In summary, this chapter aimed to provide a detailed review of sensory differences in ASD. Having introduced autism and the concept of the sensory processing, the applied and theoretical arguments for focusing on sensory differences in ASD were detailed. These arguments focused on meeting the priorities of the autistic community, providing a more unified understanding of ASD, and shifting our understanding of ASD from a medical model of disability to a social-relational framework (Fletcher-Watson & Happé, 2019; Kapp, 2019; Goodley & Runswick-Cole, 2012). Focus then turned to examining the nature and severity of sensory differences in autism. Overwhelmingly, sensory processing in ASD appears to be characterized by heterogeneity and variability in the types of sensory differences experienced. Although sensory differences can be analysed at multiple levels of explanation, using a multitude of different methods, the focus of this thesis is to understand sensory differences at the observable 'symptom level'. At this level, sensory differences have often been conceptualized within Dunn's Sensory Processing Framework. Based on is model, one of the key measures to have been developed in the Sensory Profile. Studies using this questionnaire have shown that sensory differences exist across modalities, across both directions of responsivity and across the lifespan. Indeed, a single pattern of sensory processing does not appear to be characteristic of ASD. Understanding and embracing this heterogeneity is particularly important when thinking how sensory differences might impact everyday functioning and educational outcomes. This is because different patterns of sensory processing might relate to different strengths and challenges in the classroom (Ashburner et al., 2008). Heterogeneity also means that different approaches might be needed when thinking how best to adapt the classroom environment to meet the sensory needs of pupils. There is some evidence that the observed heterogeneity might be accounted for by differences in the types of questionnaires used to assess sensory differences. For instance, some questionnaires were designed specifically for ASD whereas others were designed for the general population. This could lead to differences in the types of sensory experiences that are captured. Developmental trajectories were also considered as potential cause of heterogeneity, with some evidence suggesting that sensory symptoms remain stable or increase up to middle/late childhood, after which they decrease again into adolescent and adulthood. Again, this has important implications for the classroom because it suggests different approaches might be needed at different ages. It is also possible that sensory subtypes exist within the ASD population and that these profiles are uniquely associated with a range of strengths and difficulties. Lastly, both qualitative and quantitative evidence emphasizes the importance of context in shaping both the presentation and severity of sensory differences. As will be advocated throughout this thesis, one way to capture this variability and ensure a comprehensive understanding of sensory differences is to adopt a multi-method (qualitative and quantitative), multi-informant (parent, teachers, autistic voice) approach. Having introduced sensory processing differences in ASD, Chapter 2 will next explore why understanding these differences in an educational context is so important.

Chapter 2: Why do we need to understand sensory differences within an educational context?

2.1 Introduction

Chapter 1 explored the evidence for sensory processing differences in ASD. This literature highlighted that while many autistic individuals experience severe sensory processing differences, these experiences are heterogeneous (Ben-Sasson et al., 2019; Uljarevic et al., 2017). Indeed, differences have been found across sensory modalities and in both directions of responsivity (Leekam et al., 2007; Ben-Sasson et al., 2019; Robertson & Simmons, 2015) and as highlighted in Chapter 1, these may change with age and reporting may change depending on the measures used or the nature of the informant. Despite an increasing understanding of this variability and potential impacts on everyday functioning, it is still the case that very little is known about how these sensory experiences impact the educational outcomes of autistic pupils (Keen, Webster & Ridley, 2016; Uljarevic et al., 2017). The current thesis will argue that this represents a substantial gap in both our theoretical understanding of sensory differences, and also in our applied understanding of how best to support autistic pupils at school. To illustrate why understanding sensory differences are so important in an educational context, this chapter will begin by describing the educational landscape in the UK, before evaluating how well autistic pupils perform academically. It will be emphasized that there are substantial discrepancies in the support available for autistic pupils, and while variable, autistic individuals tend to attain lower levels of achievement compared to their neurotypical peers (Keen, Webster & Ridley, 2016). To understand why this might be the case, the second section of the chapter will discuss the factors that predict autistic and neurotypical pupil's academic achievement. It will be highlighted that, unlike neurotypical development, IQ is not always a reliable predictor of autistic pupil's achievement (Deary et al., 2007; Jones et al., 2009). This suggests that factors beyond IQ influence achievement (Jones et al., 2009; Mayes et al., 2020). Evidence will be presented to argue that sensory differences are indeed one of these factors, such that they have a unique and critical role in autistic pupils' academic achievement (Ashburner, Ziviani & Rodger, 2008). Having established this potential relationship, the third section of this chapter will examine the potential pathways by which sensory differences could impact achievement, focusing on classroom behaviour and wider school experiences (Howe & Stagg, 2016; Piller & Pfeiffer, 2016). Finally, in line with the Nordic Relational Model of Disability, the role of the classroom sensory environment in impacting achievement and on-task behaviour will be evaluated (Tøssebro, 2004; Barrett, 2015; Fisher, Godwin & Seltman, 2014). Following this review, the methodological approach and aims of the thesis will be outlined.

2.2 Autism and Education in the UK

As emphasized in Chapter 1, autism is a heterogeneous neurodevelopmental condition (Happé & Frith, 2020). This heterogeneity means that no single type of school provision will be able to meet the academic, health, and social needs of all autistic pupils (Wilkinson & Twist, 2010). A range of school provisions are therefore available in the UK, with 70% of autistic pupils attending mainstream schools and 30% attending special schools (Department for Education, 2017). Children attending special schools tend to have more complex needs that those children attending mainstream schools (Roberts & Simpson, 2016). There are, however, substantial regional differences in the availability of different types of school provision, with some areas of the UK having very little specialist provision and a fully ’inclusive’ education system (All Party Parliamentary Group on Autism, 2017). Consequently, some children must travel considerable distances to access the provision that they need to best suit their individual needs. There are also regional differences in the availability of Special Education Needs and Disability (SEND) support and knowledge of ASD (All Party Parliamentary Group on Autism, 2017). One factor that contributes to this variability is that some local authorities are able/decide to invest in educational psychology services and make them available to all schools in their area. Other local authorities however do not take this centralized approach and allow individual schools to decide the level of SEND provision needed (All Party Parliamentary Group on Autism, 2017). A child’s postcode can therefore often determine the extent of available SEND support and provision (Henshaw, 2016; Van Herwegen, Ashworth & Palikara, 2018).

Critically, these disparities still exist despite the Children and Families Act 2014 being implemented seven years ago (Boesley & Crane, 2018). The aim of this Act was to introduce a number of reforms to the SEND system with the key aim of making it more efficient (Department for Education & Department of Health, 2015). These reforms focused on identifying and meeting needs early, involving young people and their parents in decision making, and empowering children and young people to achieve their goals in life (Boesley & Crane, 2018; All Party Parliamentary Group on Autism, 2017). Central to achieving these aims was the introduction of Educational, Health and Care Plan (EHCP) (Department for Education & Department for Health, 2015). An EHCP is a legal document that describes a child's needs and details the support that will be offered to ensure that those needs are met. Not all autistic children will require an EHCP because their needs can be met using existing school resources. However, other children may require more support than would normally be provided in mainstream schools, in which case an EHCP assessment would be necessary (Department for Education & Department for Health, 2015). The aim of an EHCP assessment is to build a complete understanding of a child's needs by gathering the perspectives of professionals (e.g., occupational therapists, speech and language therapists, mental health professionals, teachers, and educational psychologists) families, and young people themselves (Boesely & Crane, 2018; Craston, Thom & Spivack, 2015). However, 42% of parents surveyed by the All Party Parliamentary Group on Autism (APPGA) reported that their local authority had refused to carry out an assessment of their child's needs the first time it was requested (APPGA, 2017). Evidence presented to the APPGA also suggests that even when assessments are approved, specialist input from professionals is not always available in all local authorities. This is highly problematic because without this input, there is danger of more complex needs not being identified (Boesely & Crane, 2018; Craston, Thom & Spivackk, 2015). Again, this emphasizes that there are considerable inequalities in both the availability and quality of support offered to autistic children attending schools in the UK (Van Hewergen, Ashworth & Palikara, 2018; Craston, Thom, & Spivack, 2015).

The consequences of these inequalities can be far-reaching. One area that has received substantial attention is the prevalence of pupil exclusions (Cole et al., 2019; Totsila, 2020; Brede, 2017). Autistic children are three times more likely to be excluded from school for a fixed period of time than children who do not have any special educational needs (All Party Parliamentary Report on Autism, 2017). In 2018, Edward Timpson was commissioned to undertake a review of school exclusions in the UK, with a particular focus on understanding why some groups of pupils are more at risk of exclusions than others (Timpson, 2019). Although a range of factors was found to be contributing to heightened exclusions, a lack of specialist settings for pupils with autism and social, emotional, or mental health needs meant that many pupils were in unsuitable schools that lacked the specialist knowledge to support their needs (Timpson, 2019). Supporting this position are the findings of Martin-Denham (2020) who undertook interviews with five caregivers of autistic children who had been excluded from mainstream schools in England. All caregivers believed that their child had received inadequate SEND support and this in turn had contributed to substantial behavioural difficulties. When asked what support needed to be put in place, caregivers highlighted the need for sensory support, movement breaks and opportunities for self-regulation (Martin-Denham, 2020). Four caregivers also believed that a greater understanding of ASD, and SEND practice more broadly was needed in schools (Martin-Denham, 2020). Echoing this view are the findings of the APPG survey in which 60% of autistic young people said that the key thing that would make school better is having a teacher who understands autism (All Party Parliamentary Report on Autism, 2017). Taken together, the literature outlined above indicates that although the Children and Families Act 2014 improved some processes, many autistic children continue to experience inequalities and negative school experiences (Brede et al., 2017; Van Herwegen, Ashworth & Palikara, 2018; Boesley & Crane, 2018). Although systemic barriers in funding are contributing to several of these issues, it is clear that a limited understanding of autism and a lack of suitable support are also contributing to the poor educational experiences for autistic pupils. Indeed, in Chapter 1 it was highlighted that, historically, much of the behavioural research in ASD has focused on the social and other RRBI components of the condition, meaning that sensory differences have largely been overlooked and are not well understood nor supported in an educational context. However, as will be argued in the following section, sensory differences, and the classroom sensory environment itself, have the potential to have substantial impacts on the achievement and classroom behaviour of autistic pupils. Building a more comprehensive understanding of sensory differences, exploring potential impacts, and identifying suitable supports therefore offers one potential avenue by which to improve the educational outcomes and experiences of autistic pupils. It is within this context in which we will now consider how well autistic pupils are performing academically at school.

2.3 How well are autistic pupils doing academically at school?

Academic achievement has been associated with an array of future life outcomes, including employment, health, and independent living (Burgess & Gutstein, 2007). Academic achievement can be measured using a range of direct and indirect assessments (Howse, 2019). Examples of direct assessments include performance on national exams (e.g., GCSE's) or scores on standardized achievement tests. Within the autism literature, a review undertaken by Keen, Webster and Ridley (2016) identified the Wechsler Individual Attainment Test (WIAT) (Wechsler, 2005) and the Woodcock-Johnson Test of Achievement (Woodcock, 2001) as the most commonly used measures of standardized achievement. The WIAT is suitable for children between the ages of 4 and 16 years and includes four scales: Reading, Maths, Writing and Oral Language, with each scale including a range of subtests (Wechsler, 2005). The Woodcock-Johnson Test of Achievement is a similar standardized measure and includes 22 subtests that capture achievement in Reading, Maths, Writing, Oral Language Abilities and Academic Knowledge (Woodcock, 2001). One advantage of standardized assessments is that they permit a direct comparison of achievement across pupils and schools (Howse, 2019; Hughes, 2014). At the same time, however, the nature of these assessments means that not all autistic pupils will be able to take part. For instance, as some subscales require a verbal response, children who are non-verbal are unable to complete the assessment (Wechsler, 2005; Hughes, 2014). Teachers have also explained that these types of assessments do not afford the opportunity to record small aspects of academic progress that are just as important to teachers, pupils, and parents. For example, in a focus group conducted by Howell, Langdon and Bradshaw (2020; 12), one SEN teacher explained "*how do you showcase how willing someone is to want to learn*?". This concern related to a broader theme of standardized assessments focusing on the development of individual skills, rather taking a holistic approach, and considering 'the whole child' (Howell, Langdon & Bradshaw, 2020). It is for this reason that many researchers and educational professionals also use indirect measures of achievement, including classroom observation, teacher reports and self-evaluations (Howse, 2019). These measures tend to be more inclusive and often capturing behaviours that go beyond academic achievement. For instance, questionnaires such as Achenbach System of Empirically Based Assessment Teacher From (ASEBA: TR), measure several aspects of school functioning, including rule-breaking behaviour, achievement, and social problems (Howse, 2019). There is, therefore, a need to consider both direct and indirect measures, when aiming to understand how well autistic pupils are doing academically at school (Howse, 2019; Howell, Langdon & Bradshaw, 2020). The following review will focus on reading and maths achievement, as developing abilities in both of these domains contributes towards an individual becoming self-sufficient and independent (Nally et al., 2018; Hodgen & Marks, 2013). Indeed, reading and maths skills are needed to complete a range of everyday activities (e.g., shopping, understanding road signs and paying bills) and are also key for securing future employment (Hodgen & Marks, 2013; Burgess & Gutstein, 2007).

2.3.1 Reading Profile

To become accurate and fluent readers, children must develop skills in five core areas (National Reading Panel, 2000). These are Phonemic Awareness (*the ability to focus on and manipulate phonemes*); Phonics (*matching the sounds of spoken English with individual or groups of letters in print*); Fluency (*the ability to read with speed, accuracy, and expression*); Vocabulary (*understanding the meaning of individual word*) and Comprehension (*the ability to process text, understand its meaning, and to integrate with what is already known*) (National Reading Panel, 2000). However, there is some evidence that autistic children show an uneven profile of achievement across these components, and at a group level, tend to have lower overall reading scores compared to their neurotypical peers (Keen, Webster & Ridley, 2016; Nation et al., 2006; McIntyre et al., 2017).

Highlighting this is the work of Nation et al. (2006) who assessed Word Recognition, Nonword Decoding, Text Reading Accuracy, and Text

Comprehension in a group of 41 autistic children between the ages of 6 and 15 years. At a group level, autistic pupils achieved Reading Comprehension scores that were at least one standard deviation below neurotypical norms, despite Word Reading and Text Accuracy falling in the average range (Nation et al., 2006). Similar findings were obtained by Minshew et al. (1994) who assessed the reading profiles of 54 autistic males (M=16.3 years) and 41 neurotypical males (M=15.38 years) matched for age, IQ, gender, race, and SES. It was found that compared to neurotypical males, autistic males achieved similar Decoding scores but significantly worse Reading Comprehension scores. However, the large standard deviations reported in the autistic group highlight that there are substantial individual differences in autistic pupils reading ability (Minshew et al., 1994; Solari et al., 2017). This indicates that not all autistic pupils will experience a relative weakness in Reading Comprehension (McIntyre et al., 2017). Indeed, in a study undertaken by Nally et al. (2018) only 4% of the sample (N=110, ages 3-17 years) evidenced an uneven profile whereby Reading Comprehension scores fell significantly below Word Reading scores. Collectively, these studies highlight that there is substantial variability in autistic pupils' reading ability (Nally et al., 2018; McIntyre et al., 2017). Understanding the factors that contribute to this variability is important for ensuring appropriate strategies are put in place to support the development of autistic pupils reading abilities (Mayes et al., 2020).

2.3.2 Maths Profile

To become accurate and fluent in maths, children must develop skills in four key areas (Geary, Hamson & Hoard, 2000; Geary, 2004). These are Procedural Calculation (*converting numerical information into mathematical equations and algorithms*); Number Fact Retrieval (*the ability to retrieve basic number facts* *automatically from long-term memory*); Word/Language Problems (*verbal problem-solving abilities*) and Visuospatial abilities. However, similar to that seen in reading, there is some evidence that autistic children show an uneven profile of achievement across these components, and at a group level tend to achieve similar or lower maths achievement compared to their neurotypical peers (Keen, Webster & Ridley, 2016). Indeed, contrary to that often portrayed in popular culture, many autistic pupils face difficulties with maths at schools (Chiang & Lin, 2007).

Evidencing this is the work of Bullen et al. (2020) who compared the maths achievement of autistic pupils (N= 77, M= 11.38 years), neurotypical pupils (N=43, M=11.60), and pupils with ADHD (N=39, M=11.64) by asking them to complete the WIAT 2. Although autistic pupils and pupils with ADHD were both delayed in the development of math skills compared to the neurotypical group, autistic pupils demonstrated a unique profile that was characterized by poorer performance on Calculation and Problem Solving, and which was significantly associated with individual differences in working memory (Bullen et al., 2020). Findings by Bae et al. (2015) also indicate that a group level, autistic pupils may achieve lower levels of maths achievement compared to neurotypical pupils. In this study 20 autistic (M=10.6 years) and twenty neurotypical children (M=10.27 years) completed the Kaufman Brief Intelligence Test, alongside measures of Word Problem abilities and Mathematical Knowledge. Compared to neurotypical children, autistic children achieved significantly lower Word Problem solving scores and also less everyday Mathematical Knowledge (Bae et al., 2015). It should be noted however that the standard deviations were much larger in the autistic group on each of the components compared to the neurotypical group. Thus, emphasizing that while autistic pupils may achieve lower scores at a group level, there are substantial individual differences in autistic pupil's maths ability (Bae et al., 2015; Chiang & Lin, 2007). Highlighting this is the work of Wei et al. (2015) who found that 20% of autistic pupils (Sample N=130, ages 6-9 years) achieved superior Calculation scores relative to IQ and Mathematical Reasoning scores. Findings therefore indicate that although a subset of autistic pupils show above average achievement, this certainly does not appear to be representative of the autistic population more broadly (Bullen et al., 2020; Chiang & Lin, 2007). Rather, at a group level achievement tends to be lower than that seen in neurotypical development (Keen, Webster & Ridley, 2016). Moreover, some autistic children evidence an uneven profile of achievement whereby Calculation is a relative strength compared to Reasoning (Wei et al., 2015). The following section will therefore review the factors that may be contributing to this variability before considering the role that sensory differences may have in influencing academic achievement.

2.4 What predicts academic achievement?

Identifying the factors that contribute to academic variability can help in developing strategies and interventions to support all pupils academically at school (Keen, Webster & Ridley, 2016). Factors external and internal to the child have been shown to predict both autistic and neurotypical pupil's academic achievement (Howse et al., 2019). An example of an external factor is socio-economic status (SES; Sirin, 2005; Lam 2014). Indeed, meta-analytic reviews have indicated that SES accounts for approximately 9% of the variance in neurotypical pupil's academic achievement (Sirin, 2005). Likewise, Wei et al. (2015) found that low-achieving autistic children were more likely to be from lower SES backgrounds compared to higher-achieving children (as assessed through household incomes and maternal education). An example of an internal factor is working memory. Working memory skills are thought to underlie success in many day-to-day classroom activities, including keeping track of progress, storing, and processing information, and remembering classroom instructions (Gathercole, Lamont & Alloway, 2006). Highlighting the importance of working memory, Alloway and Alloway (2010) asked 98 neurotypical children between the ages of 4.3 years and 5.7 years to complete a battery of verbal short-term memory and working memory tasks, alongside a measure of IQ. Six years later, children were invited back to complete the Wechsler Objective Reading Dimensions (WORD) and the Wechsler Objective Numerical Dimensions (WOND) as measures of academic achievement. It was found that working memory at age 6 explained 21% of variance in children's reading and maths scores at time two (Alloway & Alloway, 2010). Similarly, Assouline, Nipon and Dockerty (2012) found a significant positive relationship between working memory and reading (r=0.401) and maths (r=0.495) achievement in a group of 59 autistic children with IQ scores in the superior range (IQ >120). Working memory therefore makes an important contribution to both neurotypical and autistic pupil's academic achievement (Alloway & Alloway, 2010; Assouline, Nipon & Dockerty, 2012).

Nevertheless, while factors such as SES and working memory contribute to academic achievement, the amount of variance explained is generally much less than that accounted for by IQ (Guez et al., 2018; Mayes & Calhoun, 2011). Indeed, IQ has emerged as the single most powerful predictor of academic achievement (Mayes & Calhoun, 2011). Emphasizing this, Deary et al. (2007) conducted a five-year longitudinal study to assess the association between IQ and achievement in national exams in a sample of 70,000 secondary school pupils. It was found that IQ at age 11 made an important contribution to pupils' achievement at age 16, accounting for 56.6% of the variance in GCSE Maths achievement and 48.0% of the variance in GCSE English achievement (Deary et al., 2007). IQ also makes an important contribution to autistic pupils' academic achievement (Mayes & Calhoun 2003; Estes et al., 2011; Kim, Bal & Lord, 2018). This was evidenced by Eaves and Ho (1997) who found a significant positive relationship between IQ and Spelling, Reading, Maths (r= .56 to .77) scores on the WRAT-3, in a sample of 76 autistic pupils. In addition to predicting academic achievement (accounting for 44-69% of the variance in attainment), IQ has also been shown to moderate achievement; whereby autistic pupils with higher IQ make quicker gains in learning compared to pupils with lower IQ (Kim, Bal & Lord, 2018). IQ therefore accounts for a significant amount of variability in both autistic and neurotypical pupil's academic achievement (Mayes et al., 2020).

However, as will be discussed in Chapter 3, several studies have found that some autistic children evidence academic achievement that is not commensurate with intellectual ability as measured by IQ (Kim, Bal & Lord, 2018; Chen et al., 2019; Estes et al., 2011). That is, some autistic children are significantly underachieving or overachieving academically based on performance predicted by IQ (Mayes et al., 2020; Estes et al., 2011). One of the first studies to illustrate this was Jones et al. (2009) who examined the IQ-achievement profiles of 99 autistic adolescents between the ages of 14 and 16 years. Participants were asked to complete the WORD as a measure of reading achievement, the WOND as a measure of maths achievement and the WASI as a measure of IQ. An individual was classified as showing an achievement discrepancy if their scores on the reading and maths assessment were 15 points (1 SD) above or below their IQ score. Although 76% of adolescents achieved reading scores that were commensurate with IQ, and 78% achieved maths scores that were commensurate with IQ, the remaining children demonstrated significant IQ-achievement discrepancies (Jones et al., 2009). This resulted in four discrepancy groups being identified: Arithmetic Peak, Arithmetic Dip, Reading Peak and Reading Dip. For maths, overachievement (16% of sample - Arithmetic Peak) was found to be more common than underachievement (6% of sample - Arithmetic Dip). Reading overachievement (14% of sample - Reading Peak) was also slightly more common than underachievement (10% of sample - Reading Dip). Findings therefore indicate that although the majority of autistic pupils are achieving at a level commensurate with IQ, there are some pupils who evidence significant IQ-achievement discrepancies (Jones et al., 2009). Examining the nature and extent of these discrepancies is important for our understanding of the mechanisms that underlie learning, and also for informing our approach to supporting pupils academically at school.

However, as will be discussed in Chapter 3, findings are mixed with regards to the prevalence and direction (underachievement or overachievement) of these IQ-achievement discrepancies and whether the pattern reflects that seen in neurotypical development (Mayes et al., 2020; Estes et al., 2011; Jones et al., 2009). Indeed, to date, only a limited number of studies have explored whether IQ-achievement discrepancies are present in neurotypical development (Mayes et al., 2020). Moreover, as will be discussed in Chapter 3 there are methodological concerns relating to the nature of the achievement assessments used in these studies (Mayes et al., 2020). Chapter 3 of this thesis will address these issues by conceptually replicating Jones et al. (2009) and also including a age and ability matched control groups, alongside assessing a broader range of maths, and reading skills. Understanding these issues is vital because if the prevalence of IQ-achievement discrepancies is much greater in ASD than in the neurotypical development, this could suggest that factors beyond IQ are influencing autistic pupil's achievement (Estes et al., 2011; Howse, 2019; Keen, Webster & Ridley, 2016). One possibility is that these factors are autism-specific insomuch that they do not contribute to the variability in neurotypical pupil's achievement (Howse, 2019; Estes et al., 2011).

Critically, the work of Ashburner, Ziviani and Rodger (2008) suggests that sensory differences are one of these factors that might be autism-specific such that they have a unique and critical role in autistic pupil's academic achievement (beyond any impact for neurotypical pupils). This study examined the relationship between sensory processing, classroom behaviour, and educational outcomes in a group of 51 neurotypical children and 28 autistic children, between the ages of 6 and 10 years (Ashburner, Ziviani & Rodger, 2008). To examine these associations, children completed the Kauffman Brief Intelligence Test, teachers completed the Conner's Teacher Rating Scale and the Achenbach System of Empirically Based Assessment (ASEBA; Achenbach et al., 2001), and parents completed the Short Sensory Profile. For autistic pupils, it was found that auditory filtering and tactile sensitivity explained 37% of the variance in cognitive problems and inattention in the classroom, as assessed by the Connors Teacher Rating Scale (Conners, 1997). Moreover, under-responsiveness/seeks sensation and auditory filtering scores on the Short Sensory Profile accounted for 47% of the variance in autistic pupils ASEBA academic performance scores as rated by teachers (Ashburner, Ziviani & Rodger, 2008). However, there were no significant correlations between any of the scores on the Short Sensory Profile and the Connors Teacher Rating Scale and the ASEBA in the neurotypical group. Although some caution is needed due to the ASEBA being an indirect measure of academic achievement, findings do provide preliminary evidence that sensory difference can impact behaviour and achievement of autistic but not neurotypical pupils(Ashburner, Ziviani & Rodger, 2008).

However, a key limitation of Ashburner, Ziviani & Rodger (2008) is that parents, and not teachers ranked sensory differences. This is an issue because as highlighted in Chapter 1, the environment in which a child is placed can influence the presentation and severity of sensory differences (Tøssebro, 2004; Brown & Dunn, 2010). Indeed, Fernandes-Andres et al. (2015) found that when asked to report on the same child, teachers reported greater sensory differences compared to parents on the Sensory Processing Measure rating scale (Parham, et al., 2007). One reason for this discrepancy could be that sensory differences are more pronounced in the classroom environment, compared to the home environment, given its unpredictable and highly stimulating nature. This therefore raises the possibility that the impact of sensory differences on achievement may have been underestimated in Ashburner, Ziviani & Rodger (2008). This issue will be addressed towards the end of this thesis in Chapter 6 by asking teachers rather than parents to report on sensory differences, when investigating the relationship between sensory differences, academic achievement, and classroom behaviour. Furthermore, while Ashburner, Ziviani & Rodger (2008) provides initial evidence of sensory differences impacting achievement, it provides little insight into the potential mechanism underlying this relationship. Understanding these mechanisms is vital from both a theoretical perspective and also in terms of thinking about how best to support all autistic pupils at school.

2.5 How might sensory differences impact achievement and classroom behaviour?

Qualitative research can be particularly insightful for exploring how sensory differences might impact learning in the classroom. Highlighting this is the work of Howe and Stagg (2016) who asked 16 autistic pupils attending mainstream secondary schools to complete the Adolescent and Adult Sensory Profile (Dunn, 1999) alongside an open-ended qualitative questionnaire. This questionnaire asked about auditory, tactile, olfactory, and visual experiences in the classroom. Participants were then asked if and how these experiences impacted learning, and to describe the feelings associated with these experiences. Auditory differences were perceived to be most disruptive for learning, followed by tactile, olfactory, and visual differences. Participants explained that sensory differences impacted learning by disrupting concentration, causing anxiety, and creating physical discomfort (Howe & Stagg, 2016). Similar findings were obtained by Humphreys and Lewis (2008) who conducted semi-structured interviews with 20 autistic pupils to understand their experiences of attending a mainstream secondary school in England. Pupils reported that sensory differences could impact participation in class and engaging with work. Likewise, “pushing and shoving in the corridors” could cause high levels of anxiety and stress in school (Humphreys & Lewis, 2008; 37). While these studies highlight the importance of the autistic voice and emphasize that sensory differences impact not only learning but also wider school experiences, one limitation is the majority of participants were autistic males (Howe & Stagg, 2016). This is an issue because as highlighted in Chapter 1, there is some suggestion that autistic females experience significantly greater impact of unusual sensory experiences across the lifetime compared to males (Lai et al., 2011). Moreover, many autistic females do not receive a diagnosis until later in life, meaning they must navigate the school environment undiagnosed and often unsupported. The impact of sensory differences, and the interaction with other core autism features, may thus result in a very different school experience compared to that reported by earlier-diagnosed autistic males. This possibility will be explored in Chapter 4 by asking late diagnosed autistic females to reflect back on their sensory experiences at school.

It is important to acknowledge however, that there are limits to self-report (Hughes, 2014). In particular, it has been suggested that hyposensitivity is difficult to reflect on as an individual might not be aware of missing sensory input, for example a teacher calling their name (Dickie et al., 2009). It is for this reason that a multi-informant approach is needed to build a comprehensive understanding of how sensory differences might impact learning and behaviour at school. Highlighting the value of this approach is Piller and Pfiefer (2016) who interviewed eight primary school teachers and five occupational therapists (OTs) to understand how sensory differences impact participation and behaviour in the classroom. Both teachers and OTs explained that sensory differences were often situated within a particular context rather than being a stable trait. Likewise, teachers identified a variety of stimuli that pupils perceived as adverse including different textures when participating in arts and crafts, loud noises in the classroom, and tactile input from other children. Teachers also identified situations in which children would seek sensory input, including playing on the swings, smelling pen markers, and listening to a song on repeat. Teachers and OTs explained they would attempt to increase classroom participation by adopting routines and adapting the classroom environment to reduce stimulation (Piller & Pfeiffer, 2016). These findings emphasize how detrimental an incompatible environment can be, but also demonstrate the value of a multi-perspective approach (Piller & Pfeiffer, 2016). Nevertheless, the sample size was small and the nature of the school provision unclear (e.g., mainstream, special education provision). This is an issue because both the environment and type of support available to pupils can differ substantially across school provisions (All Party Parliamentary Group on Autism, 2017). Therefore, a key aim of Chapter 4 is to capture the views of teachers and parents, from a range of school provisions, on how sensory differences impact learning and behaviour in the classroom.

2.6 How might the classroom environment impact children's on-task behaviour?

Up to this point the focus has been on children's sensory differences with very little consideration of how the classroom environment might also impact learning and behaviour. According to the Nordic Relational Model of Disability, it is the interaction between an individual's functional needs and the environment in which they are placed which determines whether or not an individual experiences disability (Tøssebro, 2004). It is therefore vital that consideration is also paid to how the classroom environment might impact learning and behaviour (Goodley & Runswick-Cole, 2012). Importantly, the classroom is a uniquely stimulating and multisensory space with often upwards of twenty children playing and learning alongside one another. To learn and stay on-task in this environment, children must select information that is relevant for the task at hand while also inhibiting that which is irrelevant (Erickson et al., 2015; Oakes, Kannass & Shaddy, 2002). Importantly, children must be able to do this for an extended period of time (Erickson et al., 2015; Oakes, Kannass & Shaddy, 2002). For example, a child might need to listen to the teacher's instructions whilst also ignoring the sound of children playing in the corridor. This ability is referred to as selective-sustained attention (Ruff & Rothbart, 2001; Oakes, Kannass & Saddy, 2002).

Selective sustained attention improves with age such that older children are better able to filter out irrelevant distractors and exert voluntary attentional control for longer (Gaspelin, Margett-Jordan & Ruthruff, 2015). Highlighting this is the work of Goldman, Shaprio and Nelson (2004) who asked 51 children between the ages of 12 months and 46 months to complete the Early Childhood Vigilance Task. In this task, children are required to look at a blank computer screen in anticipation for interesting stimuli (e.g., moving cartoon characters to appear). The longer children spend looking at the screen, the more likely they are to see the cartoon when it appears on the screen. It was found that older children spent significantly longer sustaining attention towards the screen compared to younger age children (Goldman, Shaprio & Nelson, 2004). Studies conducted by Steele et al. (2012) also indicate a continuous linear improvement in the ability to sustain selective attention between the ages of 3 and 6 years. Likewise, Pozuelos et al. (2014) found that selective-sustained attention improved between the ages of 6 and 8 but remained stable after age 8 years. Taken together, these studies provide strong evidence that selective sustained attention improves through childhood.

The ability to sustain attention on task-relevant information is crucial for learning (Erickson et al., 2015; Moffett & Morrison, 2020). Indeed, according to Carrol's time-on-task hypothesis the longer an individual spends on task, the better the learning outcome (Carroll, 1963). Supporting this hypothesis are the findings of Erickson et al. (2015) who asked 24 neurotypical children (M=5.37) years to complete the Track-it Task. In this task, children were asked to pay attention to one item (e.g., a yellow diamond) that moved randomly around a grid presented on a computer screen. Children needed to track this item as they were asked to report its last grid location before it disappeared off screen. At the time however, there were an array of distractors also moving around the screen. In the homogenous condition, these distractors were identical to one another (e.g., all blue squares) but were different from the target (e.g., yellow diamond). Conversely, in the heterogeneous condition, the distractors were different from each other (e.g., a blue square, a green triangle, purple rectangle) and also different from the target (e.g., yellow diamond). Whereas the heterogeneous condition is thought to capture endogenous (top-down, goal-directed) attention, the homogenous condition is thought to capture both endogenous and exogenous (bottom-up stimuli-driven) attention. After completing the Track-It task, children completed a learning task in a mock classroom. In this set up, children sat in a semicircle and were taught three short lessons on novel topics they had not previously encountered. At the end of every lesson, children were asked to complete a worksheet to assess their learning (Erickson et al., 2015). Critically, it was found that children's learning achievement was significantly correlated with their performance on the heterogeneous Track-it task condition, but not the homogenous condition. This, therefore, indicates that children who are better able to inhibit distractors to achieve a goal, tend to obtain higher learning scores. This is particularly important when thinking about the classroom as this environment contains a multitude of potential distractors that could capture children's attention (Moffet & Morrison, 2020).

Highlighting this possibility is the work of Barrett et al. (2015) who investigated how the classroom physical environment impacted children's academic progress over one academic year. In this study, 153 classrooms across 27 schools in the UK were surveyed for evidence of Naturalness (Light, Temperature and Air Quality), Stimulation (Complexity and Colour), and Individualization (Ownership and Flexibility). Academic progress was then assessed by comparing pupils National Curriculum levels in Reading, Writing and Maths at the beginning and end of the academic year. It was found that 16% of the variability in children's academic achievement was accounted for by seven design features, including light, temperature, air quality, ownership, flexibility, colour, and complexity. This emphasizes that the classroom physical environment has the potential to have a substantial impact on academic progress (Godwin, Erickson & Newman, 2019). Notably however, the relationship between complexity, defined as "*the degree to which the classroom provides appropriate visual diversity*" (Barrett et al., 2015; 12) and academic progress was curvilinear. Thus, suggesting that there is an optimal amount of visual stimulation in the classroom, with both too little and too much stimulation negatively impacting children's progress (Barrett et al., 2015).

Highlighting that too much visual stimulation can adversely affect children's learning and behaviour is the work of Fisher, Godwin, and Seltman (2014). In this study, a teacher read stories for 5-7 minutes in a mock classroom to children (N=24, Mean Age=5.37 years) in two experimental conditions: decorated and sparse. In the sparse condition, lessons took place in a room with minimal displays and colour whereas, in the decorated conditions, walls were covered with highly stimulating displays. Children were video-recorded in each condition and their on/off-task behaviour coded using an event-based coding methodology. To assess learning, children were also asked to complete workbooks at the end of each lesson in each condition. Foremost, it was found that children spent 10% more time off-task in the decorative condition relative to the sparse. It was also found that the types of off-task behaviours evidenced by children differed between conditions such that children were significantly more engaged in Self Distraction and Peer Distraction in the sparse condition and significantly more engaged in Environmental Distraction in the decorated condition. Moreover, a mediation analysis demonstrated that more off-task behaviour in the decorated condition was associated with poorer learning outcomes compared to the sparse condition (Fisher, Godwin & Seltman, 2014). Whilst these findings emphasize that visual stimulation is an important source of variability in off-task behaviour and academic achievement, it needs to be highlighted that 15% of pupils did not show a difference in distraction between classroom conditions (Fisher, Godwin & Seltman, 2014). Thus, indicating that even within typical development there is considerable heterogeneity in susceptibility to distraction. We might expect even greater individual differences when examining how the environment impacts autistic children’s on-task behaviour, given the attentional and sensory differences highlighted in Chapter 1 of thesis.

Supporting this position are the findings of Hanley et al. (2017) who used eye tracking to record the eye-movements (as a measure of attention allocation) of autistic and neurotypical children whilst they watched videos of a teacher delivering a 5-minute lesson on Irish myths and legends on the computer screen. Similar to Fisher, Godwin and Seltman (2014), the background of these videos was manipulated to be completely sparse or to include lots of educational visual displays. To assess learning, children were asked to complete worksheets at the end of each lesson. Although visual displays impacted attention for all children, this effect was particularly pronounced for autistic children, such that this group spent more time looking at the background as opposed to the teacher. Furthermore, in terms of learning, the strongest predictor of learning was the proportion of time spent looking at the background, alongside verbal ability, and social ability (as assessed through the Social Responsiveness Scale (Constantino & Gruber, 2012). Taken together, findings indicate that although autistic children are more susceptible to visual distraction, attending to displays can impact both autistic and neurotypical children, and their ability to learn (Hanley et al., 2017). Nevertheless, this study only examined visual distraction, and did not consider how audio and audio-visual stimuli might impact attention, learning and behaviour. Classrooms are multi-sensory environments and so consideration of these inputs is vital when thinking how best to support autistic pupils with sensory differences at school.

Chapter 7 will therefore address this evidence gap by taking a more holistic approach and exploring how different sensory features of the classroom (visual, audio, and audio-visual stimuli) impact the ability of autistic and neurotypical pupils to stay on-task.

2.7 Review Conclusions

In conclusion, the aim of this chapter was to illustrate why sensory differences need to be considered in an educational context. To that end, this review began by highlighting the variation in the quality and availability of support offered to autistic pupils in school in the UK. Focus then turned to considering the academic achievement of autistic pupils, in which it was emphasized that at a group level, autistic pupils attain lower levels of achievement compared to their neurotypical peers. Evidence was then presented to show that IQ is not always a reliable predictor of autistic pupils' academic achievement (see this followed up in Chapter 3). This, therefore, could suggest that factors beyond IQ are contributing to achievement. It was argued that sensory differences could indeed be one of these factors. However, further research is needed to establish this relationship as the current literature is limited in terms of only asking parents, and not teachers, to report on sensory differences and only using indirect measures of achievement (see this followed up in Chapter 6). Likewise, although there is some preliminary evidence for a relationship between sensory differences and autistic pupils' academic achievement, little is known about the mechanisms underlying this relationship. It was emphasized that to understand this relationship, insights from multiple informants (including parents, teachers, and autistic individuals) are needed from a range of school provisions. This is because the severity and presentation of sensory differences can differ across different contexts. In particular, there is a need to understand the sensory experiences of autistic females at school, as the majority of research has focused on males (see this followed up in Chapter 5. This is an issue because as highlighted in Chapter 1, there is some suggestion that females may experience greater severity of sensory differences across the lifespan compared to males. Lastly, in line with the Nordic Relational Model of Disability, the role of the classroom sensory environment in impacting achievement was reviewed. It was argued that while several studies have shown that visual stimulation can impact learning and behaviour, the role of audio and audio-visual stimulation has been neglected (see Chapter 7). Therefore, while the current literature provides some indication that sensory differences can impact achievement and behaviour, there remain substantial gaps in our understanding of this relationship. The aim of this thesis is to therefore address these issues and undertake a comprehensive multi-method investigation into the impact of sensory processing differences on achievement and classroom behaviour for autistic pupils.

2.8 Thesis Aims

The main aim of this thesis is to investigate the relationship between sensory processing differences, academic achievement, and classroom behaviour in autistic children. This thesis will adopt a Nordic Relational Model of Disability and explore both the impact of a child’s sensory differences and the impact of sensory features of the classroom environment and consider the interaction between these factors. Central to achieving this aim is the use of multi-methods to allow for multiple perspectives to be captured. Indeed, this thesis will explore the views of parents, teachers, and autistic individuals using standardized questionnaires and assessments, qualitative surveys, and a novel experimental method, with the aim of providing a rich and comprehensive understanding of how sensory differences impact learning and behaviour in the classroom. To that end, Chapter 3 of this thesis will focus on the role of IQ in predicting autistic and neurotypical pupil's academic achievement before exploring the prevalence and direction of IQ-achievement discrepancies in both groups. Building on the findings of Chapter 3, Chapter 4 will capture the views of parents and teachers on *how* sensory differences might impact the learning and classroom behaviour of autistic pupils. Chapter 5 will explore similar issues but in this instance from the perspective of late-diagnosed autistic females who will add the autistic voice to the thesis and who will be asked to reflect back on their time at school. Moving from qualitative insights to quantitative measures, Chapter 6 will use standardized measures of achievement to understand the role that sensory differences play in impacting autistic pupils' achievement. Focus will turn to the role of the environment in Chapter 7 whereby a novel experimental method will be presented to understand how the sensory environment impacts autistic and neurotypical pupil's ability to stay on-task. Lastly, Chapter 8 will provide a general discussion of the thesis.

Chapter 3: Does IQ predict the academic achievement of autistic and neurotypical pupils?

3.1 Introduction

Academic achievement has been associated with an array of future life outcomes including employment, health, and independent living (Burgess & Gutstein, 2007). As emphasized in Chapter 2 of this thesis, the academic outcomes of autistic pupils are heterogeneous such that some pupils leave school with no formal qualifications whereas others move into further and higher education (Anderson et al., 2019). However, at a group level, there is some evidence that autistic pupils are more likely to achieve lower academic attainment compared to their neurotypical peers (Anderson et al., 2019). Indeed, at the end of Key Stage 2, whereas 65% of neurotypical pupils reached the expected standard of reading and maths achievement, only 41% of autistic pupils achieved this target (Department for Education, 2018). Identifying the factors that contribute to academic variability, both within and between the autistic and neurotypical population, is therefore vital for implementing evidence-based support and potentially improving life trajectories (Keen, Webster & Ridley, 2016).

An important first step in implementing such support is to establish if the same or different factors underlie the heterogeneity seen in neurotypical and autistic pupil's academic achievement. For neurotypical pupils, although factors such as working memory and social-economic status have been found to explain some of the variance in academic achievement, there is strong evidence to show IQ is a powerful predictor of academic success (Alloway & Alloway, 2010; Berkowitz et al., 2017; Calvin et al., 2010). Emphasizing this are the findings of Deary et al. (2007) who conducted a five-year longitudinal study to assess the association between IQ and achievement in national exams in a sample of 70,000 secondary school pupils. It was found that IQ at age 11 made an important contribution to pupil's achievement at age 16, accounting for 56.6% of the variance in GCSE Maths achievement and 48.0% of the variance in GCSE English achievement (Deary et al., 2007). This positive association has also been identified using standardized measures of achievement (Rohde & Thompson, 2007; Mayes et al., 2009). This can be highlighted by the work of Mayes et al. (2009) who examined the relationship between IQ and achievement in a sample of 214 neurotypical pupils between the ages of 6 and 12 years. It was found that 35% of the variance in Word Reading scores and 22% of the variance in Math Computation scores on the Wide-Ranging Achievement Test (WRAT 3, Wilkinson 1993) were accounted for by IQ. Findings therefore emphasize that IQ is an important and powerful predictor of neurotypical pupil's academic success (Mayes et al., 2009; Deary et al., 2007; Rohde & Thompson, 2007).

IQ also makes an important contribution to autistic pupils' academic achievement (Mayes & Calhoun 2003; Estes et al., 2011; Kim, Bal & Lord, 2018). This was evidenced by Eaves and Ho (1997) who found a significant positive relationship between IQ and Spelling, Reading, Maths (r= .56 to .77) scores on the WRAT-3, in a sample of 76 autistic pupils, all of whom had an IQ above 40. In addition to predicting academic achievement (accounting for 44-69% of the variance in attainment), IQ has also been shown to moderate achievement; whereby autistic pupils with higher IQ make quicker gains in learning compared to pupils with lower

IQ (Kim, Bal & Lord, 2018). Whilst there is heterogeneity in the amount of variance accounted, possibly due to differences in how achievement was measured (e.g., standardized measures versus national exams) or sample characteristics (e.g., cognitive ability), overall, these findings indicate that a significant amount of the variability in autistic and neurotypical pupil's academic achievement can be accounted for by IQ (Guez et al., 2018; Deary et al., 2007; Kim, Bal & Lord, 2018).

Nevertheless, a growing body of literature suggests the relationship between IQ and academic achievement is more complex in ASD than in neurotypical development, with some autistic pupils evidencing academic achievement that is not commensurate with intellectual ability (Keen, Webster & Ridley, 2016; Chen et al., 2019). That is, some autistic children are significantly underachieving or overachieving academically based on that predicted by IQ (Keen, Webster & Ridley, 2016). One of the first studies to identify such discrepancies was Jones et al. (2009). In this study, the IQ-achievement profiles of 99 autistic adolescents between the ages of 14 and 16 were examined. An individual was classified as having a Reading discrepancy if their basic Reading score on the Wechsler Objective Reading Dimension (WORD) assessment was 15 points (1 SD) above or below IQ, and a Maths discrepancy if their Numerical Operations score on the Wechsler Objective Numerical Dimensions (WOND) fell 15 points above or below IQ. Although 76% of adolescents achieved Reading scores that were commensurate with IQ, and 78% achieved Maths scores that were commensurate with IQ, the remaining children demonstrated significant IQ-achievement discrepancies, resulting in four discrepancy groups being identified: Arithmetic Peak, Arithmetic Dip, Reading Peak and Reading Dip. For Maths, overachievement (16% of sample - Arithmetic Peak) was found to be more common than underachievement (6% of sample - Arithmetic Dip). Mean Numerical Operations scores were 24 points above IQ in the Arithmetic Peak group and 19 points below IQ in the Arithmetic Dip group. Reading overachievement (14% of sample - Reading Peak) was also slightly more common than underachievement (10% of sample - Reading Dip). Mean basic Reading scores were 21 points above IQ in the Reading Peak group and 22 points below IQ in the Reading Dip group. Findings therefore indicate that although the majority of autistic pupils are achieving at a level commensurate with IQ, there are some pupils who evidence significant IQ-achievement discrepancies (Jones et al., 2009).

Within the current literature however, findings are mixed with regards to the prevalence of IQ-achievement discrepancies, and whether this is in the direction of underachievement or overachievement (Mayes et al., 2019; Chen et al., 2019). This can be highlighted by contrasting the findings of Jones et al. (2009) to that of Estes et al. (2011). To investigate if IQ contributed to autistic pupils' academic achievement, Estes et al. (2011) conducted a longitudinal study and assessed IQ, academic achievement, social skills, and problem behaviours in a group of 30 autistic pupils, first at age 6 and then again at age 9. While IQ was significantly related to Word Reading and Basic Number Skills (but not Spelling) scores on the WRAT at a group level, significant IQ-achievement discrepancies were once again identified. In terms of reading, only 38% of pupils achieved as expected based on IQ, and overachievement (36% of pupils) was more common than underachievement (26% of pupils). However, in maths 47% of pupils achieved as expected, and underachievement (40%) was much more common than overachievement (13% of pupils; Estes et al., 2011). The percentage of pupils evidencing discrepancies and the prevalence of underachievement is therefore much greater in Estes et al. (2011) compared to Jones et al. (2009). There is, therefore, a need to conceptually replicate these studies and establish if IQ-achievement discrepancies are isolated to only a small subset of autistic pupils (Jones et al., 2009) or instead reflect a more widespread issue (Estes et al., 2011), in addition to identifying the direction of the discrepancy. There is also a need to include matched (age and IQ) comparison groups to establish if the IQ-achievement discrepancies seen in ASD reflect those seen in neurotypical development (Chen et al., 2009; Mayes et al., 2020).

Addressing these three issues is important from both a theoretical and applied perspective. First, if the prevalence of IQ-achievement discrepancies is much greater in ASD than in neurotypical development, this could suggest that factors beyond IQ are influencing autistic pupils' achievement (Estes et al., 2011; Howse, 2019). One possibility is that these factors are autism-specific insomuch that they do not contribute to variability in neurotypical pupil's achievement (Howse, 2019). Highlighting this possibility is the work of Ashburner, Ziviani and Rodger (2008) who found sensory processing differences contributed to autistic pupil's academic achievement but not neurotypical pupil's achievement. Alternatively, it could be that the same factors contribute to achievement in both groups, but the influence of this factor is stronger in ASD than it is in neurotypical development (Howse, 2019). However, if only a minority of autistic and neurotypical pupil's evidence IQ-achievement discrepancies this would provide support for IQ being an important predictor of academic success (Mayes et al., 2009; Eaves & Ho, 1997). Cases of underachievement are therefore more likely to reflect undiagnosed learning difficulties (e.g., dyslexia, dyspraxia) as opposed to reflecting a more systematic issue in how IQ relates to achievement. These different theoretical positions have important implications for the types of support that would be needed in the classroom (Howse, 2019). For instance, if the prevalence of underachievement is high this might signal the need for future research to examine what other factors are contributing to pupil's academic achievement, before implementing evidence-based support.

A recent study by Mayes et al. (2020) took the first steps in addressing some of these issues by examining the prevalence and direction of IQ-achievement discrepancies in a large sample of neurotypical pupils (n=519, age range 6-12 years), autistic pupils with and without a co-occurring diagnosis of ADHD (n= 285 age range 6-16), and pupils with a diagnosis of only ADHD (n=739, age range 6-16 years). Academic achievement was assessed by asking pupils to complete the Word Reading and Numerical Operation subsets of either the WIAT or WIAT 2. In terms of reading, 73% of neurotypical children achieved in line with IQ, 14% were overachieving, and 13% were underachieving. Although the majority of pupils with ADHD (65%) also achieved reading scores that were in line with IQ, underachievement (28%) was found to be much more prevalent than overachievement (7%). Conversely, while the majority of autistic pupils (67%) also achieved reading scores that were commensurate with IQ, overachievement (23%) was found to be more prevalent than underachievement (9%). Findings therefore indicate that compared to neurotypical pupils, neurodivergent pupils were less likely to achieve reading scores that were commensurate with IQ (Mayes et al., 2020). However, whereas pupils with ADHD were more likely to evidence reading underachievement, autistic pupils were more likely to evidence reading overachievement. In terms of maths achievement, the majority of pupils in all three groups achieved scores that were commensurate with IQ (NT 71%, ADHD 74%, ASD 78%). However, different to that seen in reading, underachievement (NT 20%, ADHD 24%, ASD 12%) was more common than overachievement in all three groups (NT 9%, ADHD 2.2%, ASD 10%; Mayes et al., 2020).

Critically however, there is some evidence to suggest that the approach taken in operationalizing maths and reading achievement, namely single scores on Word Reading and Numerical Operations, may have resulted in an inflated number of autistic overachievers being identified (Wei et al. 2015; Troyb et al., 2014; Bae, Chiang & Hickson, 2015). This narrow operationalization neglects that reading and maths are multifaceted abilities such that success in these domains requires a broad range of skills. Indeed, successful reading encompasses more than Word Reading, and also draws on Phonetic Decoding and Reading Comprehension (Hulme & Snowling, 2013; Tunmer & Hoover, 2019). Likewise, successful mathematics necessitates both Calculation and Reasoning (Orton, 2004). Neglecting these components of reading and maths is an issue because previous research has shown that some autistic pupils show uneven profiles of achievement within these domains (Keen, Webster & Ridley, 2016). Highlighting this is the work of Nation et al. (2006) who assessed Word Recognition, Nonword Decoding, Text Reading Accuracy, and Text Comprehension in a group of 41 autistic children between the ages of six and fifteen. At a group level, Reading Comprehension was significantly impaired despite Word Reading and Text Accuracy falling within the average range. This uneven profile is not always identified however, as evidenced by Nally et al. (2018) who found that autistic children with Reading Comprehension difficulties also scored poorly on Word Recognition. Nevertheless, these studies emphasize the need to consider multiple aspects of reading when assessing achievement and discrepancies from IQ (Tunmer & Hoover, 2019).

This is also the case for maths achievement as highlighted by the work of Bullen et al. (2020) who examined profiles of maths achievement in autistic pupils (N= 77, M= 11.38), neurotypical pupils (N=43, M=11.60), and pupils with ADHD (N=39, M=11.64). Although autistic pupils and pupils with ADHD were both delayed in the development of maths skills, autistic pupils demonstrated a unique profile that was characterized by poorer performance on Calculation and Problem Solving, and that was significantly associated with individual differences in working memory (Bullen et al., 2020). Conversely, Wei et al. (2015), in a group of 130 autistic pupils (ages 6-9 years) found evidence of superior Calculation abilities relative to IQ and Mathematical Reasoning in 20% of the sample. This, therefore, highlights the need to assess multiple aspects of reading and maths achievement when examining IQ-achievement discrepancies, as it could be that artificial discrepancies are arising because of one area of relative strength or weakness (Keen, Webster & Ridley, 2016).

3.1.1 Current Study

The current study therefore sought to investigate the relationship between IQ and academic achievement in a group of autistic and neurotypical pupils, matched for age and cognitive ability. Whilst previous work has shown that IQ is a powerful predictor of academic success in both groups, there has also been evidence that some autistic pupils evidence achievement profiles that are not commensurate with IQ. This has raised the possibility that the relationship between IQ and achievement is more complex in ASD than in neurotypical development, such that factors beyond IQ are contributing to academic success. A key aim of the current research was therefore to conceptually replicate these findings and also include a matched comparison group to establish if the IQ-achievement discrepancies seen in ASD reflect that seen in neurotypical development (Chen et al., 2019). We were interested in comparing the prevalence of both underachievement and overachievement as this would allow key strengths to be highlighted and capitalised on in school whilst allowing the areas in which children might need greater support to be identified. The current study also built on previous work by assessing a broader range of reading and maths skills and comparing achievement across each of these domains.

The first aim was to investigate if the relationship between IQ, maths achievement and reading achievement was similar for autistic and neurotypical pupils. For both groups, it was hypothesized that IQ would be positively related to achievement in both domains and predict a significant amount of variance in scores.

The second aim was to investigate the prevalence of IQ-achievement discrepancies in ASD and in neurotypical development. Based on the work of Mayes et al. (2020) it was predicted that the majority of neurotypical children would achieve maths and reading scores that were commensurate with IQ. However, a minority of neurotypical children were expected to achieve reading and maths scores that were significantly discrepant from IQ. In terms of the direction of this discrepancy, it was predicted that there would be a similar percentage of underachievers and overachievers (e.g., relatively balanced in distribution). The majority of autistic pupils were also hypothesized to achieve reading and maths scores that were commensurate with IQ. However, given the inclusion of a broader set of skills (compared to Mayes et al., 2020, and considering the work of Nation and colleagues), it was hypothesized that where discrepancies were identified, these would predominantly be in the direction of underachievement.

The final aim was to examine if neurotypical and autistic pupils evidenced discrepancies within the domains of reading and maths. It was predicted that neurotypical pupils would evidence a balanced profile such that reading subcomponent scores would be commensurate with each other and with IQ. Likewise, maths subcomponent scores were hypothesized to be commensurate with each other and IQ. For autistic pupils, based on the previously mentioned literature, it was predicted that Reading Comprehension would be a relative weakness compared to Word Reading, Pseudoword Decoding, and IQ. Likewise, in maths, it was predicted that Numerical Operations would be a relative strength compared to Mathematical Reasoning and IQ.

3.2 Method

3.2.1 Participants

The data reported in this study come from two independent projects (McDougal, Riby & Hanley, 2020 and Chapter 6 (Sensory and Achievement). Ethical approval was granted for both projects by the local ethics committee and all data were stored and managed in line with GDPR regulations.

EM collected data from 49 children between 2016-2019. For the autistic sample, EM included children with a diagnosis of ASD who were verbal and between the ages of 6 and 15. Children with a diagnosis of ADHD or a genetic condition were excluded. For the neurotypical sample, EM included children between the ages of 6 and 15 with no known neurodevelopmental or genetic condition.

EJ collected data from 27 children between 2017-2019. For the autistic sample, EJ included children with a diagnosis of ASD, who were verbal and between the ages of 6 and 11. Children with a comorbid diagnosis of ADHD or Sensory Processing Disorder were included but not children with a comorbid genetic condition. For the neurotypical sample, EJ included children between the ages of 6 and 11 with no known neurodevelopmental or genetic condition. Both researchers confirmed the presence or absence of ASD diagnosis by parent report. This is a limitation because researchers are relying on parents to be reliable and open when disclosing their child's diagnostic status (Bishop, 2011).

EM recruited TD children through mainstream schools or through a database of families signed up to be contacted to participate in research at Durham University. Children with ASD were recruited from i) mainstream schools with Special Education Needs (SEN) provision ii) SEN or ASD specialist schools, iii) The Autism Spectrum Disorder- UK database (ASD-UK), and iv) the families database. EJ recruited TD children only through mainstream schools. Autistic children were recruited through SEN or ASD specialist school.

Participating schools were provided with project packs, consisting of information sheets, consent forms, and a privacy notice to send to parents (See Appendix A for consent forms and information sheets). If parents agreed for their child to participate, they were asked to return the consent form to school. For all other methods of recruitment, parents were contacted directly, either by the researchers or by ASD-UK. Parents provided informed consent and children provided assent prior to participation.

From this point onwards the two sub-samples are considered one core sample for this study and will not be discussed separately. In total, the final combined sample comprised 38 autistic (35 male) and 38 neurotypical (19 male) children between the ages of 6 and 14 years. Although autistic children were slightly older (M=9.30 years, SD=1.75) than neurotypical children (M=8.83 years, SD=1.26), this difference was not significant $t(74)= 1.339$, $p=0.185$. Similarly, autistic (M= 91.97, SD=12.97) and neurotypical children (M=93.03, SD=11.08) did not differ on intellectual ability $t(74)=0.380$, $p=0.705$. Therefore, the two participant groups were matched on both chronological age and IQ. Seven autistic children also had a co-occurring condition which included ADHD and Sensory Processing Disorder.

3.2.2 Measures

The Wechsler Abbreviated Scale of Intelligence- Second Edition (WASI 2) (Wechsler, 2011)

The WASI 2 is a standardized assessment of estimated intelligence suitable for individuals aged 6 to 90 years. To obtain full scale IQ (FSIQ-4), four subtests; Similarities, Vocabulary, Block Design and Matrix Reasoning, are administered. Raw subtest scores are converted to T scores, which are then converted to age standard composite scores. Table 3.1 shows the qualitative description attached to composite scores. Strong psychometric properties have been demonstrated, including excellent internal consistency (0.96) and excellent concurrent validity (0.92) (Wechsler, 2011). This measure has been used extensively with autistic and neurotypical children (e.g., Kim et al., 2018, Mayes & Calhoun, 2008; Troyb et al., 2014).

Table 3.1 Qualitative descriptions for composite scores on the WASI 2 and WIAT 2

Composite Scores	Qualitative Description
<70	Extremely Low
70 to 80	Borderline
80 to 90	Low Average
90 to 110	Average
110 to 120	High Average
120 to 130	Superior
>130	Very Superior

Wechsler Individual Achievement Test 2nd Edition (WIAT 2) (Wechsler, 2005)

The WIAT 2 provides a standardized assessment of academic achievement for children aged 4 to 16 years. There are four scales: Reading, Maths, Writing and Oral, however for the current studies only the Maths and Reading scales were administered. The Reading scale consists of three tasks: Word Reading, Reading Comprehension, and Pseudoword Decoding. The Maths scale consists of two tasks: Numerical Operations and Mathematical Reasoning. Raw subset scores are converted to age-based standard scores, which are then summed to produce Maths and Reading composite standard scores. Table 3.1 shows the qualitative description attached to composite scores. Good test-retest stability has been shown with coefficients ranging from 0.85 (good) to 0.98 (excellent), in addition to strong inter-scorer reliability 0.94 (excellent) (Wechsler, 2005). This measure has also been used extensively with autistic children and neurotypical children (e.g., Chen et al., 2019; May et al., 2013).

3.2.3 Procedure

Children completed the tasks individually either in a quiet room at school, their home, or at Durham University. Testing occurred across two sessions, split across two days to ensure that children remained focused during each assessment. In the first session, lasting approximately 30 minutes, children completed the WASI 2. In the second session, children completed the WIAT 2, which took approximately 45 minutes to administer. All children completed both assessments within a three-week period. Children provided assent and were reminded that they could withdraw at any point. All children received certificates for participating in the study, and where parental consent had been given, IQ and achievement scores were shared with the school.

3.3 Results

3.3.1 Does IQ predict autistic and neurotypical pupil's academic achievement?

3.3.1.1 Descriptive Statistics

The first aim of this study was to investigate if IQ predicted autistic and neurotypical pupil's academic achievement in reading and maths. Descriptive statistics, presented in Table 3.2, show that the full range of academic achievement is captured in the autistic sample, with scores spanning from 'Extremely Low' to 'Very Superior'. Neurotypical achievement scores also ranged from 'Borderline' up to 'Very Superior'.

Despite being matched on intellectual ability, neurotypical pupils (M=102.34) achieved significantly greater reading scores compared to autistic pupils (M=93.05), $t(74)=2.430$, $p=0.018$. Neurotypical pupils (M=102.50) also achieved significantly greater maths scores compared to autistic pupils (M=82.97), $t(74)=4.396$, $p<0.001$. In terms of differences within groups, autistic pupils achieved significantly greater scores in reading (M=93.05) compared to maths (M=82.97), $t(37)=3.522$, $p<0.001$. However, there was no significant difference between reading (M=102.34) and maths (M=102.50) scores in the neurotypical group $t(37)=-0.079$, $p=0.937$.

Table 3.2 Academic achievement descriptive statistics

Measure	Group	N	Mean	Min	Max	Std. Deviation	t	p
FSIQ-4	ASD	38	91.97	70	127	12.97	0.380	0.705
	TD	38	93.03	75	127	11.08		
Reading	ASD	38	93.05	52	148	20.14	2.430	0.018
	TD	38	102.34	71	130	12.23		
Mathematics	ASD	38	82.97	42	142	22.79	4.396	<0.001
	TD	38	102.50	74	135	15.18		

3.3.1.2 Correlation Analyses

To test the hypothesis that IQ would be positively related to achievement in both groups, correlation analyses were next conducted for the autistic and neurotypical samples separately. Linearity was established for all associations through examinations of scatter-graphs, displayed in Figures 3.1 & 3.2. Although inspection of boxplots revealed three outliers in the autistic sample, and one outlier in the neurotypical sample, these cases were retained as none had standardized residuals greater than 3 (Field, 2013) and they were meaningful in terms of capturing heterogeneity in academic achievement. Spearman rank correlation was undertaken to investigate the relationship between IQ and maths achievement in the ASD sample, as maths scores were not normally distributed $W(38)=0.929$, $p=0.019$. Pearson correlations were conducted for all other analyses.

As hypothesized, there was a significant positive relationship between IQ and autistic pupils reading achievement $r(38)=0.746$, $p<0.001$. IQ was also significantly and positively associated with autistic pupils maths achievement $r_s(38)=0.565$, $p<0.001$. Comparison of correlation coefficients thus indicate that IQ is more strongly related to autistic pupils reading achievement than autistic pupils maths achievement.

For neurotypical children, IQ was significantly and positively associated with reading achievement r(38)=0.514, *p*<0.001. As predicted, there was also a significant positive relationship between IQ and neurotypical pupils maths achievement r(38)=0.515, *p*<0.001. Comparison of correlation coefficients indicate that the strength of this association is similar for both maths and reading achievement.

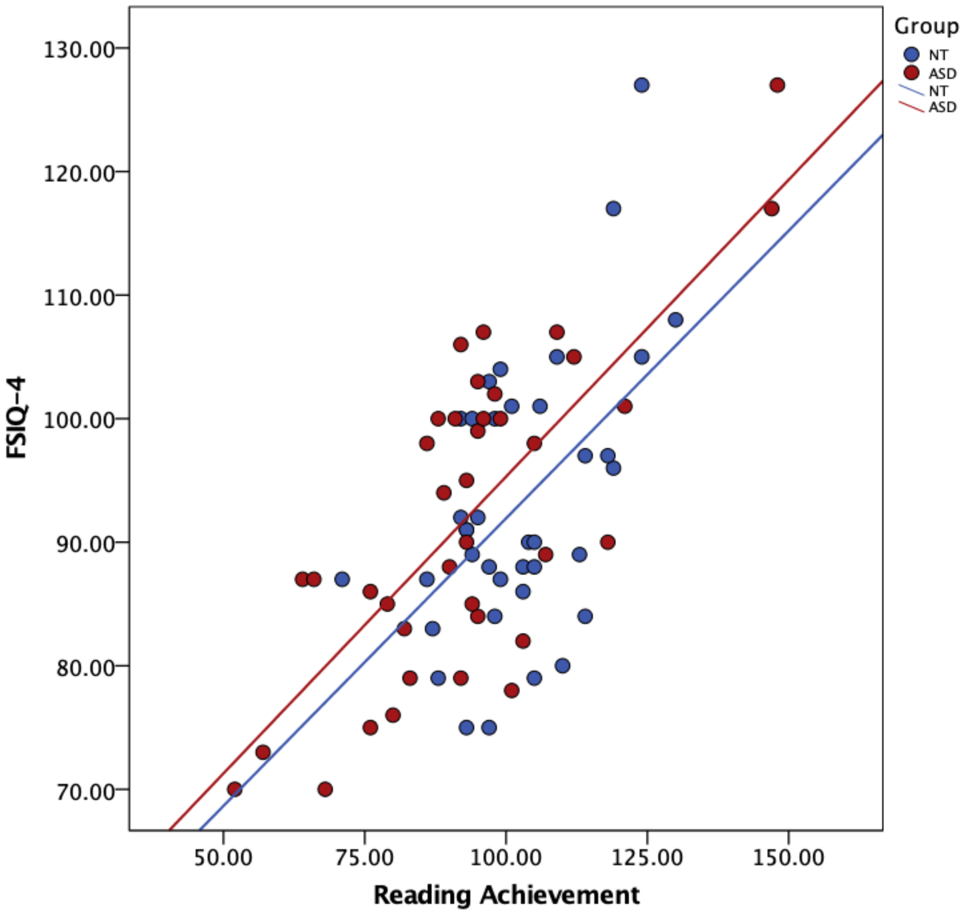


Figure 3.1 Scattergraph showing the relationship between IQ and reading achievement

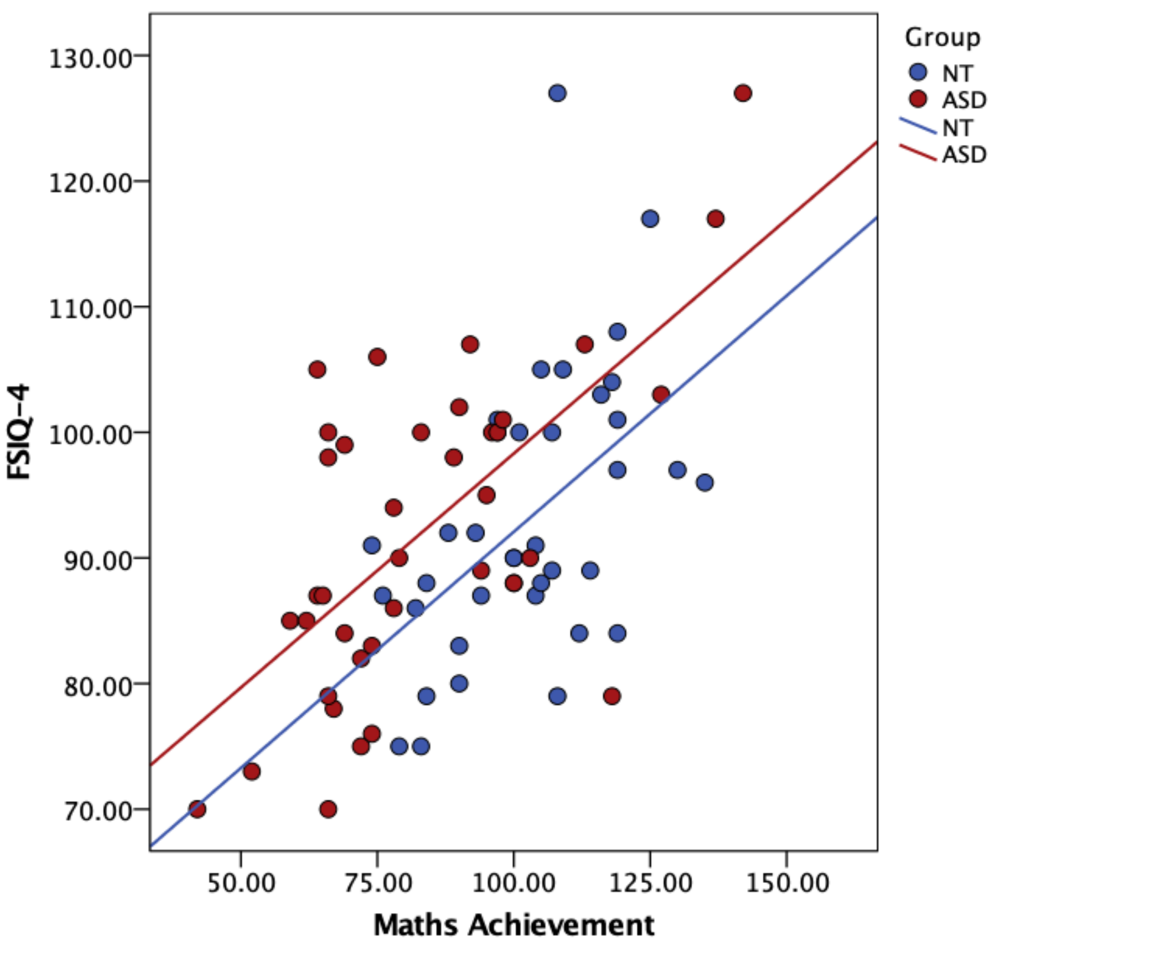


Figure 3.2 Scattergraph showing the relationship between IQ and maths achievement

3.3.1.3 Linear Regression

Although IQ was found to be significantly associated with achievement in both groups, to ascertain if IQ predicted achievement (rather than only showing an association), linear regressions using Enter was next undertaken. This was conducted for both groups separately to test the hypothesis that IQ would predict both autistic and neurotypical pupil's achievement. Homoscedasticity was established through examination of standardized residual versus standardized predictive value plots (Field, 2013).

As hypothesized, IQ significantly predicted autistic pupils reading achievement $F(1,37)=45.128$, $p<0.001$, with the model accounting for 54.5% of the variance in scores (Adjusted R^2 = .544). IQ also significantly predicted neurotypical reading achievement, $F(1,37)=12.916$, $p=0.001$, explaining 24.4% of variance in scores (Adjusted $R^2=0.244$). Coefficients for both analyses are shown in Table 3.3 below.

Table 3.3 Regression coefficients (Does IQ predict reading achievement?)

Group	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
NT	(Constant)	49.583	14.781		3.354	.002	19.605	79.561
	FSIQ-4	.567	.158	.514	3.594	.001	.247	.887
ASD	(Constant)	-13.427	16.003		-.839	.407	-45.883	19.030
	FSIQ-4	1.158	.172	.746	6.718	.000	.808	1.507

Regressions were also conducted to test the hypothesis that IQ would predict maths achievement in both groups. IQ significantly predicted autistic pupil's maths achievement $F(1,37) =26.971$, $p<0.001$ and accounted for 41.2% of the variance (Adjusted R^2 =0.412). IQ was also a significant predictor of maths achievement for neurotypical pupils, $F(1,37)=13.001$, $p=0.001$, explaining 24.5% of the variance (Adjusted R^2 = 0.245) . Coefficients for both groups are presented in Table 3.4.

Table 3.4 Regression coefficients (Does IQ predict maths achievement?)

Group	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
NT	(Constant)	36.849	18.333		2.010	.052	-.332	74.030
	FSIQ-4	.706	.196	.515	3.606	.001	.309	1.103
ASD	(Constant)	-22.751	20.554		-1.107	.276	-64.437	18.934
	FSIQ-4	1.150	.221	.654	5.193	.000	.701	1.598

In sum, the regressions showed that IQ significantly predicted reading and maths achievement in both groups, although more variance was explained in the autistic group compared to the neurotypical group. In the autistic group, IQ explained more variance for reading than for maths achievement.

3.3.2 IQ and Achievement Profiles

The second aim of this study was to investigate the prevalence of IQ-achievement discrepancies in ASD and in neurotypical development. Analyses for reading and maths are presented separately.

3.3.2.1 Reading

The number of autistic and neurotypical pupils who achieved reading scores that were commensurate with their IQ is shown in Table 3.5. For both groups, it was predicted that the majority of children would achieve reading scores that were in line with IQ. In line with these predictions, 71.1% of autistic pupils and 57.9% of neurotypical pupils, achieved in line with IQ.

The number of autistic and neurotypical pupils who underachieved or overachieved in reading is also shown in Table 3.5. For neurotypical pupils, it was hypothesized that there would be a similar percentage of underachievers and overachievers. However, in contrast to predictions, overachievement (39.5%) was much more prevalent than underachievement (2.6%). For autistic pupils, it was predicted that underachievement would be more common than overachievement. However, 18.4% of autistic pupils were overachieving in reading and only 10.5% were underachieving.

To investigate if there was a significant association between diagnosis and IQ-achievement group, Chi-Square analysis was undertaken. Unexpectedly, however, there was no significant association between diagnosis and achievement group x2(2)=5.219, *p*=0.074. It should be acknowledged however that there are very few cases in the underachieving category, and this is likely to be impacting this analysis.

Table 3.5 Crosstabs Reading achievement group x diagnostic group

		Achievement Group		
		Underachieving	Commensurate	Overachieving
NT	N	1	22	15
	% within Group	2.6%	57.9%	39.5%
	% within Achievement	20.0%	44.9%	68.2%
	% of Total	1.3%	28.9%	19.7%
ASD	N	4	27	7
	% within Group	10.5%	71.1%	18.4%
	% within Achievement	80.0%	55.1%	31.8%
	% of Total	5.3%	35.5%	9.2%

3.3.2.2 Maths

The number of autistic and neurotypical pupils who achieved maths scores that were commensurate with IQ is shown in Table 3.6. For both groups, it was predicted that the majority of pupils would achieve maths scores in line with IQ. Whilst 65.8% of neurotypical children achieved as predicted by IQ, only 50% of autistic children achieved within the predicted range.

The number of autistic and neurotypical pupils who underachieved or overachieved in Maths is also shown in Table 3.6. Although it was hypothesized that the percentage of overachievers and underachievers would be similar in the neurotypical group, overachievement was again much more common, such that 28.9% of neurotypical pupils overachieved and only 5.3% underachieved. However, in line with predictions, in the autistic group, there were more underachievers (39.5%) than overachievers (10.5%). These differences between groups are reflected in the significant Chi Square Xs(2)=14.026, *p*<0.001, Cramer V=0.430, p=0.001, with a medium effect size.

Table 3.6 Crosstabs Maths achievement group x diagnostic group

		Achievement Group		
		Underachieving	Non- discrepant	Overachieving
TD	N	2	25	11
	% within Group	5.3%	65.8%	28.9%
	% within Achievement	11.8%	56.8%	73.3%
	% of Total	2.6%	32.9%	14.5%
ASD	N	15	19	4
	% within Group	39.5%	50.0%	10.5%
	% within Achievement	88.2%	43.2%	26.7%
	% of Total	19.7%	25.0%	5.3%

3.3.3 Maths and Reading profiles across achievement groups

The final aim of this study was to examine if neurotypical and autistic pupils evidenced discrepancies within the domains of reading and maths.

3.3.3.1 Reading

Reading sub-component scores, alongside IQ are presented in Table 3.7 below. Neurotypical pupils were predicted to achieve a balanced profile such that reading subcomponents scores were commensurate with each other and with IQ. In line with these predictions, mean subcomponents scores were all within 15 points (1SD) of each other. The greatest difference (10.52 points) was between Reading Comprehension (M=97.24) and Pseudoword Decoding (M=107.76). Although Reading Comprehension and Word Reading scores were commensurate with IQ, mean Pseudoword Decoding was approaching being significantly discrepantly higher (14.74 points).

For autistic children, it was hypothesized that Reading Comprehension would be a relative weakness compared to Word Reading, Pseudoword Decoding, and IQ. However, contrary to predictions, all subcomponent scores were within 1SD of each other and with IQ. The greatest difference was between Reading Comprehension (M=86.82) and Pseudoword Decoding (M=100.24), a difference of 13.42 points. However, overall, autistic pupils evidenced a balanced Reading profile.

Table 3.7 Reading subcomponent descriptive statistics

Group	Measure	Mean	Minimum	Maximum	SD
NT	IQ	93.03	75	127	11.08
	Word Reading	102.95	72	125	11.47
	Reading Comprehension	97.24	65	121	12.43
	Pseudoword Decoding	107.76	78	123	9.57
ASD	IQ	91.97	70	127	12.97
	Word Reading	93.18	50	137	21.52
	Reading Comprehension	86.82	50	126	18.27
	Pseudoword Decoding	100.24	69	148	16.36

3.3.3.2 Maths

Maths sub-component scores, alongside IQ are presented in Table 3.8 below. Neurotypical pupils were again predicted to evidence a balanced profile such that maths subcomponents scores were commensurate with each other and with IQ. In line with these predictions, mean subcomponents scores were all within 15 points (1SD) of each other and commensurate with IQ. The greatest difference was between IQ (M=93.03) and Numerical Operations (M=106.82), although both are still within the average range.

Table 3.8 Maths subcomponent descriptive statistics

Group	Measure	Mean	Minimum	Maximum	SD
NT	IQ	93.03	75	127	11.08
	Numerical Operation	106.82	74	133	14.70
	Mathematical Reasoning	97.21	78	129	13.40
ASD	IQ	91.97	70	127	12.97
	Numerical Operations	88.82	50	141	22.18
	Mathematical Reasoning	80.58	44	145	21.07

For autistic pupils it was predicted that Numerical Operations would be a relative strength compared to Mathematical Reasoning and IQ. However, contrary to predictions, mean subcomponents scores were within 15 points (1SD) of each other and commensurate with IQ. However, whereas IQ was in the average range, Numerical Operations and Mathematical Reasoning scores fell into the low average range. It should be noted however that the standard deviations in the autistic group are much larger than that seen in the neurotypical group, indicating that there is much more variability in ASD.

3.4 Discussion

The current study sought to investigate the relationship between IQ and academic achievement in a group of autistic and neurotypical pupils, matched for age and cognitive ability. Whilst previous work has shown that IQ is a powerful predictor of academic success in both groups, there has also been evidence that some autistic pupils evidence achievement profiles that are not commensurate with IQ (Keen, Webster & Ridley, 2016; Kim, Bal & Lord, 2018). This has raised the possibility that the relationship between IQ and achievement is more complex in ASD than in neurotypical development (Keen, Webster & Ridley, 2016; Howse, 2019). However, there has been inconsistency within the literature with regards to the prevalence (small subset or widespread) and direction (underachievement or overachievement) of these IQ-achievement discrepancies. Identifying the prevalence of discrepancies is particularly important from a theoretical perspective because if only a minority of pupils are evidencing underachievement this could suggest that discrepancies are arising because of undiagnosed learning disabilities such as dyslexia. However, if the majority of pupils are showing discrepancies, this could suggest that factors beyond IQ are contributing to academic success (Howse, 2019; Chen et. al., 2019). The current study also included a matched comparison group to establish if the IQ-achievement discrepancies seen in ASD reflect those seen in neurotypical development (Chen et al., 2019). We were interested in comparing the prevalence of both underachievement and overachievement as this would allow key strengths to be highlighted and capitalised on in school whilst allowing the areas in which children might need greater support to be identified. The current study also built on previous work by assessing a broader range of reading and maths skills and comparing achievement across each of these domains. Taking this holistic approach allowed for an investigation as to whether autistic and neurotypical pupils have a balanced profile of reading and maths ability, or whether there are peaks and dips in ability within each of these domains (Nation et al., 2006; Tunmer & Hoover, 2019, Bullen et al., 2020). This investigation was especially important from an applied perspective because if peaks and dips were found, findings could recommend which components of reading and maths should be the focus of support, and whether this differs for autistic and neurotypical pupils (Bullen et al., 2020).

3.4.1 Reading Achievement in ASD

The first aim was to test the hypothesis that IQ would positively predict autistic pupil's reading achievement. Findings were in line with these predictions, with IQ explaining 55% of the variance in autistic pupils reading scores. This supports the work of Eaves and Ho (1997) who also found a significant positive relationship between IQ and reading achievement in a larger sample of 76 autistic pupils (r=0.77). Further emphasizing the close coupling between IQ and achievement is the work of Kim, Bal, and Lord (2018) who found that autistic pupils with higher IQ made quicker gains in learning compared to autistic pupils with lower IQ. Thus, highlighting that IQ also moderates autistic pupils progress in reading. Taken together, it seems therefore that at a group level, IQ makes a substantial contribution to autistic pupils reading achievement, with approximately half of the variance in scores accounted for by this factor alone (Kim, Bal & Lord, 2018; Eaves & Ho, 1997; Mayes et al., 2020).

Findings from Aim 2 of this study also support the role of IQ in predicting autistic pupil's reading achievement. It was hypothesized that the majority of autistic children would achieve reading scores that were commensurate with IQ, and that when discrepancies were identified, underachievement would be more common that overachievement. Although 71% of autistic children did achieve in line with IQ, in contrast to predictions, overachievement (18.4%) was found to be slightly more common than underachievement (10.5%). This profile is very different to that identified by Estes et al. (2011) who found that age nine, only 38% of autistic children achieved as expected in reading, 36% overachieved and 26% underachieved. There are, however, several differences between the current study and Estes et al. (2011) which could explain these differences. Alongside including a wider age range of children (6-14 years), the current study also included children with co-occurring conditions such as ADHD and Sensory Processing Disorder. There is some evidence that children with ADHD in particular, may be at greater risk of academic underachievement relative to their neurotypical and autistic peers (Silva et al., 2020; Mayes et al., 2020). It could be therefore, that the inclusion of children with co-occurring conditions may have resulted in different achievement profiles, especially in the case of overachievement, being found. However, a recent study found that 88.5% of autistic children meet the criteria for an additional neurodevelopmental disorder, emphasizing that co-occurring conditions are the norm rather than the exception (Saitio et al., 2020). Thus, by including autistic pupils with co-occurring conditions, the current study perhaps identified an achievement profile that is more representative of the wider ASD population.

Supporting this position is the fact that the findings are very similar to Mayes et al. (2020) who did include autistic pupils with co-occurring conditions in the sample. Indeed, in Mayes et al. (2020), 67% of autistic pupils achieved reading scores that were commensurate with IQ, 23% overachieved, and 9% underachieved. It seems therefore that the majority of autistic pupils are achieving reading scores that are commensurate with IQ and that overachievement is slightly more common than underachievement. From a theoretical perspective, the relatively low prevalence of IQ-achievement discrepancies, emphasizes that IQ does make an important contribution to autistic pupil's reading achievement and suggests that cases of underachievement are more likely to reflect undiagnosed learning difficulties such as dyslexia (Howse, 2019; Eaves & Ho, 1997).

It should be noted however, that such similar findings to Mayes et al. (2020) were not expected. Indeed, it was argued that the percentage of autistic pupil's overachieving may have been over-estimated in Mayes et al. (2020) as this study only assessed Word Reading (a relative strength of autistic pupils) and did not assess other components such as Reading Comprehension and Phonological Awareness (areas suggested to relative weaknesses of autistic pupils; Nation et al., 2006). It was therefore critical that the current study examined all three of these components to capture the multifaceted nature of reading, and to investigate if autistic pupils evidence peaks and dips of reading ability (Nation et al., 2006;

Tunmer & Hoover, 2019). However, in contrast to predictions, it was found in Aim 3 of this study that autistic pupils achieved a balanced profile of reading ability, whereby subcomponents scores were commensurate with each other and with IQ. Nevertheless, whilst mean Word Reading and Pseudoword Decoding scores were within the Average Range, Reading Comprehension scores were in the Low Average range. This offers some support for Nation et al. (2006) who found Reading Comprehension to be significantly impaired despite Word Reading being in the average range. A meta-analysis conducted by Brown, Oram-Cardy, and Johnson (2013) suggests that social difficulties may be contributing to these challenges. Indeed, across thirty-six studies it was found that autistic individuals struggled more with Reading Comprehension when passages were highly social in nature. Therefore, whilst the current study found that the majority of autistic children evidenced a balanced profile of reading that was also commensurate with IQ, it should be considered that the nature of the text i.e., social versus non-social could influence this profile (Brown, Oram-Cardy & Johnson, 2013).

It is also possible that the current study only identified one type of reading profile within ASD (McIntyre et al., 2017). Emphasizing this possibility is the work of McIntyre et al. (2017) who asked 81 autistic children to complete a battery of reading tasks before conducting latent profile analysis to examine if unique reading profiles could be identified. Four profiles emerged from this analysis. The first group labelled 'Readers with Global Disturbance' (33% sample) demonstrated difficulties across domains whereas the second group of 'Average Readers' (32% sample) achieved average scores across domains. Conversely, the third group of 'Readers with Comprehension Disturbance' (20% of sample) had adequate average phonology and vocabulary but specific challenges in linguistic comprehension. The final group of 'Readers with Severe Global Disturbance' (14% of sample) had severe challenges across reading components. This highlights that while the current study may have found average reading abilities that were largely commensurate with IQ, there may exist significant individual differences within ASD, such that unique profiles of reading abilities can be identified (McIntyre et al., 2017). Indeed, the large standard deviations found in the current study indicate there is vast individual differences and variability in autistic pupil's reading achievement. Future research is therefore needed to examine the prevalence and direction of IQ-achievement discrepancies within these specific Reading profiles.

3.4.1.1 Does this Reading profile reflect that seen in neurotypical development?

A key aim of this study was to establish if the IQ-achievement discrepancies seen in ASD reflect those seen in neurotypical development. To that end, although IQ was positively related to neurotypical pupil's reading achievement, it only accounted for 25% of the variance in scores; less than half of that accounted for in ASD. Whilst the total amount of variance accounted for in the neurotypical group may seem low, it should be considered that it is broadly in line with previous studies that have used standardized measures of achievement (Mayes et al., 2009). Emphasizing this is the work of Mayes et al. (2009) who found in a sample of 214 neurotypical children, that 35% of the variance in Word Reading scores on the WRAT 3 were accounted for by IQ. Therefore, although caution is needed due to small sample sizes, current findings suggest that IQ is a better predictor of *autistic* pupils Reading achievement than neurotypical pupils' achievement.

In Aim 2 of this study, it was hypothesized that the majority of neurotypical children would achieve reading scores that were commensurate with IQ, and that when discrepancies were identified, these would be dispersed evenly between underachievement and overachievement. Although the majority of neurotypical children achieved in line with IQ (57%) , 40% overachieved and 3% underachieved. This pattern is very different to that seen in Mayes et al. (2020) whereby the majority of neurotypical children achieved as expected (73%), and there was an equal number of overachievers (14%) and underachievers (13%). However, as discussed above a critical difference between Mayes et al. (2020) and the current study was the wider range of reading skills assessed. Examination of these subcomponent scores revealed that neurotypical pupils achieved Pseudoword Decoding scores that were approaching being significantly discrepant from IQ (14.74 points). Pseudoword Decoding scores were also greater than Reading Comprehension and Word Reading scores, albeit within the 1SD range. Neurotypical children therefore appear to have a relative strength in Pseudoword Decoding compared to IQ and other components of Reading. However, as Mayes et al. (2020) only assessed Word Reading, this relative strength would not have been captured which could explain why the prevalence of overachievement is much greater in the current study compared to Mayes et al. (2020). However, future research with a much larger sample is needed to replicate and explore this possibility further.

Nevertheless, findings do suggest that neurotypical children are much more likely to overachieve in reading relative to autistic children. Although several factors could be contributing to this difference, recent work by Mayes et al. (2020)

suggests that Working Memory is an important factor to consider. To examine the correlates of reading and maths under- and overachievement, 1543 pupils (285, ASD, 739 ADHD, 519 Neurotypical) were asked to complete a battery of IQ, Neurocognitive and Academic Achievement tasks (Word Reading, Numerical Operations). Across all diagnostic groups, it was found that pupils who overachieved in reading had working memory scores that were close to or exceeding IQ whereas pupils who underachieved had working memory scores that were lower than IQ (Mayes et al., 2020). This is line with the wider literature whereby working memory, rather than IQ, accounted for the greatest amount of variance in pupil's academic achievement (Alloway & Alloway, 2010). Indeed, working memory skills are thought to underlie success in many day-to-day classroom activities, including keeping track of progress, storing, and processing information and remembering classroom instruction (Gathercole et al., 2006). Critically, there is some evidence that at a group level, neurotypical pupils' evidence stronger working memory skills relative to autistic pupils, although again there is vast variability in both populations (Habib et al., 2019). Highlighting this are the findings of a recent meta-analysis which examined 34 studies and found that the ASD group had lower accuracy and error rates across a range of working memory tasks compared to the neurotypical group (Habib et al., 2019). Differences in working memory could therefore be contributing to the greater prevalence of overachievement in the neurotypical group relative to the autistic group. In terms of implications for the classroom, findings suggest that supporting Reading Comprehension and working memory are two pathways by which to improve autistic pupils reading achievement.

3.4.2 Maths Achievement in ASD

Focusing next on maths achievement in ASD, as hypothesized IQ was positively related to achievement (r=0.565) and accounted for 41% of the variance in scores. Again, this supports the work of Eaves and Ho (1997), who also reported a significant positive relationship between IQ and maths achievement (r=0.77) in a group of autistic children between the ages of 8 and 17 years. Whilst these findings emphasize that IQ makes an important contribution to autistic pupil's maths achievement, it is notable that the amount of variance accounted for is 10% less than seen in reading. This could suggest that for autistic pupils, IQ is a better predictor of reading achievement than it is for maths achievement.

Supporting this position are findings from Aim 2 of this study. It was hypothesized that the majority of autistic pupils would achieve maths scores that were commensurate with IQ and that when discrepancies were identified, they would predominantly be in the direction of underachievement rather than overachievement. Unexpectedly however, only 50% of autistic children achieved maths scores that were commensurate with IQ, 40% of children underachieved and 10% overachieved. From a theoretical perspective, this high prevalence of IQ-achievement discrepancies, particularly in the direction of underachievement, could suggest that factors beyond IQ are contributing to achievement (Howse, 2019; Estes et al., 2011). As outlined in Chapter 2, this thesis will consider how sensory processing differences might be impacting autistic pupil's achievement and success at school.

It should be noted however, that the prevalence of underachievement is much greater in the current study compared to Mayes et al. (2020) (12%) and Jones et al. (2009) (6%). Findings are however, in line with Estes et al. (2011) and Chen et al. (2019), both of whom, despite adopting very different methodologies, identified underachievement in 37%-40% of their autistic sample. Whereas Estes et al. (2011) used the same approach as the current study to establish discrepancies, Chen et al. (2019) adopted a data-driven clustering approach. This involved 114 autistic males (ages 7-12) and 97 age- and IQ-matched neurotypical children completing the maths and reading subsets of the WIAT 2, alongside measures of IQ and Working Memory. Parents were also asked to the complete The Child Behavioural Checklist to assess social and behavioural difficulties. Whereas neurotypical children grouped into one homogenous achievement cluster, autistic children were grouped into two distinct achievement clusters. In the first autistic subgroup (37% of the sample), mean maths scores were significantly below IQ and reading. However, the opposite profile was found in the second autistic subgroup (60% of sample) such that mean maths achievement was greater than mean reading achievement (60% of the sample). It was therefore concluded that overall, maths underachievement is not accompanied by reading underachievement (Chen et al., 2019). This could suggest that the factors that are contributing to autistic pupil's underachievement in reading are different to those factors that are contributing to underachievement in maths. From an applied perspective, this could suggest that subject-specific support is needed to support autistic pupils who are underachieving academically at school (Chen et al., 2019).

Findings from Aim 3 of this study indicate that a maths intervention for autistic pupils would need to support both Calculation and Reasoning. Indeed, although it was hypothesized that Numerical Operations would be a relative strength compared to Mathematical Reasoning, scores in these domains were found to be commensurate with each other and also with IQ. Nevertheless, whereas IQ was in the average range, Numerical Operations and Mathematical Reasoning scores fell into the low average range. This supports Bullen et al. (2020) who examined maths development in autistic, neurotypical, and children with ADHD, and found that autistic children evidenced a unique profile of maths ability that was characterized by poor performance on Calculation and Reasoning. Findings are however, at odds with Wei et al. (2015) who found that 20% of autistic pupils evidenced greater strengths in Numerical Operations relative to IQ and Mathematical Reasoning. These mixed findings emphasize the heterogeneity in autistic pupil's maths achievement and suggest that although a small subset of children may be gifted at maths, it is certainly not representative of the population as a whole, as is typically portrayed in popular culture (Chiang & Lin, 2007; Bullen et al., 2020).

3.4.2.1 Does this Maths profile reflect that seen in neurotypical development?

Again, a key aim of this research was to compare the maths profile seen in ASD to that seen in neurotypical development. Overall, current findings suggest that autistic pupils show a different profile of maths achievement to neurotypical pupils. Indeed, although IQ was positively related to neurotypical pupil's maths achievement, only 25% of the variance in scores was accounted for; 16% less than in the autistic group. Again, whilst the amount of variance accounted for may seem small, findings do replicate Mayes et al. (2009) who found 22% of the variance in neurotypical pupil's Numerical Operations scores were accounted for by IQ. Also different to that seen in ASD, was the fact that the majority of neurotypical children achieved maths scores that were commensurate with IQ (65.8 %), and then when discrepancies did emerge, they were more likely to be in the direction of overachievement (28.9%) as opposed to underachievement (5.3%). This low prevalence suggests that cases of underachievement in neurotypical development are more likely to reflect undiagnosed learning difficulties such as dyscalculia whereas the high prevalence of underachievement in ASD, could suggest that factors beyond IQ are contributing to success. Also different to that seen in ASD was the finding that Numerical Operations, Mathematical Reasoning, and IQ were all in the average range and commensurate with one another.

The question thus becomes why autistic pupils are significantly more likely to underachieve in maths compared to their neurotypical peers. Recent work by McDougal et al. (2020) may offer some insights as to why this may be case. This study aimed to examine if distinct profiles of achievement and attention could be identified by asking 22 autistic children (6-16 years) and 59 TD children (6-11 years) to complete standardized measures of reading and maths achievement, alongside measures of IQ and attention (divided, sustained, and selective). Hierarchical regression, using Divided Attention, Reading and Maths scores as clustering variables, was then conducted and three clusters emerged. Children in the first cluster were described as having good attention and high achievement, especially in maths, which was a relative strength compared to IQ. Only five children were classified into this group, of which only one was autistic. Children in the second group (10.5% ASD and 89.5%) had average divided attention, and average achievement in reading and maths. Conversely, children in the third group

(78.9% ASD and 21.1%) had poor divided attention and also poor achievement. Children in this group also demonstrated an IQ-achievement discrepancy that was approaching being significant, such that maths scores were 13 points below IQ. Critically, autistic children were much more likely to be clustered into this group compared to neurotypical children. At a group level, autistic children also scored lower on measures of divided attention compared to neurotypical children (McDougal et al., 2020). Taken together, these findings could suggest that weaknesses in divided attention are driving the higher prevalence of maths underachievement in ASD compared to neurotypical development. In terms of implications for the classroom, this could suggest that supporting autistic pupils to be better able to divide attention, for example between auditory and visual tasks, may reduce levels of maths underachievement. Linked to this, Chapter 7 of this thesis will consider how levels of auditory and visual stimulation in the classroom impact autistic and neurotypical ability to stay on-task, and how sensory processing differences might moderate this relationship.

3.4.3 Limitations

Limitations of this study include only using standardized measures of academic achievement (Howell, Langdon & Bradshaw, 2020). Although this approach allows for comparison across studies and populations, a more holistic view of children's achievement may have been gained by also capturing teacher and parent report (see Chapter 4 for use of this approach), observations or direct assessment of children work (see Chapter 7 for use of this approach). The use of the IQ-achievement discrepancy model to identify underachievement/overachievement also remains controversial with many researchers now suggesting a discrepancy on this measure alone is not sufficient to diagnose a learning disability (May, 2000; Restori, Katz & Lee, 2009). Although the current study did not use discrepancies in such a way, this critique highlights why a range of approaches is needed to assess achievement and success at school, and why a multi-method, multi-informant approach has been advocated throughout this thesis.

3.4.4 Conclusions

In conclusion, the current study sought to investigate the relationship between IQ and academic achievement in a group of autistic and neurotypical pupils, matched for age and cognitive ability. The key aims of this study were to establish the prevalence and direction of IQ-achievement discrepancies in ASD and to consider whether this profile reflected that seen in neurotypical development. In terms of reading achievement, IQ explained a significant amount of variance in scores for both groups of pupils, although the strength of this relationship was stronger in ASD than it was NT. Indeed, the majority of autistic pupils achieved reading scores that were commensurate with IQ (71%), and when discrepancies did emerge, overachievement (18.4%) was found to be slightly more common than underachievement (10.5%). The low prevalence of discrepancies emphasizes that IQ makes an important contribution to autistic pupil's reading achievement and suggests that cases of underachievement could reflect undiagnosed learning difficulties such as dyslexia. Autistic pupils also evidenced a balanced profile of reading ability, although Reading Comprehension was in the Low Average range whereas other scores were in the Average range. Neurotypical pupils evidenced a different profile to that seen in ASD, such that 40% of this sample were overachieving in reading and Pseudoword Decoding was a relative strength compared to IQ, Word Reading, and Reading Comprehension. It was suggested that differences in working memory could be contributing to the higher prevalence of reading overachievement in the neurotypical group compared to the autistic group. In terms of implications for the classroom, findings thus suggest that supporting Reading Comprehension and working memory may improve autistic pupils reading achievement.

In terms of maths, IQ again explained a significant amount of variance in scores for both groups, although this was less than that seen in reading. High levels of underachievement were found in the autistic group, with 40% of pupils achieving maths scores that were significantly below that predicted by IQ. Only 50% of autistic children achieved maths scores that were commensurate with IQ and only 10% overachieved. Critically, this profile differed to that seen in neurotypical development, whereby 66% of children achieved maths scores that were commensurate with IQ, and overachievement (29%) was more common that underachievement (5%). The prevalence of maths underachievement is therefore much greater in ASD than NT. This could suggest that factors beyond IQ are contributing to autistic pupil's maths achievement. Building on the work of Ashburner et al. (2008) and McDougal (2020), the following chapters will therefore consider how sensory processing differences might impact academic achievement and classroom behaviour for autistic and neurotypical pupils.

Chapter 4: Distraction, distress, and diversity: Exploring the impact of sensory processing differences on learning and school life for pupils with autism spectrum disorders.

Chapter 3 of this thesis investigated the relationship between IQ and academic achievement in a group of autistic and neurotypical pupils. Although IQ predicted achievement in both groups, significant IQ-achievement discrepancies were also identified. However, the nature of these discrepancies was different in ASD compared to that seen in neurotypical development. Thus, suggesting that different factors might be contributing to autistic and neurotypical pupil's academic achievement. Given the literature discussed in Chapter 2, one possibility is that sensory processing differences are contributing towards autistic pupil's achievement but not neurotypical pupil's achievement. The aim of the current chapter is to explore this relationship qualitatively by asking parents and teachers, *if* and *how*, sensory processing differences impact the learning and school life of autistic pupils. It should be noted that the contents of this chapter are a published paper (Jones, Hanley & Riby, 2020).

4.1 Introduction

Within the UK, 27% of pupils with a statement of Special Educational Needs or an Education Health and Care Plan (EHCP) have an Autism Spectrum Disorder diagnosis (ASD; All Party Parliamentary Group, 2017). ASD is characterized by persistent difficulties with social communication and interaction, alongside restricted and repetitive patterns of behaviour and interests (American Psychiatric Association (APA), 2013). Although the Autism Act (Her Majesty's Stationery Office

(HMSO), 2009) and the Children and Families Act (HMSO, 2014) sought to improve educational outcomes for children with ASD, many continue to under-achieve academically and experience high rates of exclusion (Brede et al., 2017; Keen et al., 2016). Moreover, 50% of children with ASD report being unhappy at school and do not feel their needs are being met (All Party Parliamentary Group, 2017). While several of the problems reported by pupils relate to their social difficulties, many highlight that sensory processing differences are equally detrimental to their classroom experiences (All Party Parliamentary Group, 2017). Yet the impact of these differences within an educational context has been neglected. The current study addresses this gap by adopting a mixed-method approach to investigate the views of parents and teachers on sensory processing and the impact on learning and school life for pupils with ASD. The aim is not to study whether sensory issues exist for children with ASD as the literature is vast on this issue (Marco et al., 2011; Rogers & Ozonoff, 2005) but rather to focus on teacher and parent views on the impact of these differences within a school setting.

Sensory processing refers to the mechanism by which the central nervous system receives input from the senses and integrates this information to generate an appropriate behavioural response (Dunn, 1997). Based on the Dunn model of sensory processing whereby children can be distinguished on hyper- and hyposensitivity to sensory input and can be profiled as a ‘sensory seeker’ or a ‘sensory avoider’, the key measure of sensory processing is the Sensory Profile (Dunn, 1997, 1999). This questionnaire asks participants to rate how frequently they respond to a sensory event (Dunn, 1999). When asking caregivers and adults with ASD to complete this questionnaire, autistic individuals are consistently found to report greater frequencies of sensory differences compared to typically developing individuals (Uljarevic et al., 2017). Critically autistic children differ on items reflecting both hypersensitivity and hyposensitivity to sensory inputs, suggesting that a single pattern of sensory processing is not characteristic of ASD; a conclusion that has now been confirmed (Rogers & Ozonoff,2005; Kern et al., 2006). For individuals with patterns of hypersensitivity, the central nervous system, requires minimal sensory stimulation to produce a response, whereas for individuals with patterns of hyposensitivity, greater stimulation is needed for a comparable response to be generated (Dunn, 1997).

The Nordic Relational Model of Disability (Tøssebro, 2004) provides a useful framework for understanding how, and under what circumstances, sensory processing differences affect the day-to-day lives of individuals with ASD. Here, 'disability' is seen to occur when there is a mismatch between an individual's functional ability and their environment. For example, a blind individual, although impaired, only becomes disabled when the environment has not been adjusted to meet his/her needs. In the case of sensory processing differences, a child with hypersensitivity may be able to fully function at home but may experience 'disability' when placed in a busy classroom with significant sensory inputs such as bright lights and noisy children (Goodley & Runswick-Cole, 2012). Given that children typically spend the majority of the school day in the same classroom, a mismatch between the environment and an individuals' sensory needs could be especially adverse (Piller & Pfeiffer, 2016).

Supporting this position are the results of Ashburner, Ziviani and Rodger (2008) who collated parent reports on the Short Sensory Profile (McIntosh, 1999), from 51 parents of typically developing children and 28 parents of autistic children aged 6-10 years. Teachers completed the Conner's Teaching Rating Scale (Connors,1997) and children completed the Kaufman Brief Intelligence Test (Kaufman & Kaufman, 1990). For typically developing children, IQ was found to be the only significant predictor of academic achievement. However, auditory filtering, under-responsiveness, and sensation seeking accounted for 47% of the variance in academic achievement for pupils with ASD. This emphasizes that a mismatch between sensory needs and the classroom environment can significantly impact academic progression (Ashburner et al., 2008). However, this study provided little insights into how sensory differences affect academic achievement, and for this consideration a qualitative approach can be particularly insightful.

Howe and Stagg (2016) took such an approach and asked 16 autistic pupils attending mainstream secondary school to complete the Adolescent and Adult Sensory Profile and an open-ended questionnaire. The questionnaire included four sections (auditory, touch, smell, and vision) and asked pupils if differences within each modality affected their learning, how it affected learning, feelings associated with these experiences, and positive outcomes related to sensory differences. Auditory differences were perceived to be the most disruptive to learning, followed by touch, smell, and vision. These sensory experiences affected learning by disrupting concentration and causing anxiety or physical discomfort (Howe & Stagg, 2016).

Anxiety related to sensory differences has been reported more widely in the literature (Neil et al., 2016; Green et al., 2012). Indeed, recent models place hypersensitivities as central in developing and maintaining anxiety for autistic individuals (Boulter et al., 2014; South & Rogers, 2007). One such model is the Intolerance of Uncertainty framework. This model proposes that an interplay between sensory sensitivities, rigidity of thought, difficulty with emotional processing, and social/environmental factors create the belief that “unexpected events are negative” and should be perceived as threatening, which then feeds into high levels of anxiety (Boulter et al., 2014; South & Rogers, 2007). Supporting this are findings from Green et al., (2012) longitudinal study that assessed 149 autistic toddlers at two time points and found sensory over-responsivity significantly predicted an increase in anxiety. Given recent estimates suggest up to 40% of the autistic population experience anxiety (van Steensel, Bogels & Perin, 2011), understanding the type of sensory experiences encountered at school and how this might relate to anxiety could be particularly important for improving school experiences for autistic pupils and informing future intervention work.

Thus, although the link between hypersensitivities and anxiety has been discussed and evidenced (Boulter et al., 2014; Howe & Stagg 2016), it is possible that the role of hyposensitivity has been overlooked. Hyposensitivity, however, has been associated with a range of psychological correlates that could be important for classroom behaviour and success, namely joint attention (Baranek et al. 2013), emotion dysregulation (Samson et al. 2013) and gross motor skills (Jasmin et al. 2009). It has been suggested that hyposensitivity is more difficult to self-report because individuals are often not aware if they have missed sensory input, for example the teacher calling their name (Smith & Sharp, 2013). Consequently, there is a need to adopt a multi-informant, multi-method approach to build a comprehensive understanding of sensory differences and their impact in school.

Taking a multi-perspective approach, Piller and Pfeiffer (2016) interviewed eight primary school teachers and five occupational therapists, who highlighted a range of stimuli and reactions that disrupted participation in the classroom for autistic pupils. Responses indicated sensory differences were often situated within a particular context rather than being a stable trait. For example, although several highly tactile tasks (e.g., painting) caused challenges for pupils with ASD, these same children would seek out touch from other pupils. Teachers explained that they would attempt to increase classroom participation by adopting routines and adapting the classroom environment. This emphasizes how detrimental an incompatible environment can be, but also demonstrates the value of a multi-perspective approach (Piller & Pfeiffer, 2016). Nevertheless, the sample size was small (n=8) and the nature of the school provision was unclear (e.g. mainstream, special educational provision). This is important because school design and sensory stimulation can vary (Hughes et al., 2014).

The current study built on previous literature by adopting a multi-method, multi-informant approach to understand the nature of sensory differences and their effect on learning and school life for autistic pupils. It is evident from the literature that sensory differences impact many individuals with ASD (Marco et al., 2011; Rogers & Ozonoff, 2005) and this study did not aim to replicate that evidence, but rather to explore how sensory issues impact in a more applied manner in the classroom.

This was achieved by asking teachers from a range of school provisions to complete an online questionnaire containing both open and closed questions, thereby permitting quantitative and qualitative insights. This approach allowed for both the measurement of impact and also the opportunity to capture rich illustrations and gather new perspectives on sensory experiences that may not have been previously considered in existing frameworks. Parents also completed a similar questionnaire to add to the multi-informant perspective. The study first aimed to examine how parents and teachers identified sensory differences as affecting behaviour (Aim 1) before exploring the type of sensory experiences encountered at school (Aim 2) and their impact on learning (Aim 3). The study also aimed to investigate the factors that influence how sensory differences affect learning (Aim 4) and finally to assess current satisfaction with awareness of sensory differences at school (Aim 5). Given the heterogeneous nature of sensory processing difference observed in ASD, we hypothesized that there would be considerable variation in the type of sensory experiences reported by parents and teachers- both in terms of severity, hyper/hypo responding, and the sensory domain (auditory, visual, tactile etc). Nevertheless, we expected that both parents and teachers would report significant impacts of sensory issues. Beyond this hypothesis, the project was exploratory in order to capture the insights of parents and teachers on sensory issues.

4.2 Method

4.2.1 Participants

Fifty-seven mothers completed the online parent questionnaire. Two caregivers reported that they had an additional child with an ASD diagnosis, leading to the experiences of fifty-nine children being represented. Demographic and school provision information is presented in Table 4.1.

Table 4.1. Parent and teacher demographic and school provision information

Parent Demographic Information	
N Parent	57
Parent Mean Age	40.00
SD Parent Age	6.08
N Children	59
Child Mean Age	10.18
Child Age Range	4.5-17.0
Distribution of school provision (Parent N)	
Mainstream	42
Special Education Provision	12
Enhanced Provision	2
Home School	3
Distribution of school provisions (Teacher N)	
Mainstream	26
Special Education Provision	10
Mainstream with enhanced provision	4
Mainstream and Special Education Provision	27
Mainstream and mainstream with enhanced provision	3

Seventy teachers (62 female) completed the online questionnaire. On average, teachers had 14.5 years of teaching experience. All reported teaching pupils with ASD although this varied from working with three children up to several hundred children. All teachers had taught in the UK. Information on school provision is provided in Table 4.1.

The insights from parents and teachers in this study are provided by those who have experience with children who have a range of different reactions or sensitivities. Indeed, 98% of parents stated that their child had sensory differences and 73% of teachers reported that at least half of the autistic children they had taught experienced sensory differences in the classroom. Parents and teachers were recruited through SENCO networks, local links with schools, and advertisements on social media.

4.2.2 Materials

Two online questionnaires for i) parents and ii) teachers were designed. These questionnaires were developed based on two previous interview schedules, exploring sensory experiences in adolescents with ASD (Ashburner et al. (2013) and parental understanding of sensory experiences (Dickie et al., 2009). Two existing surveys were also examined, one that asked teachers to consider how sensory differences affected classroom participation (Piller & Pfieffier, 2016), and a second that asked adolescents with ASD how their sensory experiences impacted their learning (Howe & Stagg, 2016).

4.2.1.1 Parent questionnaire

The questionnaire began with a demographic section that probed age and type of school attended by their child. The main section included eleven closed questions that asked either for yes/no responses or Likert-Scale responses (Not at all, Rarely, Somewhat, Frequently or All of the time), five sub-questions and nine free response questions. Figure 4.1 below shows the number of questions corresponding to each aim. See Appendix B for full questionnaire.

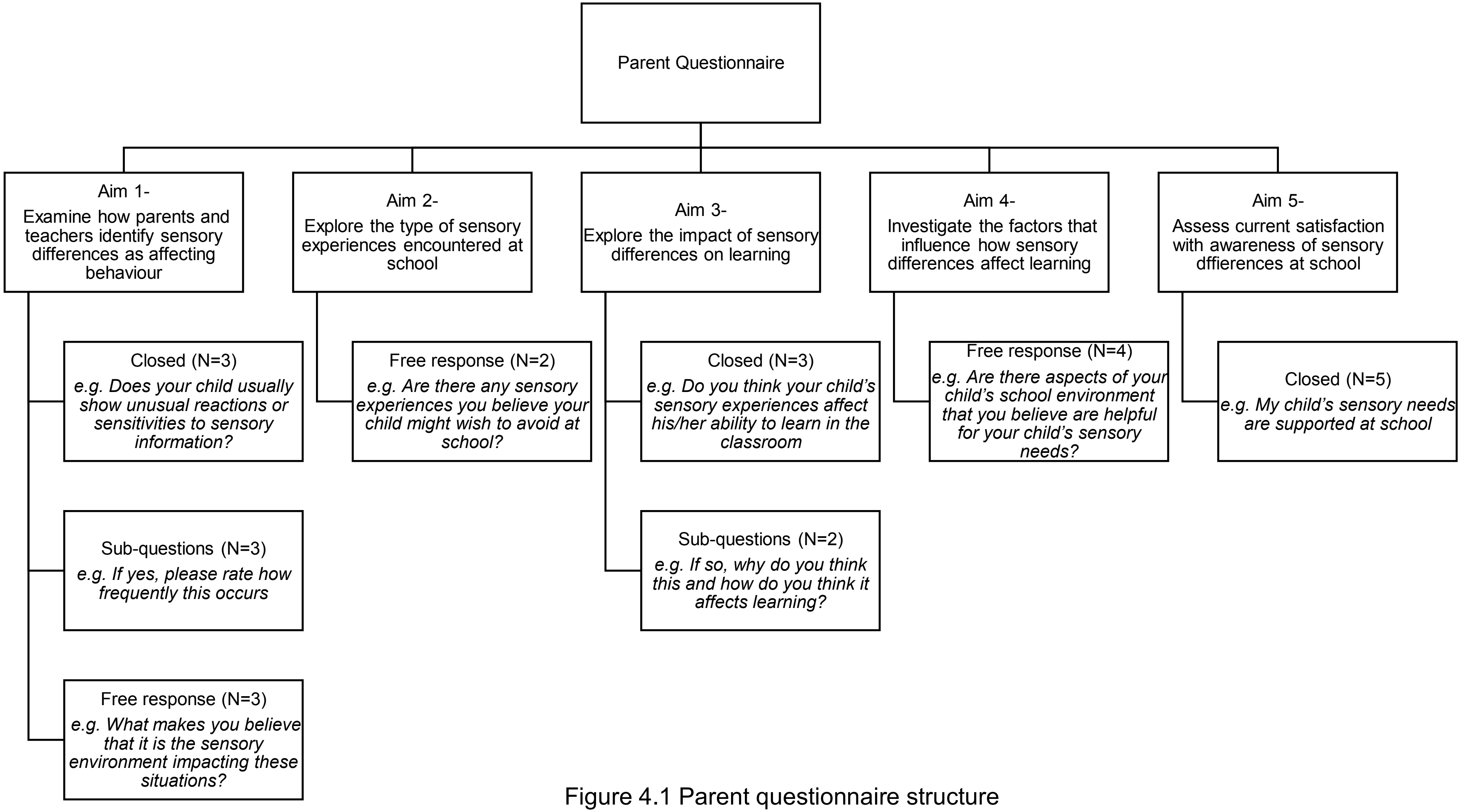
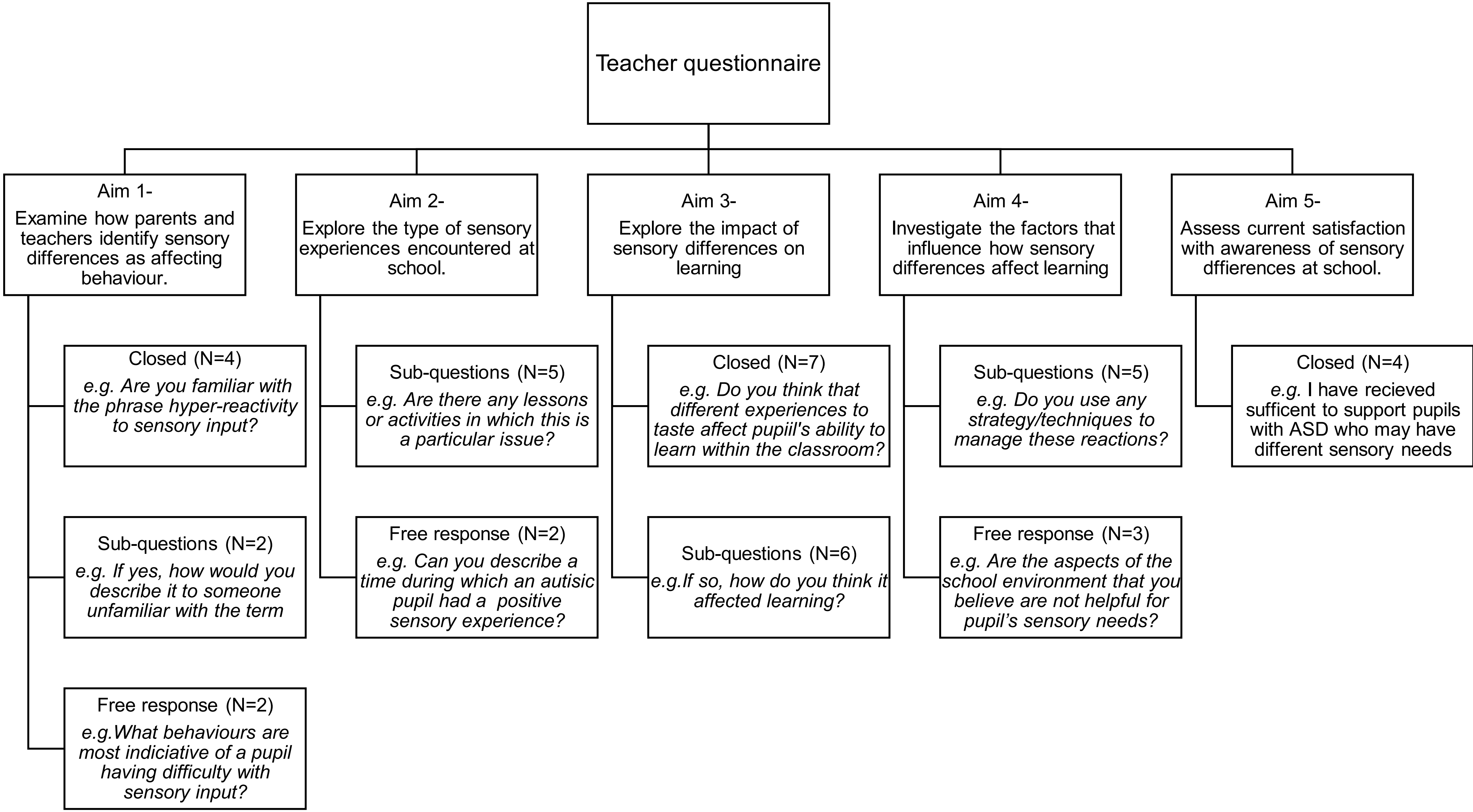


Figure 4.1 Parent questionnaire structure

4.2.1.2 Teacher questionnaire

The questionnaire began with a demographic section. The main body included 15 closed questions that asked for yes/no responses or Likert-Scale responses, 18 sub -questions and 7 free-response questions. Figure 4.2. shows the number of questions corresponding to each aim. See Appendix C for full questionnaire.


Teacher questionnaire
Aim 1-
Examine how parents and teachers identify sensory differences as affecting behaviour.
Aim 2-
Explore the type of sensory experiences encountered at school.
Aim 3-
Explore the impact of sensory differences on learning
Aim 4-
Investigate the factors that influence how sensory differences affect learning
Aim 5-
Assess current satisfaction with awareness of sensory dffierences at school.
Closed (N=4)
e.g. Are you familiar with the phrase hyper-reactivity to sensory input?
Sub-questions (N=2)
e.g. If yes, how would you describe it to someone unfamiliar with the term
Free response (N=2)
e.g.What behaviours are most indiciative of a pupil having difficulty with sensory input?
Sub-questions (N=5)
e.g. Are there any lessons or activities in which this is a particular issue?
Free response (N=2)
e.g. Can you describe a time during which an autisic pupil had a positive sensory experience?
Closed (N=7)
e.g. Do you think that different experiences to taste affect pupiil's ability to learn within the classroom?
Sub-questions (N=6)
e.g.If so, how do you think it affected learning?
Sub-questions (N=5)
e.g. Do you use any strategy/techniques to manage these reactions?
Free response (N=3)
e.g. Are the aspects of the school environment that you believe are not helpful for pupil’s sensory needs?
Closed (N=4)
e.g. I have recieved sufficent to support pupils with ASD who may have different sensory needs

4.2.2 Procedure

After obtaining ethical approval from the local ethics committee and ensuring that the research was GDPR complaint, the link for the online questionnaire, hosted via Bristol Online Survey (www.onlinesurvey.ac.uk), was distributed through SENCO networks in the UK and shared on social media. All data were anonymous, and participants were able to omit any questions they did not wish to answer.

4.2.3 Data Analysis Strategy

Qualitative data were analysed using data-driven thematic analysis. In line with Braun and Clarke (2006), and the process of data immersion, data were first read and re-read by the first author to ensure familiarly and closeness with the data. At this point, initial thoughts and ideas were also written down. The first author then took each question in turn and attached codes to the data. Codes represented features of the data that were considered pertinent to each of the study's aims. Although each question corresponded to a particular aim, often participants would include information that was also relevant for another of the study's aims. The next stage involved the first author grouping similar codes to identify themes within the data set. All three authors then examined these themes and ensured there was enough data to support its existence. Themes that were too heterogeneous and did not have enough supporting data were subsequently removed. After re-reading the data and ensuring that the refined themes accurately reflected the full essence of parent and teacher responses, as a team we named each of the themes. Finally, the lead author chose examples from the data to illustrate each theme. 20% of the data were double coded by two independent researchers with expertise in autism and an inter-rater agreement level of 96% was obtained. Quantitative data (Likert scale and Yes/No responses) were analysed using descriptive statistics and Fisher's exact test.

4.2.4 Positionality

Positionality "*reflects the position that the researcher has chosen to adopt within a given research study*" (Savin-Baden & Major, 2013). Positionality can influence the entire research process from initial inception up to interpreting and disseminating findings (Unluer, 2012). When conducting qualitative research, it is vital that researchers reflect upon their positionality and examine how their backgrounds, perspectives and biases may have shaped their thinking and decision making. This is key in ensuring rigor, transparency, and credibility (Unluer, 2012).

I am a white, non-autistic woman, in my mid-twenties, educated at Durham University. These features of my social identity meant that I approached this research from a position of privilege and power. I also approached this researcher as an outsider, having spent only a couple of weeks volunteering at a primary school before undertaking this research. This, alongside having no children, meant that I had a limited experiential understanding of what it meant, or felt like, to be a teacher, parent, or autistic pupil. I did, however, have an MA in Developmental Psychology and a growing expertise in autism, albeit from an academic perspective. Whilst Dwyer and Buckle (2009) argue that being an outsider can lead to greater objectivity, Bonner and Tolhurst (2002) argue that outsiders can lack an understanding of the culture being studied. It should be noted that I did not disclose my social identity to participants; only that I was a researcher at Durham University interested in sensory processing differences.

Given my background, it is perhaps unsurprising that my motivation for this research initially stemmed from an academic interest in wanting to understand how sensory differences interacted with other features of ASD. However, as I began spending more time at school, engaging with teachers and pupils, I became more focused on applied impacts and achieving better outcomes for autistic pupils. This influenced my decision to critically evaluate the medical model of disability and frame my research within the Nordic Relational Model. This decision may have led to me emphasizing contextual factors more than I might have done, had I framed my research within the medical model. This decision also permitted me to reject the term 'sensory deficits' and instead use the phrase 'sensory differences. Nevertheless, although findings are in line with studies that have asked autistic pupils directly about their sensory experiences at school, it should be emphasized that I have interpreted findings from a neurotypical perspective. It is therefore possible that my neurotypical expectations and experiences of the world may have led to me pathologizing some aspects of autistic pupil's behaviour, despite making a conscious effort not to. It is for this reason that greater co-production between autistic and non-autistic individuals is needed to prevent research being framed within only a neurotypical understanding of the world (Fletcher-Watson & Happé, 2019).

4.3 Results

Results for each of the five aims are outlined in turn with extracts from participants included and the school provision noted to compare experiences across school type. Table 4.2 below lists the themes identified during thematic analysis.

Table 4.2 Thematic analysis results

Aim	Themes	Example Quote
1) Identification of sensory differences	Changes in the environment are accompanied by changes in behaviour	You can't always tell but it is often changes in sensory stimulation that can cause a positive or negative effect. (Teacher, Mainstream and Special Provision)
	Understanding a child's idiosyncrasies	I know the children well enough to know what makes them react to certain sensory stimuli. (Teacher, Special and Mainstream Provision)
	Negative reactions	He shows clear signs of distress, hands over ears, crying, going to his dark den, getting his chew hammer out and asking for tight cuddles from his support worker. (Parent, Mainstream)
2) Sensory experiences at school	Auditory- Loud, unpredictable.	Both my boys are extremely sensitive to loud, unexpected noise. Fire alarms can be extremely distressing. They become very upset and can cry for long periods of time after the loud noise. (Parent, Mainstream)
	Tactile- Diverse reactions	We use a lot of different materials in the art room and sometimes students have either very positive or negative reactions to these. (Teacher, Special)
	Visual- Fluorescent lights, displays	Classrooms which had too much stimulation for asd pupils e.g. highly coloured displays, lots of things hanging down from the ceiling etc. (Teacher, Mainstream)
	Taste- Distress at lunch time.	Pupils getting stressed at lunchtimes because they don't like or are forced to try different foods. (Teacher, Enhanced Provision)
	Olfactory- Incidental smells	Smells may be much stronger for those on the spectrum, maybe even not detected by staff or other pupils. Pupils can become very distracted by smells that they perceive are very strong. (Teacher, Mainstream and Special)
3) Impact on learning	Distraction	Affects concentration on what teacher is saying (i.e. things like peers in room tapping a pen, sliding a ruler across desk, talking or whispering or messing around when he is trying to concentrate on what teacher saying.. (Parent, Mainstream)
	Distress	Going into crisis for that child - flapping, run away, shouting, crying or just distressed. (Teacher, Enhanced Provision)

	Anxiety	She gets stressed, clammy, her heart races, she digs her nails into her hands and says she feels angry when the class is too loud and busy. (Parent, Mainstream)
	Classroom participation	Some children can’t access classroom themselves because of the noises, spaces, heat and surfaces. (Teacher, Mainstream and Special)
	Tool for learning	I have a child who has ASD and was deaf- he was hyper stimulated by sensory touch etc and responded really well to have a tablet or diddle toy as calming tool. (Teacher, Mainstream and Enhanced Provision)
4) Factors that influence how sensory differences affect learning.	Child Agency/Control	For projects in which students work more at their own pace and are responsible for getting their own supplies I will give student a checklist so they can organize themselves and their materials. Sometimes I will offer students the choice to work at a quieter table in the room. (Teacher, Special)
	Predictability	When there is an activity which she is unfamiliar with, she tends to experience sensory overload. If she is fully prepared beforehand then she manages to cope quite well. (Parent, Mainstream)
	Classroom design	Often classroom environments are too visually busy which means many youngsters don't know what to attend to and are overwhelmed. This is particularly an issue in mainstream primary Foundation classrooms where everything is accessible/out all of the time. (Teacher, Mainstream and Special)
	Occupational therapy tools	Many of our children with ASD wear and have access as necessary to headphones or fiddle toys (Teacher, Mainstream and Enhanced Provision)
	School resources	We do not have multisensory rooms therefore any multisensory tasks we want to undertake we have to create our own experiences. Class sizes can also make this difficult. (Teacher, Mainstream)
	Staff knowledge	No 1 thing is understanding by all staff so they can prepare children, provide quiet time or activity as needed, explain to visitors etc. If staff don't 'get it' life is going to be very hard and children's mental health and academic achievements will suffer. (Teacher, Mainstream)

4.3.1 Identification of sensory differences

Parents and teachers explained three ways in which they identified sensory differences as affecting a child's behaviour. First, teachers (N=12) and parents (N=4) explained how changes in the environment were accompanied by changes in behaviour, for instance one teacher (mainstream and enhanced provision) reported "*I know that it is the humming noise of the projector that is causing distress to a child because the child will be calmer and will work better once it is turned off*". Understanding a child's idiosyncrasies also allowed parents (N=3) and teachers (N=8) to identify the sensory environment as the source of distress. For example, one teacher (enhanced provision) described a child who "*really did not like to touch anything that made him 'dirty'- didn't like to paint, touch play dough etc. This would make him flap, hit out and sometimes scratch or scream. He really did not like it and always reacted in the same sort of way*." Negative reactions also indicated that the child was experiencing sensory difficulties (Teachers N=15, Parents N=19) and included attempts to limit sensory input, with one parent (mainstream) explaining "*They try to protect themselves by covering their ears, closing their eyes, pulling their t-shirts over their noises to block out the smells*".

4.3.2 Sensory Experiences Encountered at School

The second aim was to explore the type of sensory experiences encountered and assess how frequently these experiences affected learning and school life. Table 4.3 shows that 49% of parents and 36% of teachers believed sensory differences affected life at school all of the time. Likewise, 47% of parents and 30% of teachers believed sensory differences affected learning all of the time. Importantly, no teacher believed that sensory differences had no impact and only one parent believed that sensory differences didn't impact learning. There was no significant difference in the distribution of responses between parents and teachers for impact on school life (Fisher Exact Test, two-sided), *p*=0.523. Although there was a significant difference in the distribution of responses for the effect on learning (Fisher Exact Test, two sided), *p*=0.038, adjusted (for multiple comparisons) pairwise comparisons were non-significant, *p*>0.05. This demonstrates that both teacher and parents perceive sensory differences as having a profound impact on aspects of schooling for pupils with ASD.

Table 4.3 Impact of sensory processing as reported by parents and teachers (number of responses and percentages)

	Not at all and Rarely		Sometimes		Frequently		All the time		N Total
	N	%	N	%	N	%	N	%	
Impact of sensory processing									
Life at school – Teachers	0	1.4	15	21.7	28	40.6	25	36.2	69
Life at school – Parents	1	1.8	10	17.5	18	31.6	28	49.1	57
Learning at school – Teachers	1	1.4	19	27.5	28	40.6	21	30.4	69
Learning at school - Parents	3	5.3	16	28.1	11	19.3	27	47.4	57
Impact by modality									
Auditory	1	1.5	14	20.9	34	50.7	18	26.9	67
Visual	6	8.6	34	49.3	22	31.9	7	10.1	69
Taste	31	44.9	33	47.8	3	4.3	2	2.9	69
Tactile	7	10.5	27	40.3	23	34.3	10	14.9	67
Smell	19	28.4	28	41.8	18	26.9	2	3	67

To understand if differences within a particular sensory modality were driving this effect, the questionnaire asked teachers to report how frequently differences within each sensory modality affected learning. Table 4.3 shows that auditory differences are perceived to affect learning most frequently by teachers, with 78% stating differences within this domain affected learning all the time or frequently, followed by tactile differences (49%), visual (42%) olfactory (30%) and taste (7%). Similarly, 70% of parents reported auditory as being the most disruptive for learning, followed by tactile (16%), visual (5%), taste (5%) and olfactory (4%).

Parents and teachers reported a range of sensory experiences encountered by pupils at school, although these were often negative in nature. Within the auditory domain, loud unpredictable noises (Teachers N=11) were the most common source of distress (e.g. fire alarms, hand-dryers, noise from other pupils). However, lower-intensity sounds were also troublesome and included the sound of pencil on paper (Teacher, mainstream, and enhanced provision) and the white-board pen (Teacher, mainstream and enhanced provision). Only two teachers reported enjoyable auditory experiences, and both related to music. For instance, one teacher (mainstream and enhanced provision) explained, "*soothing music helps one of my little people concentrate. The other little people in my group can only tolerate it if played quietly*."

Tactile experiences evoked more diverse reactions, especially when they were social in nature. For example, one parent (mainstream) reported that their child would seek out "*physical touch such as hugs, kisses, repeatedly tapping someone, touching and squeezing their face. He likes to be really close to people*". Conversely, ten teachers and ten parents reported that children "*hated being* *touched by people*”. Teachers reported that tactile differences were most prominent in situations such as assembly, group work, and transitioning through corridors.

Negative visual experiences related to *“fluorescent lights*”, “*strip lights*”, and “*classroom with lots of displays*” (Teachers N=17). Given the nature of these stimuli, unenjoyable visual experiences occurred throughout school. Few parents (N=2) reported that their child would seek out visual input and teachers (N=2) only noted positive visual experiences in relation to the use of visual timetables. However, it must be considered that this positive experience arose because of the increased structure afforded by visual timetables rather than the actual stimulus itself.

Taste differences were reported only to disrupt learning through affecting the child’s nutrition or causing distress at lunchtime (Teachers N=11), illustrated here by one teacher (special) “*Restricted diets = sub optimal nutrition = impact on energy levels for processing information*”. For olfactory experiences, “*PE changing room” and “incidental smells such as perfume and cleaning products*” were reported as unenjoyable sensory experiences (Teachers N=20, Parents N=6). Seventeen parents also highlighted that their child would seek out vestibular or proprioceptive input, illustrated here by one parent (mainstream) suggesting “*She might seek vestibular input as this is calming for her. So spinning/swinging on chair*”.

4.3.3 How do sensory differences affect learning?

Parents and teachers reported several ways by which sensory differences could affect learning at school. Foremost, parents (N=22) and teachers (N=40) perceived sensory differences as causing distraction in the classroom. Visual sources of distraction included light fittings and classroom displays whereas tactile sources included other children and clothing, illustrated here by one teacher (mainstream) explaining "*because if a child is more focused on what they are wearing it distracts them from their work*". Teachers interpreted auditory distraction to be caused by an inability to "*tune out the noises they don't need affecting their ability to listen to instructions/input*".

Sensory differences also caused distress, which was expressed through emotional and physical reactions (Teachers N=37). Teachers described how children reacted to sensory stimuli by "*lashing out*", displaying "*agitated behaviours*" or responding with "*meltdowns, tears, screaming, tantrum like behaviour".* Parents noted similar behaviours, with three also reporting incidents of self-harm, for example one-parent (special) stated in "*corridors, open halls where sounds can be echoed, my child will self-harm and try to cover his ears*".

Teachers (N=15) and parents (N=15) reported high levels of anxiety that was perceived to disrupt learning. One teacher (mainstream) explained, "*if something is making them anxious or uncomfortable or overstimulated it's going to be really hard to learn anything*" whereas another teacher stated, "*I have seen heightened anxiety and increasingly more challenging behaviours in many pupils who have not had their sensory needs met*".

Classroom participation was also affected by sensory differences (Teachers N=37, Parents N=26). This included limited participation, leaving the classroom, or being unable to attend school all together, as illustrated by one parent (enhanced provision) writing "*he accessed no formal education for over 6 months. He now accessed full time education and is beginning to make progress"*.

Finally, teachers (N=5) reported how they could harness these sensory differences to improve regulation and learning in the classroom. For example, a teacher (mainstream) described one pupil "*was soothed by feeling a soft blanket, when pupil was distressed the soft blanket would help calm him down*."

4.3.4 Factors that influence how sensory differences affect learning.

The fourth aim was to explore the factors that facilitated or inhibited a child's sensory differences from affecting their learning. Across modalities, increasing a child's agency was central in preventing distressing sensory experiences (Teachers N=16). For example, teachers reported how they would manage visual sensitivities by allowing children to "*work individually on an IPad offering pupils control of how much visual stimuli they can manage*" (mainstream and special). Linked to the idea of agency was predictability, with teachers (N=18) reporting how they would minimize the likelihood of unexpected events by establishing routines, as shown in the following quote from a teacher (mainstream and special) "*we structure the pupils day around the events, we pre-empt, and let the pupil know*".

Classroom designs were found to both facilitate and inhibit learning challenges. Teachers spoke of the "*deliberately stimulating*" nature of classrooms and how they would modify these spaces to meet the needs of their pupils. For instance, one teacher (enhanced provision) explained "*I have been able to introduce children into a year 6 classroom that is quiet, calm and still. The displays are neat, tidy and uniformed*". Accompanying these adaptions were modifications in school policy, for example providing early lunch passes and implementing different start and end times to the day.

Parents and teachers (N=39) also reported that occupational therapy tools aided children in their learning. Most commonly reported were the use of ear defenders, weighted blankets, dividers, pop-up barriers, and individual workstations. Sensory diets and sensory breaks were also implemented, as were gradual programmes of de-sensitization. School resources also determined the extent to which sensory differences affected learning (Teachers N=43, Parents N=44). Overwhelmingly, parents and teacher reported that "*small class sizes*", high staff to pupil ratio and 1:1 work enabled their child to fulfil their potential at school. This can be emphasized by a parent (special) who explained, "*he cannot manage being in a classroom more than 9. He cannot access many activities without 1:1 support*". Multisensory rooms, sensory integration rooms, and hydrotherapy were also beneficial. However, these resources were much more readily available in special educational provision than in mainstream schools. The lack of such resources in mainstream school often led to the idea that the mainstream setting was incompatible with children's needs (Parent special school N=8, mainstream N=3), as evidenced by the following extract: Parent (home-school) "*no local mainstream* *schools have class sizes small enough or the skillset to effectively manage his challenging behaviour, but a special school would not be appropriate to meet his academic needs*".

Finally, staff knowledge was seen as key in supporting the sensory needs of pupils (Parents N=19, Teachers N=27). This included knowledge on autism and sensory processing but also encompassed knowledge of each child's need. For example, one parent explained "*my child's school is a special school, and they are fully aware of his and all the other kids in the class's sensory profiles. When they allocate groups, this is primary concern*". This was not the case for many parents, with 33 calling for more training and better communication between families and schools. Indeed, many parents highlighted that "*they know best*", illustrated by "*teachers need to listen and accept that parents know best in most areas, not ignore parents' requests*" (mainstream).

4.3.5 Satisfaction with awareness and current understanding of sensory differences

The final aim was to assess teacher and parent satisfaction with current training and awareness of sensory issues in school (Aim 5). Table 4.4 shows that although 32% of teachers strongly agreed that schools work closely with parents to support pupils with sensory differences, only 19% of teachers strongly agreed that they had received sufficient training to support pupils.

Table 4.4 Satisfaction with awareness of sensory differences

	Strongly Disagree		Disagree		Somewhat		Agree		Strongly Agree		N Total
	N	%	N	%	N	%	N	%	N	%	
Teachers											
I have received sufficient information and training to support pupils with ASD with different sensory needs.	3	4.3	7	10.1	21	30.4	25	36.2	13	18.8	69
School works closely with parents and pupils to support the sensory needs of the individual in class	2	2.9	7	10.1	7	10.1	31	44.9	22	31.9	69
Schools and teachers need more guidance to support ASD pupils who might have different sensory experiences.	0	0.0	3	4.3	13	18.8	31	44.9	22	31.9	69
I am not confident in my ability to teach pupils on the Autism Spectrum who have different sensory experiences	19	27.5	20	29.0	19	27.5	5	7.2	6	8.7	69
Parents											
School is aware that my child might experience and react to sensory information differently.	4	7.0	4	7.0	8	14.0	16	28.1	25	43.9	57
School works closely with parents and pupils to support sensory needs.	11	19.3	10	17.5	11	19.3	11	19.3	14	24.6	57
My child's sensory needs are supported in school	12	21.1	9	15.8	13	22.8	12	21.1	11	19.3	57
The school environment is compatible with my child sensory needs	14	24.6	17	29.8	12	21.1	10	17.5	4	7.0	57
Teachers have received sufficient training and guidance to support pupils on the Autism Spectrum who may have different experiences and reactions to sensory information	17	29.8	11	19.3	10	17.5	9	15.8	10	17.5	57

Conversely, while 44% of parents strongly agreed that school was aware pupils with ASD might have sensory differences, 21% strongly disagreed that their child's sensory needs were supported at school. These findings illustrate that although schools might be aware of sensory differences, greater training is needed to implement policies that can support sensory needs and enhance learning opportunities for pupils with ASD

4.4 Discussion

This study adopted a multi-method approach to explore parent and teacher perspectives on the nature of sensory differences at school and their impact on learning for autistic pupils. Parents and teachers alike were able to provide rich insights into the type of sensory experiences encountered at school, highlight several pathways by which these differences could affect learning, and identify factors that influence how sensory differences impact learning. Findings from this study emphasize that sensory differences can have a profound effect on aspects of schooling for autistic pupils and offer several suggestions for teacher training and intervention development.

We first aimed to explore how parents and teachers identified sensory differences as affecting behaviour. Key to this was understanding a child's idiosyncrasies and exposure to negative reactions. In line with the Nordic relational model, informants also explained how changes in the environment were often accompanied by changes in behaviour, for example "*He is fine any other time but when thunder and lightning are happening behaviour changes almost instantly*" (Teacher, special school). Whilst this reasoning is consistent with findings from Dickie et al. (2009), in which parents explained sensory reactions only occurred at certain times with certain things, it must be acknowledged that this type of attribution could lead to more subtle sensory experiences being missed. For instance, it might be easier to notice a child holding their hands over their ears in response to thunder than it is to notice a child reacting to smells from the canteen, yet both could be equally detrimental to the classroom experience.

Acknowledging these constraints is important when considering findings from Aim 2, in which we asked about the type of sensory experiences at school and their impact on learning. Parents and teachers reported auditory differences as being the most disruptive for learning, citing loud noises (fire alarms, hand-dryers, noise from other pupils) as common sources of distress. Mirroring the views of autistic adolescents in Howe and Stagg (2016), tactile experiences were reported as being second in terms of impact, followed by visual, olfactory and taste. Although reactions to auditory and tactile stimuli might be more readily observed, and by proxy reported as most disruptive by informants, the consistency with autistic adolescents here suggests there are particular properties inherent to auditory and tactile stimuli that result in them having the greatest disruption on learning.

Insights from the current study suggest that it is the often uncontrollable and unpredictable nature of auditory and tactile stimuli that are driving this effect. Emphasizing this are findings from the tactile domain, whereby teachers reported "*unexpected touch*" and "*close proximity to other children*" in situations such as, "*assemblies*" "*group work*" and "*transitioning through corridors*" were highly distressing. This differs from the positive experiences reported by informants, for example "*physical touch such as hugs, kisses, repeatedly tapping someone, touching* *and squeezing their face. He really likes to be close to people*" (Parent, mainstream), whereby the pupil can exert control and agency over the interaction. Predictability and control could also explain why negative visual experience, including "*fluorescent lights*" and "*strip lights*", despite occurring throughout school, were ranked as third in terms of impact on learning. Indeed, compared to auditory and tactile stimuli, which often change rapidly, visual stimuli such as classroom displays tend to remain relatively constant throughout the school term.

Supporting this are the findings from Robertson and Simmons (2015) focus group in which autistic adults reached a consensus that the ability to control a stimulus determined whether it was perceived as distressing or enjoyable. Importantly, when participants felt they had agency, many were able to interact with stimuli in positive ways, for example listening to loud music of their choice. Collectively, findings suggest that one strategy to increase the number of positive sensory experiences at school and reduce impact on learning would be to increase agency and control for pupils. Teachers in the current study offered several examples of how they were achieving this, for example "*Giving the students time to explore a room completely and look at things before they are expected to work*" (Teacher, mainstream) and "*Creating their own sensory experiences, such as mixing paint in the water trough*" (Teacher, mainstream).

However, as noted by teachers, classrooms are "*deliberately stimulating places, they are loud, crowded and rarely completely calm*", and controlling every aspect of the environment would be impossible. Moreover, previous research suggests creating rigid and certain environments may not benefit mental health in the longer term

(Boulter et al., 2014). This is a concern when considering findings from Aim 3 of this study, whereby parents and teachers reported high levels of anxiety that affected learning. For instance, one parent (mainstream) explained "*she either appears anxious or angry. How can you possibly learn with all that adrenaline rushing through you? It's like asking someone to do long division when they're free falling from a plane. Not going to happen*". The high levels of anxiety reported here are in accordance with recent estimates that suggest 40% of the ASD population experience anxiety (van Steensel, Bogels & Perin, 2011). Recent models propose that hypersensitivities play a central role in developing and maintaining anxiety for autistic individuals, for example the Intolerance of Uncertainty framework (Boulter et al., 2014). This model proposes that an interplay between sensory sensitives, rigidity of thought and difficulty with emotional processing, and social/environmental factors create the believe that unexpected events are negative and should be perceived as threatening, which then feeds into high levels of anxiety (Boulter et al., 2014). As discussed, much of the sensory stimuli noted as distressing in the current study was unexpected and unpredictable, supporting this relationship. Current findings thus suggest that one way to improve mental health and academic outcomes for autistic pupils would be through gradually increasing tolerance of uncertainty.

The importance of intervention is highlighted by findings from Smith and Sharp (2013) in which participants explained that periods of high stress can lead to heightened sensitivities that in turn increase anxiety, and so forth. Participants noted a range of reactions that occurred in response to these situations, including anger, attacking the sensory input and escape. The current study contributes to the literature by demonstrating how similar responses can manifest in a school environment and impact upon learning. Indeed, parents and teachers explained that sensory differences often led to distress which was expressed through "*lashing out*", "*flapping*" or the "*opposite-shutting down, into silence and stillness with head down and using their arms to shut out external stimulation*". This is also in line with Baker et al. (2008) who found significant correlations between visual and tactile differences and disruptive behaviour. Parents and teachers also explained that sensory differences could affect learning by reducing participation; a theme akin to escape identified by Smith and Sharp (2013). In an applied classroom setting, this presented as limited engagement, leaving the classroom or being unable to attend school altogether. For instance, one parent (mainstream) explained "*He begs us to home school him. He misses a lot of lessons, often just getting the worksheet, then withdrawing from class to work elsewhere*".

Sensory differences were also perceived to cause distraction in the classroom. Teachers interpreted auditory distraction to be caused by an inability to "*tune out the noises they don't need affecting their ability to listen to instructions/input*." This supports findings from Ashburner, Ziviani and Rodger (2008) study in which auditory filtering difficulties were found to contribute to variance in autistic pupils reading achievement. Likewise, participants in Howe and Stagg' (2016) study reported auditory differences could result in a "*reduction in concentration*", which affected learning. Teachers also reported classroom displays and fluorescent lights as sources of distraction. The finding that the sensory environment can cause distraction and increase off-task behaviour is in line with previous research (e.g Fisher, Godwin and Seltman, 2014). By manipulating the levels of visual stimulation in two mock classroom (decorated, sparse) it was shown that the decorated environment caused poorer learning outcomes and 10% more off-task behaviour (Fisher, et al., 2014). Taken together, findings suggest managing levels of auditory input in the classroom and minimizing visual clutter could improve academic progress for autistic pupils.

Indeed, teachers in the current study identified classroom design as a key factor in creating positive sensory experiences. Teachers offered several examples of how they adapted their classrooms to meet the needs of their pupils, for example by ensuring that "*the displays are neat, tidy and uniformed*." Supporting this practice are findings from Barrett et al., (2013) multi-site study in the UK that found seven design parameters, including light, temperature, complexity, and colour accounted for 16% of achievement variation over the course of an academic year. Importantly, the majority of these pupils were typically developing and can be expected, based on previous research, to have had minimal difficulties with sensory processing (Dunn, 1999). Yet even here, the sensory nature of the classroom was found to have an effect. This, therefore, emphasizes that managing sensory stimulation in the classroom may be beneficial for all pupils, not just those with a diagnosis of ASD.

However, as noted by teachers and parents in the current study, some schools are much more readily equipped to implement such changes. School resources, which included number of staff and access to occupational therapy tools, were seen as central in determining whether positive or negative sensory experiences were had at school. This was also reflected in findings from Aim 5, whereby 44% of parents agreed that school was aware pupils with ASD might have sensory differences, yet 21% of parents did not feel as though their child's sensory needs were being supported. Linked to this was the idea that neither mainstream nor special school would be appropriate to meet the needs of autistic pupils. Echoing this view are insights from a recent paper that demonstrated although parents of children with ASD, Williams Syndrome and Down Syndrome all faced challenges in finding suitable educational provision or their child, autistic children seemed to be disproportionally disadvantaged (Van Herwegen, Ashworth & Palikara, 2018). Similar concerns were raised in the All-Party Parliamentary Report, leading to the Government proposing to develop an 'Autism and Education' strategy by the of 2020 (All Party Parliamentary Group, 2017). Findings from the current study very much emphasize the need to encompass sensory differences within this framework.

4.4.1 Limitations and Future Directions

Although the study demonstrated that parents and teachers are able to provide rich and informative insights regarding the impact of sensory differences in the classroom, the study did not include direct insights from pupils with ASD. This is a limitation because parents and teachers can only report on the behavioural outcomes of sensory differences and therefore may neglect the internalized effects of sensory experiences. Similarly, negative behavioural responses may be easier to identify than positive sensory experiences, which could explain why parents and teachers reported a limited number of enjoyable sensory experiences. Furthermore, the study relied on insights collated via questionnaires. Future work should therefore include autistic pupils and use varied methods (e.g., beyond questionnaires) to ensure their lived experiences are fully captured and allow for positive and negative sensory experiences to be reported in equal measure. It would be a useful next step to take a participatory perspective and feed these findings back to autistic individuals to ask whether they endorse the issues that have been raised by the parents and teachers in the current manuscript. The insights of autistic individuals on these issues can also help inform the direction of further research on these sensory issues.

The study also included an exploration of potential similarities / differences reported for pupils in mainstream versus specialised educational provision and there were some interesting insights based on schooling, both from parents and teachers. These differences warrant further investigation to ensure that all learning environments are suited to the needs of pupils with ASD. There is no doubt that both parents and teachers see sensory reactions and sensitivities as impacting upon learning for children with ASD and these multi-informant insights are particularly useful for gathering a wide variety of illustrations of how these differences might present in the child and impact their daily functioning.

4.4.2 Implications

The current study adopted a mixed-method, multi-informant approach with teachers and parents to understand how sensory differences affect learning and school life for autistic pupils. Parents and teachers reported that a significant proportion of children with ASD were affected by unusual sensory reactions of sensitivities and the study aimed to understand these impacts. The first aim was to examine how parents and teachers identified sensory differences as affecting children’s behaviour. Key to this was understanding that changes in the environment were often accompanied by changes in behaviour, knowing a child’s idiosyncrasies and exposure to negative reactions.

The second aim was to understand the type of sensory experiences encountered at school and to assess how frequently these experiences affected learning and school life. Sensory differences, particularly within the auditory and tactile domain have a profound impact on learning. Responses from parents and teachers suggested that unpredictability and lack of control over stimuli caused specific challenges for pupils with ASD. Overall, sensory experiences, irrespective of school provision, were often negative although there was considerable heterogeneity in the experiences perceived as enjoyable or distressing.

Parents and teachers, across school provisions, explained that sensory differences affected learning through causing distraction, distress, anxiety and withdrawal from participation. The study considered the factors that influence how sensory differences affect learning, with parents and teachers reporting agency, predictability, classroom design, school resources and staff knowledge as key in minimizing the impact of sensory differences. Large class sizes and limited resources were challenges in mainstream schools, with several parents and teachers perceiving the mainstream environment as incompatible with pupil's sensory needs. Finally, teachers and parents believed more training was needed to support pupils with sensory differences in the classroom. The insights provided by this multi-informant study can inform future research on sensory processing and aid the development of targeted interventions to ensure that autistic pupils obtain positive learning experiences at school.

Chapter 5: Short Report- Retrospective insight on sensory school experiences from late-diagnosed autistic women

Findings from Chapter 3 of this thesis suggested that different factors might be contributing to autistic and neurotypical pupil's academic achievement. Drawing on evidence presented in Chapter 2, it was suggested that sensory processing differences may have a significant role in contributing towards autistic pupil's academic achievement. To explore this possibility, in Chapter 4 parents and teachers were asked if and how sensory processing differences impacted the learning and school life of autistic pupils. While these findings provided valuable insights on the nature of sensory differences at school and emphasized the impact that unsupported sensory needs can have on learning, one limitation of this study is that it did not incorporate the views of autistic individuals. Gathering insights from autistic individuals is vital however for validating the views of parents and teachers and for understanding the lived experience of autistic pupils at school. As such, in the current chapter, late-diagnosed autistic females are asked to reflect on their time at school and to consider the impact of sensory processing differences on learning and school life. It should be noted that this chapter has been prepared as a brief report publication ready for submission to a journal.

5.1 Introduction

School continues to be a challenging experience for many autistic pupils. Levels of bullying, exclusion and academic underachievement remain high, and 50% of pupil's report being unhappy at school (All Party Parliamentary Group, 2017). Whilst several of these issues relate to pupils' social differences, difficulties with sensory processing have also been reported to contribute to a challenging school experience (All Party Parliamentary Group, 2017).

Sensory processing differences are experienced by an estimated 69% to 93% of autistic individuals and occur in both directions of hyper and hyposensitivity (Ben-Sasson et al., 2019). At school, these differences have been reported by autistic pupils, parents, and teachers to reduce concentration, induce anxiety, and limit classroom engagement (Howe & Stagg, 2016, Jones, Hanley & Riby, 2020). These sensory impacts also extend to the playground and effect play and the diversity of social networks. (Cosbey et al., 2012). Although further research into sex differences in sensory processing is needed, there is some suggestion that autistic females experience a significantly greater impact of unusual sensory experiences across the lifetime (Lai et al., 2011). However, there is no research focused on the impact of sensory differences at school for autistic females.

Currently, three times as many males as females are diagnosed with Autism Spectrum Disorder (ASD; Loomes et al., 2017). When females do receive a diagnosis of ASD, it is often later than males and after a history of misdiagnosis (Loomes et al., 2017). It is these late-diagnosed women who are perhaps most representative of the autism female phenotype, often flying under the radar by not conforming to a male model of ASD (Mandy et al., 2012). As a consequence, many autistic females must navigate the school environment and the associated sensory challenges, undiagnosed and unsupported. The impact of sensory differences, and the interaction with other core autism features, may thus result in a very different school experience compared to that of earlier-diagnosed autistic males.

The current study therefore aimed to explore the impact of sensory processing differences on school life for late-diagnosed autistic females. Autistic females completed an online questionnaire focused on sensory experiences at school, their impact on school life, and strategies used to manage these sensory experiences. It was hypothesized that sensory differences would have had a substantial impact on school life for these females, specifically in terms of social participation and anxiety. However, beyond this hypothesis the project was exploratory in nature so as to capture the lived experiences of autistic females as they reflected on their time at school.

5.2 Method

5.2.1 Participants

Sixty female adults (mean =33.49years, SD=9.85) who received a diagnosis of ASD after finishing school (mean age of diagnosis =27.69, SD=13.85) completed the online questionnaire. Participants confirmed their diagnosis of ASD via self-report. This is a limitation because it is possible that some participants are self-diagnosed, as opposed to having received an official diagnosis. The majority of participants had had been taught in the UK (55%) and North America (25%). Participants were highly educated with 66% achieving at least a Bachelor’s degree. Twenty-three percent of participants had also received an additional neurodevelopmental and/or mental health diagnosis. Specific data on socioeconomic status and race/ethnicity were not recorded. Participants were recruited via social media.

5.2.2 Materials

The bespoke online questionnaire contained 36 questions (9 free-response questions, 11 Likert scale questions and 16 sub-questions). This paper will focus only on the qualitative data. Questions focused on the type of sensory experiences encountered at school, how these experiences impacted learning, and strategies used to manage sensory differences. For instance, "*Were there any sensory experiences you sought out at school? What were they?*" See Appendix D for full questionnaire.

5.2.3 Procedure

After obtaining ethical approval from the local ethics committee, the link for the online questionnaire, hosted via Online Surveys (www.onlinesurveys.ac.uk) was shared on social media. Participants provided informed written consent. Data were anonymous and participants were able to omit any questions they did not wish to answer.

5.2.4 Data Analysis

Data were analysed using data-driven thematic analysis. In line with Braun and Clarke (2006), data were read and re-read by the first author to ensure familiarity with the data. Each question was then taken in turn and codes attached to the data. Next, the first author grouped similar codes to identify themes within the data. All authors examined these themes and removed themes that were too variable. Data were then re-read to ensure that the refined themes captured the full of essence of participants responses. 20% of the data were re-coded by an independent researcher and 96% inter-rater reliability was obtained.

5.2.5 Positionality

As discussed in Chapter 4, positionality can influence the entire research process from initial inception up to interpreting and disseminating findings (Unluer, 2012). Reflecting upon one's positionality is therefore key in ensuring rigorous, transparent, and credible qualitative research. I am a white, Welsh, non-autistic woman, in my mid-twenties.

These features meant that I approached this research from a position of privilege and power. However, different to that seen in Chapter 4, for this study there were features of my social identity that placed me as an insider and others than placed me as an outsider. I shared with participants the experience of being a woman and could identity situations from own past of navigating social norms and teenage friendship groups at school. Likewise, I shared with participants the experience of going to university and being mid-twenties. I was therefore somewhat familiar with the language and cultural references made by some participants. Nevertheless, as emphasized in Chapter 4, I was an outsider when it came to understanding the lived experiences of autistic pupils at school. Especially pertinent to this study is the experience of being mis- or undiagnosed and not receiving a diagnosis until adulthood. The power dynamic in this study was also unequal with me designing, interpreting, and disseminating findings with little opportunity for participants to feedback and be part of this process. This is a substantial limitation and one that I aim to address in future co-produced work.

5.3 Results

Sensory experiences at school were largely negative, as evidenced in the following reflection: "*It was everything - the lights (fluorescent tubes), the smell of the wax used to clean the tiled floor, the smell of 30 children and the noise of 30 children, the clock on the wall, the noise of the whole school, humming with talk.*"

Three themes and 9 subthemes were identified that related to these experiences, as shown in Table 5.1.

Table 5.1 Thematic Analysis Results (N= number of females discussing this issue out of a total of 60)

Theme	Sub-Theme	N	Example Quote
Emotional and physical reactions	Meltdowns/Shutdowns	10	I used to cry quietly throughout the whole lesson then have a total sobbing fit/meltdown at the end and alarm the poor teacher
	Physical Discomfort	20	High pitched sounds too. Mostly those metal things in music class. That you hit with mallets. Like a glockenspiel but higher! Little dings of pain
	Teasing by peers	8	Being made fun of because I would cry when there was too much noise, or flashing lights or people were talking loudly
Mental Health	Anxiety	20	The classrooms were very loud. In particular I used to have anxiety attacks after maths class because I loved the subject but the sound of everyone talking while doing the work was too overwhelming for me
	Camouflaging	6	I held it in at school and used to meltdown silently at home- mother wouldn't tolerate it. I ended up having breakdown in my mid twenties- mis dx with depression - awful meds. Lost my job and functioning.
	Social Opportunities	8	I had an extremely negative time at school, resulting in extreme anxieties and stress. I was so anxious I couldn't speak to anyone or smile, leading to me being unable to make friends or ask for help. I was bullied by three people, who I originally thought were my friend
Social Participation	Filtering stimuli	6	I would often miss what was being said either because I couldn't hear it clearly over other noise, or couldn't focus on it to take it in.
	Social Spaces	11	It made it even harder for me to make friends, because the environment in which you were expected to do so (the playground/lunch hall) were so difficult for me that I tried to avoid them as much as possible.
	Library	25	Mostly I just tried to seek quiet spaces, like the library and the garden (but that's more the absence of other sensory experiences than the presence of them).

Theme 1: Emotional and Physical Reactions

The school sensory environment was reported to cause meltdowns (N=10) and physical discomfort (N=20). For instance, one participant explained "*The screeching of the chairs was so bad that it made my teeth physically hurt".* Eight recalled being teased by peers for these types of reactions, for example "*being made fun of because I would cry when there was too much noise or flashing lights*."

Theme 2: Mental Health

Sensory experiences were associated with high levels of anxiety at school (N=20). One participant explained "*I would have panic attacks at secondary school in assemblies. There were too many people and it got too noisy and overwhelming*." Six reported camouflaging their anxiety, with one participant reflecting that they were not "*permitted to do things like stimming or publicly melting down or expressing anxiety, so I tried to keep it all inside and just get exhausted later.*" Anxiety also impacted social opportunities (N=8) as evidenced in the following extract: "*I had an extremely negative time at school, resulting in extreme anxieties and stress. I was so anxious I couldn't speak to anyone or smile, leading to me being unable to make friends or ask for help*."

Theme 3: Social Experiences

Sensory differences also exacerbated an already challenging social experience at school. Indeed, 28 participants experienced bullying and a further 15 described challenges in maintaining friendships. Difficulties in filtering stimuli (N=6) further limited opportunities for social interaction, as emphasized by the following quote:"*I cannot tune in to 1 person and hear "every" conversation in a busy room, this means I can't* *hear or interact with the people next to me as the auditory input was too much to bear*."

Social spaces (assemblies, school yard) were also inaccessible for many autistic females due to the levels of sensory stimulation (N=11). Enjoyable sensory experiences therefore took place in spaces such as the library or outdoors as this allowed for solitude, reduced stimulation and an opportunity to engage in reading (N=25). This is highlighted by the following two extracts; Participant one "*There are enjoyable smells (old books and new books) and it was always never lit quite the same way."* Participant two: *"I loved the smell of old and shade and darkness… It was so quiet there with all the other children gone. I felt safe. I felt like I could be a little bit of me there."*

5.4 Discussion

The current study aimed to explore the impact of sensory processing differences on school life for females who were late diagnosed with ASD. Participants were able to provide rich recollections of their sensory differences and emphasized that these differences negatively impacted upon their school experiences. Critically, it is only these late-diagnosed autistic females, and not other informants such as teachers, who can reflect on the lived experience of navigating the school sensory environment undiagnosed. The voices of these individuals are invaluable therefore in terms of shaping our understanding of sensory differences and providing insights into how we can best support and identify difficulties at school.

Sensory differences could exacerbate an already-challenging social world by reducing access to social spaces and restricting opportunities for social connectivity.

Assemblies, school yards and spaces where socializing usually took place were often too overwhelming for participants, resulting in 25 females seeking a reduction in stimulation in the library or in nature. Although females in the current study reported enjoyable experience in these spaces, autistic adults have previously reported that avoidance of stressful sensory environments can result in isolation and loneliness (Smith & Sharp, 2013). This is a particular concern when thinking about autistic females, because different from autistic males, their high motivation for friendships may not be fulfilled, leading to social exclusion (Sedgewick et al., 2016).

This was evident in the current study with 28 females reporting bullying at school. Even when able to access social spaces, opportunities for social engagement remained difficult as many participants faced challenges filtering sensory stimuli and tuning into peers. It was these busy, stimulating environments that also induced meltdowns and physical discomfort, which in turn could result in further teasing (and withdrawal) from peers. Collectively, findings highlight the strong interplay between sensory and social differences and suggest that adapting the school sensory environment could result in improved social experiences for a broad neurodiverse population at school (Cosbey et al., 2012).

Sensory differences were also associated with anxiety at school. Although 42% of the autistic population experience anxiety, there is some suggestion that autistic females are particularly at risk for developing internalizing disorders (Hollocks et al., 2019; Mandy et al., 2012). In line with previous research, anxiety often occurred in environments where loud, unpredictable sensory input was common (e.g transitioning through corridors) (Howe & Stagg, 2016). The intolerance of uncertainty framework places sensory sensitivities as central in developing and maintaining anxiety for autistic individuals (Boulter et al., 2014). Within this framework, an interplay between sensory differences, rigidity of thought, difficulty with emotional processing and social/environmental factors, create the belief that unexpected events are negative and should be perceived as threatening. One approach to reducing levels of anxiety at school could therefore be gradually increasing tolerance to uncertainty.

There is also a need to improve recognition of anxiety in school as females in the current study reported camouflaging their anxiety until they arrived home. Camouflaging aspect of one's identity/behaviour has been associated with a heightened risk of depression, anxiety, and suicidality, and again appears more common in females (Hull et al., 2017). There is a suggestion that camouflaging autistic traits is one factor that is contributing to female being under/misdiagnosed (Mandy et al., 2012). Raising awareness of camouflaging and improving recognition of anxiety in schools may therefore reduce the number of autistic females who receive a late, or incorrect diagnosis and create opportunities for early support and intervention.

Asking later-diagnosed females to reflect upon their school experiences is not without limitations. Foremost, these accounts may not represent current pupil's experiences, as changes in legislation and diagnostic criteria is likely to have improved access to accommodations and awareness of ASD at school. Finally, although this study sought to capture the views of females, so as to give a voice to individuals historically overlooked, without a male comparison group we cannot ascertain if the interaction between sensory and social challenges at school are unique to females or vary across sex. Future work should therefore explore these issues in a sample of males and female pupils currently at school.

In conclusion, the current study aimed to explore the impact of sensory processing differences on school life for late-diagnosed autistic females. Sensory experiences were largely negative and affected school life by causing emotional and physical responses, impacting mental health, and exacerbating an already difficult social world. Findings emphasize the strong interplay between sensory differences, social experiences, and anxiety at school. Adapting the sensory environment, or helping individuals manage their sensory differences, could result in improvements in each of these domains at school.

Chapter 6: Do sensory processing differences impact academic achievement and classroom behaviour?

6.1 Introduction

Despite 60-90% of autistic children experiencing sensory processing differences, little is known about how these differences relate to educational outcomes (Ben-Sasson et al., 2019). As emphasized throughout this thesis, sensory differences are not inherently adverse and can bring joy for many autistic individuals (Ashburner et al., 2013; Robertson & Simmons, 2013; Smith & Sharp, 2013). Examples include listening to music through headphones, watching the colours in a fish tank, or lying under a weighted blanket (Smith & Sharp, 2013). Nevertheless, it is clear from Chapters 4 and 5 that when the environment is not compatible with an individual's sensory needs, these differences can be highly distressing and negative (Ashburner et al., 2013; Kirby et al., 2015; Jones, Hanley & Riby, 2020). The school classroom, which is often busy, loud, and colourful, is a crucial environment to consider (Ashburner, Ziviani & Rodger, 2008). Indeed, with children spending the majority of their school day in the same classroom, a mismatch here could have a profound impact on behaviour and learning (Barrett et al., 2013; Goodley & Runswick-Cole, 2012).

6.1.1 Impact on Behaviour

The impact of sensory differences on classroom behaviour and learning was supported by the findings from Chapter 4 in this thesis. When asking parents and teachers about the perceived impact of sensory differences at school, 49% of parents and 36% of teachers believed sensory differences affected school life all of the time. In terms of behaviour, parents and teachers identified sensory differences as causing distraction in the classroom, evoking high levels of anxiety, and limiting opportunities for participation (Jones, Hanley & Riby, 2020). Similar accounts are offered by autistic pupils, with touch and auditory differences causing physical discomfort and reducing concentration (Howe & Stagg, 2016; Humphrey & Lewis, 2008). Elsewhere in school, sensory differences have also been reported to exacerbate an already challenging social world (Cosbey, Johnston & Dunn, 2010). Chapter 5 highlights this interplay with late-diagnosed autistic women reflecting on the challenges of entering social spaces such as the canteen due to noise levels and proximity to other pupils.

Factors such as predictability, control, and agency have, however, been reported to ameliorate the potential effect of sensory challenges (Smith & Sharp, 2013; Ashburner et al., 2013; Robertson & Simmons, 2015). Indeed, in a focus group conducted by Robertson and Simmons (2015) autistic adults discussed how being able to control sensory input reduced anxiety and facilitated participation in spaces that are typically rich in sensory input e.g., music concerts. Predictability and agency also appear to be critical for autistic children and adolescents (Howe & Stagg, 2016; Ashburner et al., 2013). Teachers in Chapter 4 seemed aware of these factors and would attempt to increase predictability and provide opportunities for sensory needs to be met (Jones, Hanley & Riby, 2020). For example, one teacher explained how providing a child with a weighted blanket reduced distraction and increased engagement during carpet time. Collectively, it seems that while sensory differences certainly have the potential to negatively affect behaviour, appropriate support and adaptations can facilitate more positive behaviours and limit sensory distress both inside and outside of the classroom (Piller & Pfeiffer, 2016; Robertson & Simmons, 2015).

6.1.2 Impact on Academic Achievement

Findings from Chapter 3 of this thesis indicated that a substantial number of autistic children were achieving at a level that was not commensurate with intellectual ability. Of particular concern was the finding that 40% of autistic children were underachieving in maths. Although neurotypical children also evidenced significant IQ-achievement discrepancies, this was overwhelmingly in the direction of overachievement rather than underachievement. Identifying the sources of academic heterogeneity, especially underachievement, is vital because academic achievement is known to predict an array of future life outcomes including, health, employment, and independent living (Burgess & Gutstein, 2007).

Importantly, the work of Ashburner, Ziviani and Rodger (2008) suggests that sensory differences may have a unique and crucial role in contributing to autistic pupil's academic achievement. This study examined the relationship between sensory processing, classroom behaviour, and educational outcomes in a group of 51 neurotypical children and 28 autistic children, between the ages of 6 and 10. Children completed the Kauffman Brief Intelligence Test, teachers completed the Conner's Teacher Rating Scale and the Achenbach System of Empirically Based Assessment (ASEBA), and parents completed the Short Sensory Profile. In line with reports on the autistic lived experience (Howe & Stagg, 2016), tactile sensitivity and auditory filtering were found to explain 37% of the variance in autistic pupil's cognitive problems and inattention in the classroom, as assessed by the Connors Teacher Rating Scale. Moreover, under-responsiveness/seeks sensation and auditory filtering scores on the Short Sensory Profile accounted for 47% of the variance in autistic pupils ASEBA academic performance scores as rated by teachers (Ashburner, Ziviani & Rodger, 2008). No such associations were found in the neurotypical group, however. Therefore, while caution is needed due to ASEBA scores being an indirect measure of academic achievement, findings do provide preliminary evidence that sensory difference can impact the behaviour and achievement of autistic pupils (Ashburner, Ziviani & Rodger, 2008).

Supporting this evidence are the findings of a recent study conducted by Butera et al. (2020). Similar to Ashburner, Ziviani and Rodger (2008), 52 parents of autistic and neurotypical children, between the ages of 8 and 14 years, were asked to complete the School Performance section of the Child Behaviour Checklist and the Short Sensory Profile 2. It is important to note that different from the original Short Sensory Profile, the Short Sensory Profile 2 allows for both modality scores, and quadrant scores to be calculated, as outlined in Dunn's Sensory Framework (Dunn, 2014). Quadrant scores are thought to provide greater insight into sensory processing as they describe both the neurological threshold (hypersensitivity or hyposensitivity) and the approach taken to manage that threshold (passive to active), rather than simply describing the modality affected (Dunn et al., 2014). Importantly, the same person can score highly on more than one of these quadrants, for example they may score highly on both Sensitivity and Seeking (Dunn et al., 2014). There is some suggestion that these co-occurring profiles could be related to unique behavioural and academic outcomes (Butera et al., 2020). This possibility was examined by Butera et al. (2020), and it was found that a profile characterised by increased sensory sensitivity alongside reduced sensory avoidance accounted for the greatest amount of variance (28.6%) in achievement, after controlling for additional variables such as IQ, ADHD and other sensory features. In the classroom, a child with this profile might experience distress due to hypersensitivity but do little to limit sensory input (Dunn, 2014).

However, a key limitation of both Ashburner, Ziviani and Rodger (2008) and Butera et al. (2020) is that parents, and not teachers, ranked sensory differences. This is an issue because it neglects the importance of context in influencing the presentation and impact of sensory differences (Fernandes-Andres et al., 2015; Brown & Dunn, 2010; Goodley & Runswick-Cole, 2012). As discussed in Chapter 1, the Nordic Relational Model of Disability suggests that sensory differences only become adverse when the environment is incompatible with an individual's sensory needs (Goodley & Runswick-Cole, 2012). A child with hypersensitivity therefore may become distressed and experience disability when placed in a busy, loud classroom but not in a quiet space at home (Goodley & Runswick-Cole, 2012). Supporting this model are the findings of Fernandes-Andres et al. (2015), who found teachers reported greater sensory differences compared to parents on the Sensory Processing Measure rating scale (Parham et al., 2007). Teacher insights are therefore needed to gain a more representative understanding of how sensory differences relate to academic achievement. Similarly, the teacher questionnaires used to probe achievement by Ashburner, Ziviani and Rodger (2008) and Butera et al. (2020) are indirect measures of achievement and also assess a range of other behaviours associated with school performance. As such, there is a need to use more direct academic achievement assessments when considering how sensory differences relate to educational progress.

6.1.3 Quadrants or Subtypes

There is also a need to consider how best to characterize and capture sensory differences in ASD (Cascio et al., 2016; DeBoth & Reynolds, 2017). Recently, there has been a call to move away from quadrants and instead towards a data-driven subtyping approach (DeBoth & Reynolds, 2017; Lane et al., 2010; Little et al., 2017; Schaaf & Lane, 2015). One reason for this is that patterns of hypersensitivity and hyposensitivity may differ across sensory modalities and have important implications for behaviour (Schaaf & Lane, 2015). Likewise, sensory differences could be confined to a particular sensory modality e.g., typical visual sensory processing alongside differences in auditory processing (Schaaf & Lane, 2015). However, as quadrant scores are produced by combining items from different modality sections, this pattern of sensory differences is unlikely to be captured using Dunn's Sensory Framework.

As such, Lane et al. (2010, 2011, 2014) aimed to move away from Dunn's Sensory Framework and sought to investigate if autistic children with similar profiles of sensory processing could be identified using data-driven, model-based cluster analysis. In the largest of these studies, the parents of 228 autistic children (aged between 2-10 years) were first asked to complete the Short Sensory Profile. Model-based cluster analysis, using the seven factor scores from the Short Sensory Profile was then conducted, and four homogenous subtypes were identified. The first cluster was characterized by typical sensory processing (n=84), whereas the second group demonstrated extreme taste/smell sensitivities (n=92). Conversely, the third cluster was characterized by extreme scores in low energy weak (n=23), while the final group showed differences across all sensory domains (n=29). To investigate if these subtypes were associated with different cognitive and behavioural outcomes, the ADOS, the Mullen Scales of

Early Learning and the Stanford Binet 5th Edition were also administered, to assess autism symptom severity and nonverbal IQ. Critically, it was found that cluster membership was predictive of unique difficulties such that the taste/smell group was strongly associated with communication challenges, but the low energy/weak profile was related to greater levels of maladaptive behaviours (Lane et al., 2010). Findings therefore highlight that there is heterogeneity in the nature of sensory processing differences such that some autistic individuals experience differences across modalities, whereas differences are confined to specific modalities for other individuals. Likewise, differences can be in the direction of hypersensitivity, hyposensitivity, or a combination of both. However, when using Dunn's Sensory Framework to characterize sensory processing differences, these modality-specific differences are in danger of being overlooked. As such, when investigating how sensory processing differences impact achievement and behaviour, it may be beneficial to adopt both a quadrant and data-driven subtyping approach to ensure the complexity and heterogeneity of sensory differences is captured.

Several research groups have now undertaken this subtyping approach to characterizing sensory processing in ASD, using a variety of measures and clustering techniques (Uljarevic et al., 2016; Tomchek et al., 2018; Ausderau et al., 2016). A recent review by DeBoth and Reynolds (2017) reported that although several studies have identified a group characterized by typical patterns of sensory processing, and a second characterized by global differences, there remains substantial disagreement on how best to describe the responses seen in other children (DeBoth & Reynolds, 2017). Importantly, to date, no research has investigated if comparable subtypes can be identified within an educational setting using the Sensory Profile School Companion

(DeBoth & Reynolds, 2017). Given the importance of the environment in shaping the presentation and impact of sensory differences this represents a substantial gap in the literature (Brown & Dunn, 2010). Moreover, identifying subtypes and understanding how they relate to behavioural and cognitive outcomes could allow for tailored adaptions and individualized support to be implemented in the classroom.

6.1.4 Current Study

The current study aimed to investigate the relationship between sensory processing, academic achievement, and classroom behaviour in a group of primary aged children with a diagnosis of ASD. Building on previous work, this study contributes to the literature by asking teachers, and not parents to reflect on children's sensory differences. This difference in informants is important given the role of the environment in shaping the presentation of sensory differences (Brown & Dunn, 2010; Goodley & Runswick-Cole, 2012). This study will also be the first, to the authors knowledge, to probe academic achievement using a direct and standardized measure, rather than a teacher questionnaire. Again, this is important because the teacher questionnaires used previously also measure aspects of school functioning that go beyond academic achievement i.e., attendance and social skills (Butera et al., 2020). Lastly, this chapter extends previous work by adopting a novel clustering approach to explore if sensory subtypes can be identified, before examining their relation to academic achievement and classroom behaviour.

The first aim of this study was to examine the relationship between sensory processing differences, as assessed through quadrant scores on the School Sensory Profile, and academic achievement, as assessed through reading and maths composite scores on the WIAT (Wechsler, 2011*)*. It was predicted that greater sensory differences would be associated with poorer academic achievement and account for a significant amount of variance in scores.

The second aim of this study was to investigate the relationship between sensory processing differences and classroom behaviour, as assessed through the Conner's Teacher Rating Scale *(*Conners, 2008*)*. It was also predicted that greater sensory differences would be associated with more challenging classroom behaviour and predict a significant amount of variance in scores.

The third aim of this study was to move beyond Dunn's Sensory Framework and investigate if sensory subtypes could be identified using modality scores on the School Companion Sensory Profile 2 as clustering variables. If sensory subtypes could be identified, the next aim was to examine their association with educational outcomes. Although sensory subtypes were predicted to emerge, given the exploratory nature of this aim, there was no specific hypotheses in terms of the nature of subtypes, or their relation to academic achievement and classroom behaviour.

6.2 Method

6.2.1 Participants

Children for this study were recruited through SEN or ASD specialist schools using SENCO networks and local links with the community. Children were invited to take part if they had a diagnosis of ASD, were verbal and between the ages of 6 and 11 years. Children with a co-occurring condition such as ADHD were also included. However, children who were outside of this age range, did not have a diagnosis of ASD, or whose first language was not English, were not able to participate. The presence of an ASD diagnosis was confirmed by parent report. As noted in earlier chapters, this could be considered a limitation because researchers are having to rely on parents' understanding and openness when disclosing their child's diagnostic status. Given the heterogeneous nature of cognitive and academic ability, children were not excluded based on IQ or achievement scores. Participating schools were provided with project packs, consisting of information sheets, consent forms, and a privacy notice to send to parents (See Appendix A for consent forms and information sheets). If parents agreed for their child to participate, they were asked to return the consent form to school, and children provided assent prior to participation.

Twenty-eight autistic children participated in this study. However, five children were unable to complete the reading and maths components of the WIAT 2 and were therefore excluded from the analysis. The final sample therefore included 23 autistic children, 20 of whom participated in the study detailed in Chapter 3 of this thesis. The youngest child was 6 years and 1 month and the oldest 11 years and 6 months (M=8.92, SD=1.40). Nine children had an additional diagnosis (6 ADHD, 2 Sensory Integration Disorder, 1 Learning Difficulties). Only 11 Social Responsiveness Scale-2 (Constantino, 2002*)* questionnaire forms were returned from parents, but all indicated substantial social difficulties (Mean Total T Score= 79.92, SD =7.82, Min=68.00, Max=90).

6.2.2 Measures

The Wechsler Abbreviated Scale of Intelligence- Second Edition (Wechsler, 2011)

Estimated intellectual ability was assessed through the WASI 2. See Chapter 2 for an overview of the measure.

Wechsler Individual Achievement Test 2nd Edition (WIAT 2) (Wechsler, 2005)

Children completed the reading and maths scales of the WIAT 2 as a measure of academic achievement. See Chapter 2 for an overview of the measure.

The School Companion Sensory Profile 2 (SCSP) (Dunn, 2014)

The School Companion Sensory Profile 2 is a 44-item questionnaire that asks teachers to report how frequently a child in their class responds to a sensory event in the described manner, for example "*struggles to complete tasks in a noisy setting*", on a six-point Likert Scale (Does Not Apply, Almost Never, Occasionally, Half The Time, Frequently, Almost Always). The SCSP allows for Quadrant (Seeking; Avoiding; Sensitivity; Registration) and modality (Auditory; Visual; Touch; Movement; Behaviour) scores to be calculated (See Chapter 1 for a description of quadrants and modalities). The same person can score high or low on more than one quadrant or modality. The range of scores and classification cut-offs are presented in Appendix E. Quadrant scores were used to assess sensory processing differences for Aim 1 and 2. Modality scores were used as clustering variables for the third aim of this study as the goal was to move beyond Dunn's Sensory Framework and adopt a data-driven approach. Good psychometric properties have been found, with internal consistency coefficient alphas ranging from 0.84 to 0.92 for quadrant score and 0.81 to 0.85 for modality scores (Dunn, 2014). However, in the current sample Cronbach alpha values for quadrant scores were lower and ranged from 0.641 (Avoiding) to 0.820 (Seeking). Likewise, Cronbach alpha values for modality scores in the current sample ranged scores ranged from 0.610 (Touch) to 0.792 (Movement).

Conners 3 Teaching Rating Scale-Short (Connor 3-TS) (Conners, 2008)

The Connor's 3-TS (Connors, 2008) is a 41-item standardized questionnaire, consisting of five scales, which asks teachers to rate how well a statement describes a child's behaviour in the classroom. Items are scored on a 4-point Likert Scale (Not True At All, Just A Little Bit True, Pretty Much True, Very Much True). Raw scores on the five scores: Inattention, Hyperactivity/Impulsivity, Learning Problems/Executive Functioning, Aggression and Peer Relations are then converted to T-scores by comparing the target student with same gender and age norms in the manual. An overall total score is not provided. Higher T-Scores indicate that the child is showing greater than expected levels of disruptive behaviours in the classroom, given their age and gender. Connors 3-TS shows good psychometric properties with internal consistency ranging from 0.87 (good internal consistency) to 0.94 (excellent internal consistency) on the five scales (Connors, 2008). Cronbach alpha values for the current sample ranged from 0.671 (acceptable) to 0.898 (good).

The Social Responsiveness Scale 2 (SRS 2) (Constantino, 2002)

The Social Responsiveness Scale is a 65-item standardized caregiver questionnaire that provides a quantitative measure of autistic traits for children between the ages of 4 to 18 years old. Caregivers are asked to report the frequency of listed behaviours on a 4-point Likert Scale (Not True to Almost Always True), for example '*is socially awkward even when trying to be polite'*. Raw scores on the five scales: Awareness, Cognition, Communication, Motivation and RRB are then converted to T-scores by comparing the target student with same gender norms in the manual. See Appendix F for a description of T-score ranges. Raw scores on the five scales can also be totalled and then converted to a singular T-score which describes the severity of social difficulties. The SRS has demonstrated good psychometric properties, with a reported internal consistency of 0.95 (Constantino & Todd, 2003).

6.2.3 Procedure

Children completed the tasks individually in a quiet room at school; typically, this was the school library. Testing took place across two sessions, split across two days to ensure that children remained focused during each assessment. In the first session, which lasted approximately 30 minutes, children completed the WASI 2. In the second session, which lasted approximately 45 minutes, children completed the Reading and Maths subscales of the WIAT 2. All children completed both assessment within a three-week period. Children provided assent and were reminded that they could withdraw at any point. Consenting parents were sent the Social Responsiveness Scale 2 questionnaire and instructed to return the questionnaire to researchers via school. Teachers were asked to complete the School Companion Sensory Profile and the Connors 3-TS and to return both to the researchers in an envelope provided. All children received a certificate for participation in the study, and where parental consent had been given, IQ and achievement scores were shared with the school.

6.3 Results

6.3.1 Descriptive Statistics

As shown in Table 6.1, a wide range of academic ability was observed in the current sample, with achievement scores ranging from Extremely Low to High Average.

Whereas IQ (M=84.52) and reading (M=84.35) were both in the Low Average range, mean maths achievement (M=73.91) was in the Borderline range.

Table 6.1 IQ and Achievement Descriptive Statistics (N=23)

	Mean	Minimum	Maximum	Std. Deviation
FSIQ-4	84.52	66	105	10.90
Reading	84.35	57	118	17.55
Maths	73.91	46	118	17.40

The majority of children in the current study experienced substantial sensory differences, as shown in Figure 6.1. Indeed, 91% of children achieved Avoiding scores that were at least 2 standard deviations from the norm, and 73% achieved Sensitivity scores at least 2 standard deviations from the norm. Differences were also evident in Seeking (39% of children showing Seeking behaviours ‘Much More Than Others’) and Bystander (43% of children showing Bystander behaviours ‘Much More Than Others’). In terms of typical sensory processing, only 17% of children evidenced Seeking behaviours ‘Just Like the Majority’ and only 8% of children demonstrated Bystander behaviours ‘Just Like the Majority’. Likewise, only 4% of children were reported to have typical ‘Just Like the Majority’ Sensitivity and Avoiding behaviours. Sensory differences were therefore highly prevalent and severe across quadrants.

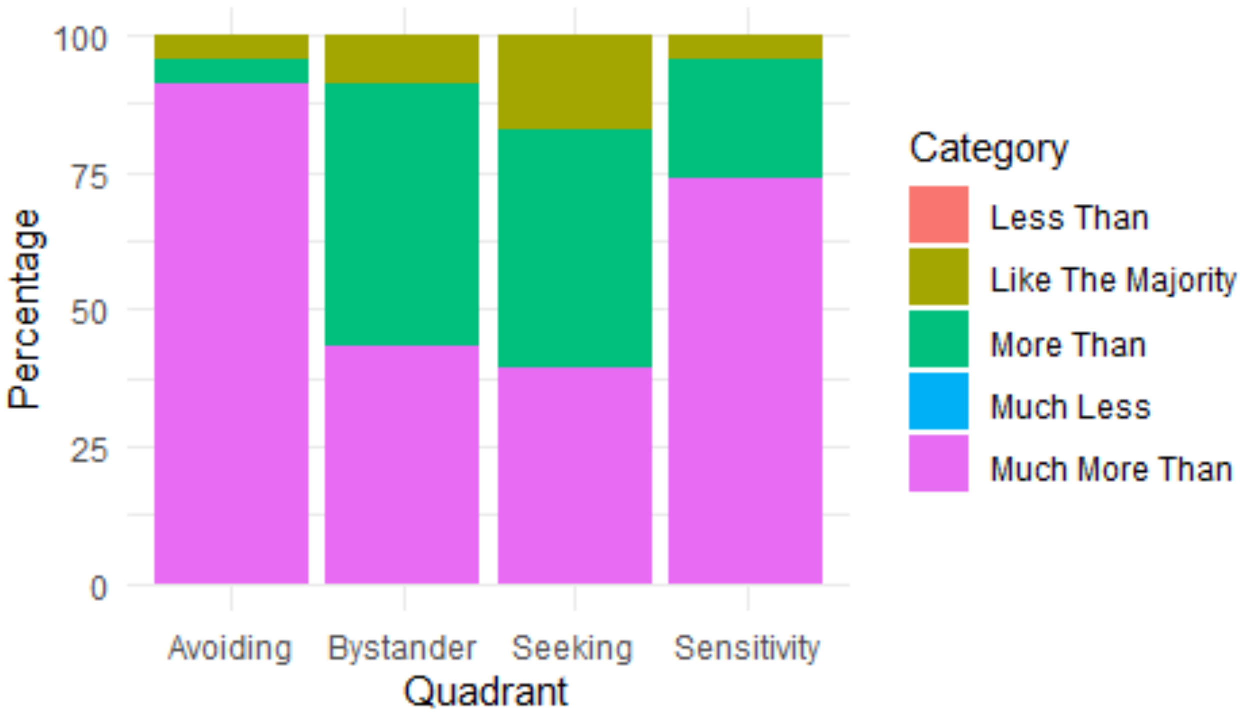


Figure 6.1 Classification of sensory differences across quadrants

This is emphasized by examining quadrant mean scores, shown in Table 6.2. Mean Seeking (M=25.57) and Bystander (M=37.39) scores fall in the 'More Than Others' range whereas mean Sensitivity (M=35.22) and Avoiding (M=36.26) fall in the Much More Than Other Range.

Table 6.2 Raw Quadrant Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Sensitivity	23	18.00	45.00	35.22	7.05
Seeking	23	10.00	37.00	25.57	6.84
Avoiding	23	18.00	51.00	36.26	8.32
Bystander	23	22.00	62.00	37.39	9.63

6.3.2 Relationship between sensory processing and academic achievement

6.3.2.1 Correlation Analyses

To test the hypothesis that greater sensory processing differences would be related to poorer academic achievement, correlation analyses were first conducted. As data were all normally distributed Pearson correlations (one-tailed) were undertaken. Although one outlier was identified through examination of boxplots, this case was retained as the standardized residuals were below three. Given the small sample size and the number of correlations conducted, to reduce the likelihood of a Type 1 error, Bonferroni correction was applied and a new alpha value of p=0.004 was adopted. Results are presented in Table 6.3. below.

As seen in Chapter 3, there was a significant and large positive relationship between IQ and reading $r(23)$=0.707, p<0.001. Although IQ was positively related to maths achievement, this relationship was not significant when adjusting for multiple comparisons, $r(23)$=0.436, p=0.038.

There was a significant positive relationship between Sensitivity scores and reading achievement $r(23)$=0.616, p=0.002. Although Sensitivity scores were also related to IQ, this relationship was not significant when adjusting for multiple comparisons $r(23)$=0.499, p=0.015. These associations are shown in Figure 6.2. There were no significant associations between any of the sensory quadrants and maths achievement (see Table 6.3).

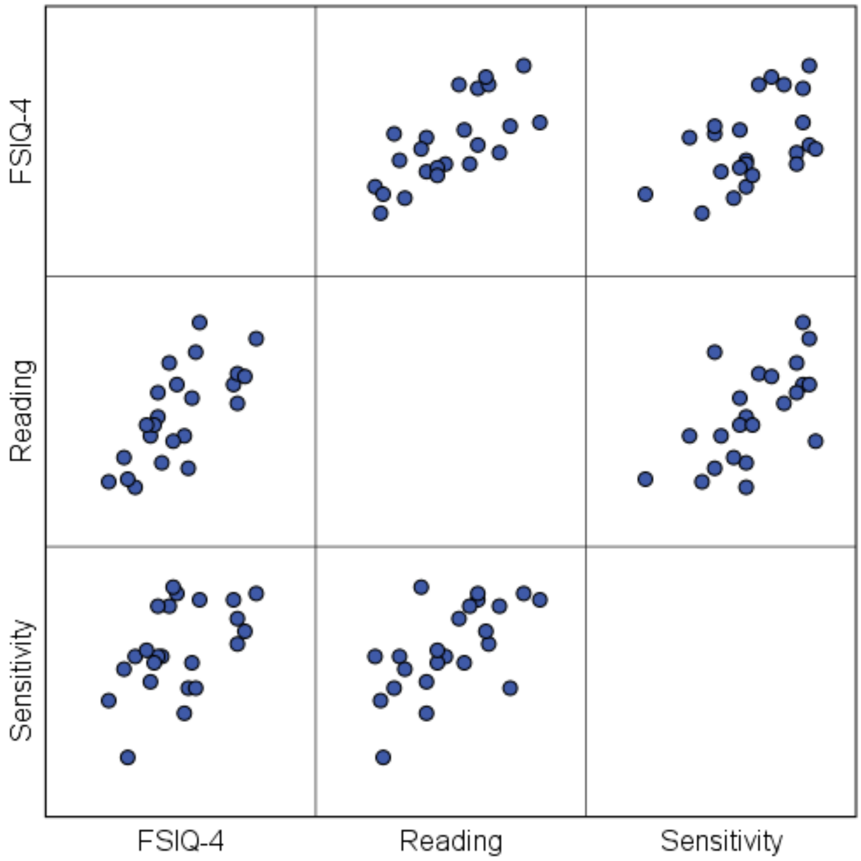


Figure 6.2 Scattergraph showing the relationship between IQ, Sensitivity and Reading

Given the findings of Butera et al. (2020) in which an interaction between Sensitivity and Avoiding explained the greatest change in variance, correlations between quadrants were next explored. Again, given the small sample size, and number of correlations undertaken, to reduce the likelihood of a Type 1 error, Bonferroni correction was applied and a new alpha value of p=0.006 was adopted. As shown in Table 6.3 there were a number of significant associations. Consequently, in line with Butera et al. (2020) data were centred, and interaction terms were created for all dependent variables where r >0.3. However, none of these interaction terms were significantly associated with Reading or Maths and were therefore not entered into the regression model.

Table 6.3 Correlations between sensory quadrants and achievement (N=23)

		FSIQ-4	Reading	Maths	Seeking	Sensitivity	Bystander	Avoiding
FSIQ-4	Pearson Correlation	1	.707*	.43	.327	.499	-.087	.004
	Sig. (2-tailed)		<0.001	.038	.128	.015	.694	.984
Reading	Pearson Correlation	.707**	1	.544*	.322	.616*	-.084	.303
	Sig. (2-tailed)	.000		.007	.135	.002	.704	.159
Maths	Pearson Correlation	.436	.544*	1	.066	.342	.028	.270
	Sig. (2-tailed)	.038	.007		.764	.110	.899	.213
Seeking	Pearson Correlation	.327	.322	.066	1	.563*	.579*	.221
	Sig. (2-tailed)	.128	.135	.764		.005	.004	.311
Sensitivity	Pearson Correlation	.499	.616*	.342	.563*	1	.068	.575*
	Sig. (2-tailed)	.015	.002	.110	.005		.757	.004
Bystander	Pearson Correlation	-.087	-.084	.028	.579*	.068	1	.275
	Sig. (2-tailed)	.694	.704	.899	.004	.757		.204
	N	23	23	23	23	23	23	23
Avoiding	Pearson Correlation	.004	.303	.270	.221	.575*	.275	1
	Sig. (2-tailed)	.984	.159	.213	.311	.004	.204	

6.3.2.2 Hierarchical Regression

Although Sensitivity and IQ were found to be significantly associated with reading achievement, to investigate if they also predicted achievement (rather than only being associated), hierarchical multiple regression was next undertaken. Hierarchical regression was conducted as opposed to multiple linear regression as it allowed for IQ to be controlled for and the unique variance accounted for by Sensitivity to be examined. Based on the strength of correlations, FSIQ-4 was entered in Stage 1 and Sensitivity in Stage 2. Although Sensitivity and FSIQ-4 remained highly correlated after centering, VIF statistics were within the acceptable range (1.322) as were tolerance statistics (0.751) (Field, 2013). Mahalanobis distances revealed no multivariate outliers and residuals indicated homoscedasticity.

Coefficients are presented in Table 6.4. At Stage 1, FSIQ-4 contributed significantly to the regression model $F(1,22)=20.961$, $p<0.001$, and explained 47.6% of the variance in reading scores (Adjusted $R^2 = 0.476$). Introducing Sensitivity scores led to a significant change in R^2, $F(1, 20)=4.516$, $p=0.046$. Taken together, IQ and Sensitivity scores contributed significantly to the regression model $F(2,20)=14.494$, $p<0.001$, and accounted for 55.1% of the variance in pupils reading scores (Adjusted $R^2= 0.551$). Sensitivity scores therefore account for an additional 7.5% of the variance in reading scores, after taking into account IQ.

Table 6.4 Hierarchical Multiple Regression Coefficients

Stage		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-11.809	21.169		-.558	.583		
	FSIQ-4	1.138	.248	.707	4.578	.000	1.000	1.000
2	(Constant)	11.244	22.395		.502	.621		
	FSIQ-4	.856	.265	.532	3.226	.004	.751	1.332
	Sensitivity	.873	.411	.350	2.125	.046	.751	1.332

In summary, the first aim of this study was to examine the relationship between sensory processing differences, as assessed through quadrant scores on the School Companion Sensory Profile, and academic achievement. A significant positive relationship between Sensitivity and reading achievement was identified, such that children with greater differences in this quadrant also had greater reading achievement scores. Hierarchal regression analyses indicated that after controlling for IQ, Sensitivity scores explained a small but significant amount of variance (7.5%) in reading achievement.

6.3.3 Relationship between sensory processing and classroom behaviour

The second aim of this study was to investigate the relationship between sensory processing quadrants and classroom behaviour. Descriptive statistics for Connor's 3-TS are presented in Table 6.5 below. On average, the greatest challenges were experienced in peer-relations, followed by hyperactivity and aggression. Indeed, the maximum T score of 90 was achieved on these scales by six children in hyperactivity, eight children in aggression and six children in peer-relations. Thus, indicating significant challenges. Executive function had the lowest mean T score (M=58.09) and also the smallest standard deviation (SD=8.34). Given so many ceiling T scores, raw scores were used for correlation and regression analysis to capture the true variability in autistic pupil's behaviour (a cut off T score of 90 suppresses this variability).

Table 6.5 Conner's Classroom Behaviour T Score Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Inattention T	21	43.00	80.00	64.05	10.07
Hyperactivity T	21	50.00	90.00	72.14	14.96
Executive Function	21	41.00	76.00	58.09	8.34
Aggression T	21	40.00	90.00	70.29	19.77
Peer Relations T	21	50.00	90.00	77.52	12.95

6.3.3.1 Correlation Analysis

To test the hypothesis that greater scores on sensory processing quadrants would be associated with more challenging classroom behaviour, correlation analyses were undertaken (one-tailed). Where data were not normally distributed Spearman correlations were conducted. Given the small sample size and the number of correlations conducted, Bonferroni correction was again applied and a new alpha value of $p = 0.003$ was adopted.

Several significant associations were identified and are shown in Table 6.6. There was a large and significant positive relationship between Bystander and Inattention $r(21)= 0.619$, $p=0.003$. There was also a large and significant positive relationship between Seeking and Hyperactivity $r(21)=0.721$, $p<0.001$. Although Seeking $r(21)=0.541$, $p=0.011$ and Sensitivity $r(21)=0.437$, $p=0.047$, were positively related to Aggression, these relationships were not significant following Bonferroni correction. Likewise, the positive relationship between Seeking and Inattention $r(21)= 0.514$, $p=0.017$, and positive relationship between Seeking and Peer-Relations $r(21)=0.\ 578$, $p=0.006$ was not significant after adjustment for multiple comparisons.

Table 6.6 Correlations between classroom behaviour and sensory processing quadrants (N=22)

		Seeking	Avoiding	Sensitivity	Bystander
Inattention	Pearson	.514	.048	-.048	.619**
	Sig. (2-tailed)	.017	.837	.837	.003
Hyperactivity	Pearson	.721**	-.148	.292	.264
	Sig. (2-tailed)	.000	.523	.199	.247
Executive Function	Spearman	.166	-.223	-.254	.366
	Sig. (2-tailed)	.472	.331	.266	.103
Aggression	Spearman	.541*	.072	.437*	.181
	Sig. (2-tailed)	.011	.756	.047	.431
Peer- Relations	Pearson	.578	.387	.345	.536
	Sig. (2-tailed)	.006	.083	.126	.012

Building on the findings of Butera et al. (2020) it was also examined if interactions between sensory quadrants were associated with classroom behaviour. As described above, data were centred, and interaction terms were created for all dependent variables where r>0.3. This led to three interaction terms being created: Sensitivity*Seeking, Bystander*Seeking and Avoiding*Sensitivity. Spearman correlations (due to data not being normally distributed) were then undertaken to examine the relationship between these interaction terms and scores on each of the Conner's domains (two-tailed). Again, to reduce the likelihood of a Type 1 error, Bonferroni correction was applied and a new alpha value of 0.007 adopted. As shown in Table 6.7 below, there was a positive relationship between Seeking*Sensitivity and Inattention $r(21)=0.433$, $p=0.050$. However, this association was not significant following adjustment for multiple comparisons. As shown in Table 6.7 there were no other significant relationships, before or after Bonferroni correction.

Table 6.7 Spearman correlations between sensory interactions and classroom behaviour (N=21)

		Seeking * Sensitivity	Bystander *Seeking	Sensitivity * Avoiding
Inattention	Correlation	0.433	0.152	0.039
	Sig. (2-tailed)	0.050	0.512	0.866
Hyperactivity	Correlation	0.310	-0.246	-0.074
	Sig. (2-tailed)	0.172	0.283	0.751
Executive Function	Correlation	0.298	0.133	-0.005
	Sig. (2-tailed)	0.190	0.564	0.982
Aggression	Correlation	0.341	0.062	0.029
	Sig. (2-tailed)	0.131	0.789	0.899
Peer- Relations	Correlation	0.120	0.102	-0.198
	Sig. (2-tailed)	0.605	0.659	0.390

6.3.3.2 Linear Regressions

To investigate if sensory quadrants were also predictive of classroom behaviours, as opposed to only being associated, two linear regressions were undertaken; one to examine if Bystander scores predicted Inattention and a second to investigate if Seeking scores predicted Hyperactivity. Bystander scores significantly predicted Inattention $F(1,20)= 11.785$, $p=0.003$ and accounted for 35% of the variance in scores (Adjusted $R^2= 0.350$). Likewise, Seeking significantly predicted Hyperactivity $F(1,20)=20.568$, $p<0.001$ and accounted for 49.5% of the variance in scores (Adjusted $R^2= 0.495$).

6.3.4 Can sensory subtypes be identified and do subtypes differ on academic achievement and classroom behaviour?

The third aim of this study was to move beyond Dunn's Sensory Processing Framework and adopt a data-driven clustering approach to examine if sensory subtypes could be identified using modality scores from the School Companion Sensory Profile 2 as clustering variables. If sensory subgroups were identified, the second aim was to explore if these subgroups differed on academic achievement and classroom behaviour. Descriptive statistics for raw sensory modality scores are first presented in Table 6.8. Mean modality scores fall at least 2 standard deviations from the norm on all modalities apart from Visual (mean score in this modality was 1SD from the norm). This further emphasises that as a group, autistic children are experiencing substantial sensory differences.

Table 6.8 Descriptive Statistics for Raw Modality Sensory Scores

	N	Min	Max	Mean	Mean Qualitative Description	SD
Auditory	23	12	32	22.09	Much More Than Others	5.66
Visual	23	11	32	22.04	More Than Others	4.86
Touch	23	6	35	22.61	Much More Than Others	6.63
Movement	23	15	38	25.13	Much More Than Others	6.86
Behaviour	23	20	48	36.48	Much More Than Others	8.67

The extent of these differences is highlighted in Figure 6.3 below. 65% of children achieved auditory scores that were 2SD greater than the norm. Likewise, 74% of children achieved Behaviour scores that were 2SD greater than the norm. Overall, descriptive statistics indicate that sensory differences are highly prevalent and often severe across modalities.

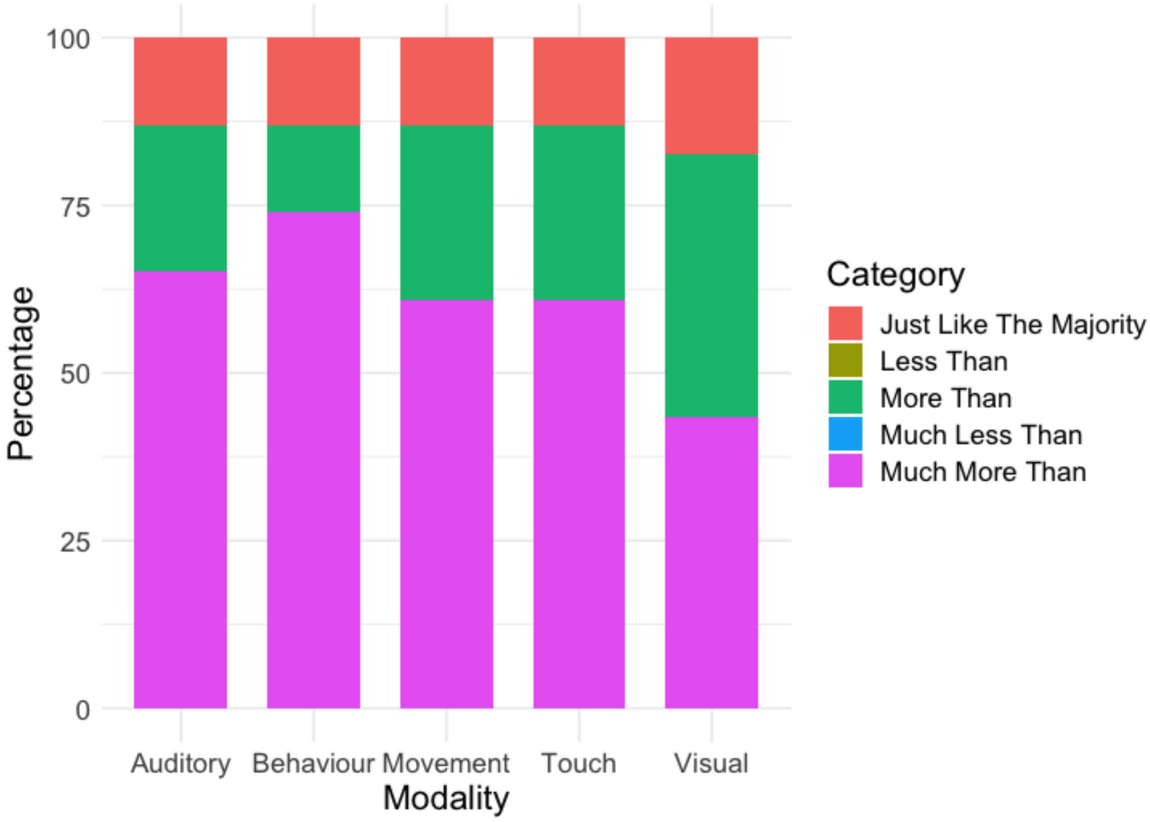


Figure 6.3 Classification of sensory differences across modalities

To examine if sensory subtypes could be identified model-based cluster analysis was undertaken. Cluster Analysis is a statistical technique that seeks to identify subtypes of individuals who behave similar to one another within a dataset (Everitt et al., 2020). Model Based cluster analysis fits a range of models to the data and uses the Bayesian Information Criterion to determine the best model. A large BIC value indicates strong evidence for the selected model. As clustering involves generating groups based on the distance between points in space, modality scores were standardized (converted to Z scores) to ensure the relative weight of each modality was equal (Everitt et al., 2011). Standardized modality scores were then entered as clustering variables in the 'McClust' package in R (Fraley et al., 2012)

Figure 6.4 presented below shows the BIC values for each model considered in the analysis. Each model is represented by a different colour line and a combination of the letters E, V, I. ‘E’ stands for equal, ‘V’ for variable and ‘I’ for coordinate axes. The first letter in each model name refers to the volume, the second to shape, and third to orientation, of clusters. For example, in the ‘EEE’ model clusters would have the same volume, shape and orientation. Figure 6.4 shows that the greatest BIC value was achieved for the EII model with a two-cluster solution (BIC= - 333.19, Log Likelihood = -147.78).

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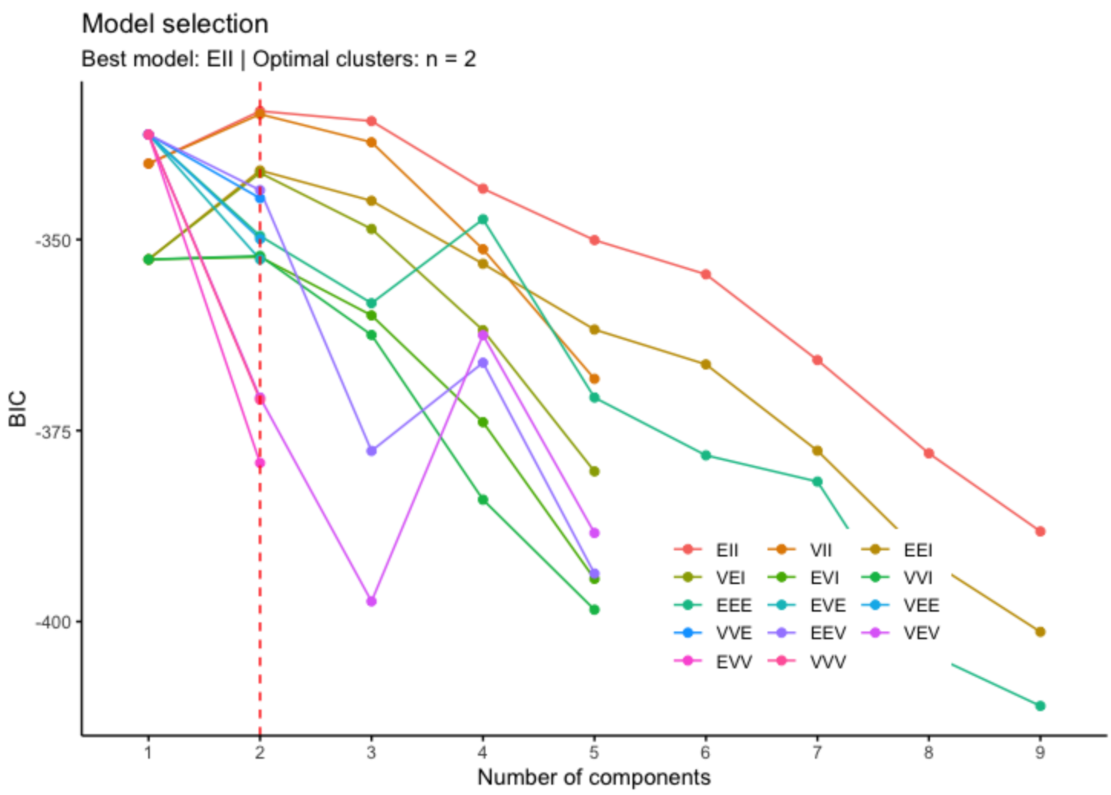


Figure 6.4 Model Selection using BIC values

Seventeen children were classified into Cluster 1 and 6 were grouped into Cluster 2. Descriptive statistics for cluster modality scores are presented in Table 6.9 below. Cluster 1 evidenced greater scores (indicative of greater differences) across all modalities compared to Cluster 2. The greatest difference between clusters was on the Behaviour modality (difference of 15 points) and smallest difference on the Movement modality (difference of 4 points). It is important to note that although sensory differences were less severe in Cluster 2 relative to Cluster 1, mean modality scores for Cluster 2 were still overall 1SD above the norm and in the 'More Than Others' range.

To investigate if differences in modality scores between clusters were significant a MANOVA was next undertaken. Results are shown in Table 6.9 below. However, caution is needed when interpreting these findings due to the small and unequal cluster sizes. It can be seen that Cluster 1 had significantly greater mean scores on all modalities apart from Movement where scores did not differ significantly between groups.

Table 6.9 Differences between clusters on sensory modalities

	Cluster	N	Mean	SD	F	p
Auditory	1	17	24.41	4.35	21.035	p<0.001
	2	6	15.50	3.15		
Visual	1	17	23.53	4.32	8.056	0.010
	2	6	17.83	3.92		
Touch	1	17	24.88	5.43	11.219	0.003
	2	6	16.17	5.64		
Movement	1	17	26.12	7.38	1.371	0.255
	2	6	22.33	4.50		
Behaviour	1	17	40.41	5.84	32.805	p<0.001
	2	6	25.33	4.46		

6.3.4.1 Do clusters differ on academic achievement?

Having identified two sensory subgroups that differed quantitively in terms of the severity of sensory differences, the next aim was to examine if clusters differed on IQ and academic achievement. Descriptive statistics and results from independent sample t-tests are shown in Table 6.10. Although Cluster 1 (M=86.53) had greater mean IQ compared to Cluster 2 (M=78.83), this difference was not significant *t*(21)= 1.531, *p*=0.141. In terms of academic achievement, reading scores were greater in Cluster 1 (M=87.71) compared to Cluster 2 (M=74.94) but this difference was not significant *t(*21)=1.598, *p*=0.125 Likewise, groups did not differ on maths achievement *t(21*)=0.469, *p*=0.644.

Table 6.10 Differences between clusters on demographics and academic achievement

	Cluster	N	Min	Max	Mean	SD	t	p
Age	1	17	6.11	11.50	9.15	1.50	1.328	0.199
	2	6	7.20	9.50	8.28	0.86		
FSIQ	1	17	70.00	105.00	86.53	10.77	1.531	0.141
	2	6	66.00	89.00	78.83	9.99		
Reading	1	17	64.00	118.00	87.71	15.77	1.598	0.125
	2	6	57.00	107.00	74.94	20.27		
Maths	1	17	49.00	118.00	74.94	15.74	0.468	0.644
	2	6	46.00	100.00	71.00	22.93		

6.3.4.2 Do clusters differ on classroom behaviour?

Clusters however did differ on some aspects of classroom behaviour, as shown in in Table 6.11. Children in Cluster 1 (M=7.31) had significantly poorer peer-relations compared to children in Cluster 2 (M= 3.80), *t*(19)=2.290, *p*=0.034. Cluster 1 (M=11.88) also had greater hyperactivity scores compared to Cluster 2 (M=7.20), with this difference approaching significance, *t*(19)=1.977, *p*=0.063. Overall, findings align with Aim 2 of this study and emphasize that greater sensory difference are associated with greater challenges in classroom behaviour.

Table 6.11 Differences between clusters on classroom behaviour

	Cluster	N	Min	Max	Mean	SD	t	p
Inattention	1	16	4	15	10.19	3.49	1.287	0.214
	2	5	2	11	7.80	4.09		
Hyperactivity	1	16	3	18	11.88	4.91	1.977	0.063
	2	5	4	11	7.20	3.27		
Executive Function	1	16	2	15	8.44	3.86	-0.298	0.769
	2	5	7	14	9.00	2.92		
Aggression	1	16	0	13	6.19	4.76	1.751	0.096
	2	5	0	7	2.20	2.95		
Peer- Relations	1	16	3	13	7.31	3.16	2.290	0.034
	2	5	1	7	3.80	2.28		

In summary, the third aim of this study was to adopt an explorative data-driven approach to examine the presence of sensory subtypes. Using School Companion Sensory Profile modality scores as clustering variables, two clusters were identified that differed quantitively in terms of the severity of sensory differences. Although Cluster 1 has significantly greater sensory differences compared to Cluster 2, it is important to note that sensory differences in Cluster 2 were still atypical. Having identified sensory subtypes, the next aim was to examine if subtypes differed on academic achievement and classroom behaviour. Whilst clusters did not differ on academic achievement, they did differ on classroom behaviour, such that the higher-sensory group exhibited poorer peer-relations and greater hyperactivity in the classroom.

6.4 Discussion

The current study sought to investigate the relationship between sensory processing differences, academic achievement, and classroom behaviour in a group of primary aged children with a diagnosis of ASD. Different from previous work, this study asked teachers, and not parents, to reflect on pupils' sensory behaviours, as the presentation and impact of sensory differences at school could be very different from that seen in the home environment (Fernández-Andrés et al., 2011; Brown & Dunn, 2010). This study also aimed to extend previous work by characterizing sensory differences first using Dunn's Quadrants and then by adopting a data-driven clustering approach using modality scores as clustering variables. Also, novel in the current study, was the use of standardized and direct assessments of reading and maths to probe academic achievement, rather than relying on teacher questionnaires, which often capture broader aspects of school performance (e.g. attendance and social networks; Butera et al., 2020).

The first aim of this study was to examine the relationship between sensory processing differences, as measured by quadrant scores on the School Companion Sensory Profile, and academic achievement. Of note is that the prevalence of sensory differences is exceptionally high in the current sample, supporting the suggestion that sensory differences are a central feature of the autism phenotype (Ben-Sasson et al., 2019; Grapel, Cicchetti & Volkmar, 2015). Differences were most prevalent for the quadrants corresponding to hypersensitivity, with 91% of children exhibiting Avoiding behaviours 'Much More Than Others' and 74% displaying Sensitivity behaviours 'Much More Than Others'. Importantly, hyposensitivity was also prevalent, with 40% of children demonstrating 'Seeking' behaviours 'Much More Than Others' and 43% displaying Bystander behaviours 'Much More Than Others'. This is in line with the findings of Kientz and Dunn (1997) who found autistic children deviated from neurotypical children on Sensory Profile items reflecting both hypersensitivity and hyposensitivity. Overall, a single pattern of sensory processing does not appear to be characteristic of ASD (Ben-Sasson et al., 2019; Lane et al., 2014; Ausderau et al., 2014).

It was hypothesized that these sensory differences would be significantly associated with academic achievement and would explain a significant amount of variance in pupil's performance. A significant positive relationship between Sensitivity and reading achievement was identified, such that children with greater differences in this quadrant had greater reading achievement scores. Moreover, after controlling for IQ, Sensitivity scores were found to explain a small but significant amount of variance (7.5%) in autistic pupils' reading achievement. This stands in complete contrast to Ashburner, Ziviani & Rodger (2008), who found that sensory processing differences, as reported by caregivers, were negatively associated with autistic pupils' school performance. Specifically, under-responsiveness and seeks sensation scores accounted for 47% of the variance in autistic pupil's achievement scores. Likewise, an interaction between Sensitivity and Avoiding predicted poorer school performance in the study of Butera et al. (2020).

Previous work has indicated that sensory differences tend to be elevated in the classroom relative to the home environment (Fernández-Andrés et al., 2015). In line with the Nordic Relational Model of Disability, one explanation for this difference is that the school environment is perhaps more incompatible with children's sensory needs relative to the home environment (Goodley & Runswick-Cole, 2012). As such, a child with hypersensitivity may become distressed and experience disability when placed in a busy, loud classroom but not in a quiet space at home (Goodley & Runswick-Cole, 2012). Consequently, one may have predicted sensory differences to be negatively associated with academic achievement, and that the size of this association would possibly be greater when asking teachers and not parents to reflect on children's sensory behaviours. However, different from Ashburner, Ziviani and Rodger (2008) and Butera et al. (2020) children in the current study attended special schools, not mainstream schools. Whilst findings from Chapter 4 of this thesis highlight that sensory challenges, such as fire alarms and transitioning through corridors, are similar across provisions, special schools were seen by parents and teachers to be better equipped to support these challenges (Jones et al., 2020). Indeed, tools such as multisensory rooms, OT equipment, and 1:1 provision were perceived to be much more readily available in special schools relative to mainstream provision. Consequently, teachers in the current study may have been better able to access these resources to support the sensory needs of pupils and reduce potential impacts on academic achievement.

This, however, does not explain why Sensitivity was *positively* related to reading achievement. According to Dunn's Sensory Framework, 'Sensors' (hypersensitivity and passive response) are theorized to have a high level of awareness and attention to detail, although they can appear distractible or hyperactive (Dunn, 2014). It is possible that a high level of awareness and attention to detail supported the positive association with reading in the current study. The association between hypersensitivity and attention to detail has previously been documented by Liss et al. (2006). In this study, the caregivers of 144 autistic children were asked to complete an extended version of the Sensory Profile, the Vineland Adaptive

Behaviour Scale, and were also asked to report on over selective attention and exceptional memory. Using cluster-analysis, a subgroup compromising 10% of the sample was identified, which was characterized by hypersensitivity, exceptional memory, and over-focused attention. The authors suggested that over-focus and perseverative behaviours may be a way in which individuals could manage hypersensitivity by limiting sensory inputs into a narrow, controllable scope (Liss et al., 2006). Such an approach could be beneficial for learning and may explain why Sensitivity was associated with achievement in the current study. Future research is therefore needed to probe the relationship between attention and sensory quadrants.

Moving from a cognitive explanation to a more perceptual account, the positive relationship between Sensitivity and reading achievement could also be explained in terms of perceptual capacity and load theory (Lavie et al., 2004, Remington et al., 2009). Perceptual capacity refers to the amount of information an individual can process at any given time (Lavie, 2005, 2010). For tasks containing a great deal of information (high perceptual load), successful completion requires an individual allocating all of their perceptual capacity to the task. However, this is not needed for a task containing little information (low perceptual load), meaning an individual has spare perceptual capacity to process other task-irrelevant information (Lavie, 2005, 2010; Lavie et al., 2004). There is some suggestion that autistic individuals have enhanced perceptual capacity compared to neurotypical individuals (Remington et al., 2009; 2012; Remington & Fairnie, 2017). Under conditions of high load, this enhanced capacity is thought to improve task performance as it allows for a greater amount of task-relevant information to be processed. However, when capacity is not met, such as under conditions of low perceptual load, autistic individuals may begin processing task-irrelevant information resulting in distraction (Remington et al., 2009; 2012). Critically, Brinkert and Remington (2020) recently demonstrated that increased perceptual capacity was associated with sensory hypersensitivity in a large group of autistic and neurotypical adults. In this study, individuals were asked to complete a primary auditory search task and a secondary detection task, in which perceptual load was manipulated across trials by increasing set sizes from one sound up to six. Individuals with higher self-reported levels of hypersensitivity were able to complete the detection task, not at the detriment of the primary task, even at the higher set sizes. Thus, suggestive of enhanced perceptual capacity (Brinket & Remington, 2020).

In the classroom, increased perceptual capacity may be beneficial for learning, as it would allow for more task-relevant information to be processed, whilst also increasing susceptibility to distraction- especially under conditions of low perceptual load (Remington et al., 2019). Behaviourally, this seems very similar to the description of 'Sensitivity' outlined in Dunn's Framework' in which 'Sensors' are theorized to have a high level of awareness and attention to detail, although can appear distractible or hyperactive (Dunn, 2014). Supporting this description was the finding that Sensitivity also predicted greater inattention and aggression in the classroom. Therefore, although caution is needed due to the small amount of variance accounted for, and the lack of a neurotypical comparison group, a second potential explanation for the positive relationship between Sensitivity and reading is that children with higher Sensitivity scores can process more task-relevant information under conditions of a high perceptual load to the benefit of learning.

However, under conditions of low perceptual load, they may become more susceptible to distraction and exhibit behaviours such as inattention and aggression in the classroom. Future research is therefore needed to investigate the relationship between patterns of sensory processing, perceptual capacity, and academic achievement. Critically, perceptual capacity needs to be assessed in a more ecologically valid environment (Remington et al., 2019). For instance, in a classroom with varying levels of visual stimulation rather than in a controlled lab with low-level stimuli, which arguably only taps into basic perceptual and cognitive processes.

Lastly, the third way that Sensitivity may have promoted reading achievement is through disruptive classroom behaviours. Whilst externalizing behaviours such as aggression are largely associated with poorer academic achievement, disruptive behaviours at times can also promote learning (Finn, Pannozzo & Voelkl, 1995; Tymms & Merrell. 2011). For Sensors, who typically don't respond actively to hypersensitivity, disruptive behaviour such as aggression could alert the teacher quickly to a problem, enabling them to receive support and get back on task (Dunn, 2014; Finn, Pannozzo & Voelkl, 1995). Indeed, Segal-Andrews (1994) found disruptive behaviours, especially by students who usually have positive relationships with peers and staff, often resulted in constructive teacher responses that promoted learning such as being asked to read aloud, putting work on the board or being asked to answer questions more frequently. This constructive approach might be more evident in terms of reading achievement, compared to maths, as reading skills are often required across subjects. Also supporting this explanation is work from the ADHD literature (Tymms & Merrell, 2011; Pham, 2016). A study by Tymms and Merrell (2011) examined the relationship between reading and maths attainment and teachers' ratings of ADHD-related behaviours in a sample of 12,251 children at the end of their first year at school. Whereas inattention was strongly related to underachievement, impulsivity, particularly 'Blurting Out Answers' promoted reading and maths attainment (Tymms & Merrell, 2011). Overall, findings from Aim 1 of this study seem to suggest that under particular conditions, sensory differences, perhaps through cognitive, perceptual, or behavioural mechanisms, can promote reading achievement.

While findings from Aim 1 illustrate some positive aspects of sensory differences, results from Aim 2 emphasize that sensory differences are overall associated with more challenging school behaviours and experiences. Indeed, the second aim of this study was to examine the relationship between sensory processing differences, as assessed through quadrant scores, and classroom behaviour. Sensory differences, particularly seeking, were found to predict a range of challenges in the classroom, including inattention, hyperactivity, and poorer peer-relations. Although Dunn's Framework associates seeking with hyposensitivity, seeking can also reflect hypersensitivity as children may seek out predictable, controllable input as a means by which to control their environment and manage their hypersensitivities (Dunn, 2014; Boyd et al., 2009). Highlighting this are findings from Chapter 5 of this thesis in which late-diagnosed autistic women reflected on trying to increase vestibular input (examples include climbing trees and swinging on the chair) in an attempt to self-regulate and manage hypersensitivities in school. The association of seeking with both hypersensitivity and hyposensitivity could explain why this pattern in particular is associated with a wider range of behavioural challenges in the classroom.

Nevertheless, some caution is needed with this interpretation. As teachers completed the School Companion Sensory Profile and the Conner's questionnaire, the strong association between sensory differences and classroom behaviour could in part be due to shared variance across questionnaires. Moreover, the School Companion Sensory Profile contains items that could reflect similar behavioural/attentional challenges that are captured in the Conner's Questionnaire. Even so, findings are in line with qualitative work presented in Chapters 4 and 5 whereby sensory differences are reported to cause high levels of distraction, anxiety, and social difficulties in the classroom (Humphreys & Lewis, 2008; Howe & Stagg, 2016).

The third aim of this study was to examine if sensory subtypes could be identified using modality scores as clustering variables. If sensory subtypes were identified, the final aim was to investigate if sensory subtypes differed on academic achievement and classroom behaviour. Given the exploratory nature of this aim, there were no specific hypotheses in terms of the number of subtypes that would emerge, or if subtypes would differ on academic achievement and classroom behaviour. Two sensory subtypes were identified that differed quantitatively in terms of the severity of sensory differences. Although Cluster 1 had mean modality scores that were greater than Cluster 2, children in Cluster 2 still evidenced substantial sensory differences. This differs from the findings of DeBoth and Reynolds (2017) who reviewed eight subtyping studies and concluded that there appears to be a subtype characterized by typical sensory processing, and a second characterized by global differences. There exists, however, substantial disagreement on how to best to describe the responses seen in other children (DeBoth and Reynolds, 2017). One explanation for the absence of these subtypes in the current study is that the sample was too small and underpowered for qualitative variation to be identified (Everitt et al., 2011). In a sample of 23, if only one child differed on a particular dimension, the algorithm would have added this child to the nearest cluster in mathematical space. However, in a sample of 230, if 10 children differed on a particular dimension, a new cluster consisting of only these children, may have been identified (Everitt et al., 2011). Caution is therefore needed when interpreting findings from Aim 3 of this study. It should also be noted that because of the small sample size, Bonferroni adjustment has been used throughout this chapter and that this is very conservative statistical approach. Despite this, findings do support results from Aim 2 of this study and highlight that sensory processing differences, as characterized by both quadrant and modality scores, are associated with a range of behavioural challenges in the classroom. Future research, with a much larger sample, is needed, however, to examine the relation between sensory subtypes and educational outcomes.

Limitations of this study include only asking teachers to report on sensory differences. Consequently, this study can only explore how observable sensory differences impact on academic achievement and classroom behaviour. Future studies should, therefore, adopt a multi-informant approach and ask pupils, alongside teachers, to reflect on sensory differences to gain a more holistic understanding of effects on achievement (Piller & Pfeiffer, 2016). Likewise, this study only included children in special schools and therefore findings can’t be generalized to mainstream schools because as discussed, the sensory environment and available support are likely to differ substantially across provisions. Future studies could also therefore directly compare the impact of sensory differences on academic achievement across school provisions.

In conclusion, the current study sought to examine how sensory processing differences related to academic achievement and classroom behaviour in a group of primary aged children with a diagnosis of ASD. Although sensory differences (as assessed through quadrant scores and modality-based clusters) were associated with a range of behavioural challenges in the classroom, hypersensitivity with a passive behavioural response (Sensitivity) was positively related to reading achievement and accounted for a small but significant amount of variance in scores, after controlling for IQ. Findings seem to support the Nordic Relational Model of Disability and could suggest that when the environment is compatible with children's sensory needs, patterns of sensory Sensitivity, can promote learning (Goodley & Runswick-Cole, 2012). The mechanism underlying this relationship may include cognitive factors such as attention and coping strategies, perceptual factors such as enhanced perceptual capacity, or indeed behavioural factors including impulsivity. However, when sensory needs are not met, these differences can also result in a range of behavioural challenges in the classroom, that over time, may result in negative school experiences and outcomes.

Chapter 7: How does the classroom sensory environment impact on-task behaviour?

7.1 Introduction

As emphasized throughout this thesis, a typical classroom in the UK is a loud, colourful, and stimulating place, with often upwards of twenty children playing and learning alongside one another. To learn and stay on-task in this environment, children must select information that is relevant for the task at hand while also inhibiting that which is irrelevant (Erickson et al., 2015; Oakes, Kannass & Shaddy, 2002). For example, a child might need to listen to the teacher's instructions whilst also ignoring the sound of children playing in the corridor. As discussed in Chapter 2, the ability to do this, and maintain this state for some time, is referred to as selective sustained attention (Ruff & Rothbart, 2001; Oakes, Kannass & Saddy, 2002). Selective sustained attention improves with age, such that older children are better able to filter out irrelevant distractors and exert voluntary attentional control for longer (Gaspelin, Margett-Jordan & Ruthruff 2015). Across all ages, however, better learning outcomes are generally achieved the longer an individual can stay on-task and filter out irrelevant distractors (Carrol's time on-task hypothesis, 1963, as outlined in Chapter 2).

One of the first studies to comprehensively examine the ability of neurotypical children to stay on-task in the classroom was conducted by Godwin et al. (2016) in the USA. In this study, researchers aimed to examine the prevalence and nature of children's off-task behaviour, and to understand if this changed as a function of academic level (school year group), time of year, and instructional format. To this end, children from 22 classes, ranging from kindergarten (5.5 years old) up to fourth grade (10 years old), were observed in one-hour sessions at the beginning, middle, and end of the school year. During these sessions, each child was observed in turn in 20-second intervals, and coders used eye-gaze and contextual cues to determine if the child was on- or off-task. Children were deemed to be on-task if they were looking at the teacher, the instructional activity, or relevant instructional materials. It should be emphasized that children were not expected to be looking at their teacher or instructional material 100% of the time. For instance, a child might look away when thinking about cognitively demanding tasks; a response known to be beneficial for learning (gaze aversion; Doherty-Sneddon, 2012). However, this looking away can become detrimental to academic progress when it turns into distraction and prolonged off-task behaviour. It was such instances of off-task behaviour that Godwin et al. (2016) sought to capture such that children were deemed to be off-task when they evidenced Self-Distraction, Peer-Distraction, Environmental Distraction, Walking, or Other.

When using this classification scheme, children were reported to spend on average 30% of instructional time off-task (Godwin et al., 2016). However, this varied as a function of time and age, such that children were significantly more likely to be on-task at the beginning of the school year compared to the end of the school year. Third graders (between 7-8 years) also spent significantly less time on-task relative to fourth graders (between 8-9 years). In addition, it was found that certain types of off-task behaviour were more prevalent than others such that Peer Distraction (44.12%), Environmental Distraction (24.74%) and Self-Distraction (15.91%) together accounted for 85% of all children's off-task behaviour. Again however, the prevalence of these behaviours also varied across instructional format and time of year. In terms of instructional format, Peer-Distraction peaked during independent work, whereas Self and Environmental Distraction peaked during whole-group instruction. Likewise, whereas Peer Distraction peaked during the middle of the school year, Self-Distraction and Environmental Distraction increased over time, peaking at the end of the school year (Godwin et al., 2016). This pattern is perhaps counter to expectations as it suggests rather than habituating to the classroom environment, children become increasingly susceptible to environmental distraction across the school year (Godwin et al., 2016; Imuta & Scarf, 2014).

This is of particular concern as recent findings by Moffett and Morrison (2020) suggest that environmental distraction can have a significant impact on children's academic achievement. In this study, 172 kindergarten children (M=5.76 years) were observed during one school day, across a variety of lessons, to examine how different types of off-task behaviour related to educational outcomes. Different from Godwin et al. (2016), whereby children were observed only in 20-second intervals, children in this study were observed continuously, for an average of 3 hours. This was achieved by placing two video cameras inside in each classroom. Coders then used this footage to determine if a child was on- or off-task, before identifying the source of off-task behaviour. Off-task behaviours were similar to those captured in Godwin et al. (2016) and included, Other activity (*engaged in another activity such organizing a pencil case*); Nonengaged (similar to Environmental Distraction in Godwin et al., 2016-*Looking around the room at other children, or some other part of one's desk*); Interacting with a peer (*Talking or playing with a peer when not instructed to*); Other (*None of the above three categories*). To assess how these off-task behaviours related to academic outcomes, children were also asked to complete the Letter-Word Identification and Applied Problems scales of Woodcock-Johnson III achievement assessment. Critically, not all types of off-task behaviour were found to be detrimental to learning. Indeed, whereas time spent 'Interacting with a peer' positively related to achievement, time spent 'non-engaged' predicted significantly fewer gains in reading comprehension (Moffett & Morrison, 2020). Taken together, the work of Godwin et al. (2016) and Moffett and Morrison (2020) emphasize that children can become increasingly susceptible to environmental distraction over the school year and that this can have a significant impact on academic progress. An important first step in reducing these potential impacts is to identity the factors that contribute to high levels of off-task behaviour in the classroom. These findings can then in turn allow for evidenced-based modifications and support to be implemented.

Whilst instructional format and time of year have been identified as factors that influence the prevalence of off-task behaviour, one factor that has been largely overlooked is the role of the classroom sensory environment (Godwin et al., 2016; Moffett & Morrison, 2020; Godwin, Erickson & Newman, 2019). As emphasized throughout this thesis, classrooms offer a large variety of potential sensory experiences. For instance, when sat in an art lesson a child might notice the colourful visual displays on the wall, or the noise of children babbling outside, or the smell and colour of different paints. Findings from Chapters 4 and 5 indicate that sensory inputs can have a significant impact on children's learning and behaviour (Jones, Hanley & Riby, 2020). Certain types of sensory inputs were however, reported to be more impactful on behaviour than others. Indeed, teachers ranked auditory experiences to be the most disruptive for learning, followed by visual and tactile input (Jones, Hanley & Riby, 2020). Qualitative insights indicated however, that the majority of negative tactile experiences occurred outside of the classroom e.g., unexpected touch by peers in the corridor or sitting next to peers in assembly, whereas auditory and visual stimuli caused distraction and off-task behaviour inside the classroom. Consequently, although there is a need to manage tactile experiences in school this study will focus only on how aspects of the visual and auditory classroom environment impact children's off-task behaviour.

7.1.1 Visual stimulation in the classroom

The work of Barrett et al. (2015) highlights that the amount of visual stimulation in the classroom is an important factor to consider when thinking about children's learning. This study aimed to investigate how aspects of the classroom physical environment impacted children's academic progress over one academic year. To this end, 153 classrooms across 27 schools in the UK were surveyed for evidence of Naturalness (Light, Temperature and Air Quality), Stimulation (Complexity and Colour), and Individualization (Ownership and Flexibility). Academic progress was then assessed by comparing pupils National Curriculum levels in Reading, Writing and Maths at the beginning and end of the academic year. Each national curriculum level has three sublevels and on average pupils are expected to progress two sublevels per year. National curriculum levels were converted to points and totalled to produce an overall progress score. It was found that 16% of the variability in children's overall progress scores was accounted for by seven design features, including light, temperature, air quality, ownership, flexibility, colour, and complexity. It should be emphasized, that while the total amount of variance accounted for may initially seem small, in terms of national curriculum levels, this equates to a difference of 1.34 sublevels between the most and least effectively designed classrooms (Barrett et al., 2015). This, therefore, emphasizes that the classroom physical environment has the potential to have a substantial impact on academic progress (Godwin, Erickson & Newman, 2019). In terms of the relative importance of each design parameter, Naturalness explained 49% of the effect on the overall progress model, Individualization accounted for 28% and Stimulation 23%. Notably however, the relationship between complexity, defined as "*the degree to which the classroom provides appropriate visual diversity*" (Barrett et al., 2015; 122) and academic progress was curvilinear. Thus, suggesting that there is an optimal amount of visual stimulation in the classroom, with both too little and too much stimulation negatively impacting children's progress (Barrett et al., 2015).

Emphasizing that too much visual stimulation can adversely affect children's learning and behaviour is the work of Fisher, Godwin, and Seltman (2014). In this study, a teacher read stories for 5-7 minutes in a lab classroom to children (N=24, Mean Age=5.37 years) in two experimental conditions: decorated and sparse. In the sparse condition, lessons took place in a room with minimal displays and colour whereas, in the decorated conditions, walls were covered with highly stimulating displays. Children were video-recorded in each condition and their on/off-task behaviour coded using an event-based coding methodology. Similar to Godwin et al. (2016) off-task behaviour was classified into one of the following four mutually exclusive categories; Self-Distraction, Peer Distraction, Environmental Distraction, Other. To assess learning, children were also asked to complete workbooks at the end of each lesson in each condition. Foremost, it was found that children spent 10% more time off-task in the decorative condition relative to the sparse. It was also found that the types of off-task behaviours evidenced by children differed between conditions such that children were significantly more engaged in Self-Distraction and Peer Distraction in the sparse condition and significantly more engaged in Environmental Distraction in the decorated condition. Moreover, a mediation analysis demonstrated that more off-task behaviour in the decorated condition was associated with poorer learning outcomes compared to the sparse condition (Fisher, Godwin & Seltman, 2014). Whilst these findings emphasize that visual stimulation is an important source of variability in off-task behaviour and academic achievement, it needs to be highlighted that 15% of pupils did not show a difference in distraction between classroom conditions (Fisher, Godwin & Setlman, 2014). Thus, indicating that even within typical development there is heterogeneity in susceptibility to distraction. Recognizing heterogeneity and individual differences is important when considering that there is often upwards of twenty children in a typical classroom. As such, there is a need to build on the work of Fisher, Godwin and Seltman (2014) and consider how individual differences affect children's ability to stay on-task in rich visual environments that are typical of primary school classroom in the UK. Importantly, this approach could allow children who are at increased risk of off-task behaviour to be identified, and for early tailored support to implemented.

There is also a need to recognize that the classroom is becoming an increasingly neurodiverse space, meaning that there is also a need to consider how the classroom visual environment impacts the ability of neurodiverse pupils to stay on-task (Wood, 2019). The current study however will focus specifically on children with diagnosis of ASD as this group are known to have attentional preferences and difficulties which could make then especially susceptible to the effects of the environment (Guillion et al., 2014; Ames & Fletcher, 2010). Namely, rather than prioritizing social information such as eyes as faces (as seen in typical development), there is a tendency for autistic individuals to prioritize non-social information such as objects and backgrounds for attention (Riby & Hancock, 2009; McPartland et al., 2011; Birmingham, Bischof & Kingstone, 2008). As emphasized previously, it is not the assumption that children should be looking at their teacher or instructional material 100% of the time. However, this attentional profile may result in autistic children being less likely to direct their attention towards their teacher or classmates, and instead towards non-social features of the classroom environment (Hanley et al., 2017). In addition to these attention atypicalities, sensory processing differences may also have the potential to increase the prevalence of off-task behaviours in the classroom (Ashburner, Ziviani & Rodger, 2008; Butera et al., 2020). Indeed, parents and teachers in Chapter 4 of this thesis reported that autistic children experiencing sensory differences would often become distressed and distracted by input such as unpredictable noises, fluorescent lights, and colourful walls displays (Jones, Hanley & Riby, 2020). Likewise, it was found in Chapter 6 that children with greater levels of sensory seeking behaviours also demonstrated greater hyperactivity, inattention, and poorer peer-relations in the classroom. Moreover, there is some suggestion that it is in multisensory environments such as the classroom, where children have to integrate and process information from multiple sensory streams, that sensory differences become most apparent and challenging for children with autism (Smith

& Sharp, 2013; Marco et al., 2011). Therefore, these attentional and sensory differences may make autistic children especially susceptible to environmental distraction and off-task behaviour in the classroom (Ashburner et al., 2008; Hanley et al., 2017).

To test this hypothesis, Hanley et al. (2017) used eye-tracking to record the eye-movements (as a measure of attention allocation) of autistic and neurotypical children whilst they watched videos of a teacher delivering a 5-minute lesson on Irish myths and legends on the computer screen. Similar to Fisher, Godwin and Seltman (2014), the background of these videos was manipulated to be completely sparse or to include lots of educational visual displays. To assess learning, children were also asked to complete worksheets at the end of each lesson. Although visual displays impacted attention for all children, this effect was particularly pronounced for autistic children, such that this group spent more time looking at the background as opposed to the teacher. Furthermore, in terms of learning, the strongest predictor of achievement was the proportion of time spent looking at the background, alongside verbal ability, and social ability (as assessed through the Social Responsiveness Scale). Taken together, findings seem to indicate that although autistic children are more susceptible to visual distraction, attending to displays at the expense of attending to the teacher can impact both autistic and neurotypical children, and their ability to learn in classroom tasks (Hanley et al., 2017). The classroom however is a multi-sensory space such that in addition to inhibiting irrelevant visual information, to stay on-task, children must also filter out irrelevant auditory information (Godwin, Erickson & Newman, 2019). Consequently, there is a need to build on the work of Hanley et al. (2017) and also consider how auditory and audio-visual information affect the ability of autistic and neurotypical children to stay on-task in the classroom (Godwin, Erickson & Newman, 2019).

7.1.2 Auditory stimulation in the classroom

For neurotypical children, how, and the extent to which, noise generated from inside the classroom affects behaviour, seems to depend on the type of noise and the task undertaken (Klatte, Bergstrom & Lachmann, 2013; Clark & Paunovic, 2018). This was evidenced by Dockrell and Shield (2006) who examined how different types of classroom noise affected the ability of children between the ages of 7 and 8 to complete verbal (Reading Literacy and Spelling) and non-verbal (Speed of Processing and Arithmetic) tasks. Children were allocated to one of three noise conditions: Base (typical quiet classroom conditions), Babble (the noise of children babbling), and Babble Plus Environmental (the noise of children babbling plus intermittent environmental noise such lorries). Stimuli were played at 65dB(A) as previous work had indicated this to be the average noise level when children were working individually (Shield & Dockrell, 2004). For verbal tasks, children achieved the greatest scores in the Babble Plus Environmental condition and lowest scores in the Babble condition. However, for non-verbal tasks children achieved the greatest scores in the Base condition and the lowest scores in the Babble Plus Environmental condition. The authors propose that poorer performance on the verbal tasks in the Babble condition could be due to speech disrupting working memory processes by competing with target verbal material (Dockrell & Shield, 2006). Conversely, it was suggested that greater performance on verbal tasks in the Babble Plus Environmental condition could be due to this noise encouraging "*children to actively focus on the task*" (Dockrell & Shield, 2006;

23). However, to the author’s knowledge, how audio and audio-visual stimulation affects the ability of neurotypical children to stay on-task has yet to be explored.

Likewise, there has been little research into how audio and audio-visual stimulation affect the ability of autistic children to stay on-task. Yet qualitative and quantitative insights suggest that autistic children may be particularly vulnerable to the effects of noise inside the classroom (Robertson & Simmons, 2015; Ashburner et al., 2013; Ashburner, Ziviani & Rodger, 2008). Emphasizing this are the findings from Chapters 4 and 5 of this thesis in which parents, teachers and autistic adults reported classroom noise to be a considerable source of distraction and distress for autistic children (Jones, Hanley & Riby, 2020). Indeed, although loud and unpredictable sounds such as fire-alarms were reported to be the most distracting and disruptive for learning, lower-intensity noise such as the sound of pen on a white-board were also reported to be distracting (Jones, Hanley & Riby, 2020). Experimental work by Keith, Jamieson and Bennetto (2019) also indicates that classroom noises may be especially stressful for autistic children. In this study, the relationship between classroom noise, task complexity and autonomic arousal was examined in a group of autistic and neurotypical adolescents between the ages of 12 and 17 years old. Participants were asked to complete a forward digit span (simple cognitive task) and backward digit span task (more complex cognitive task) in both a quiet and classroom noise condition, while measures of sympathetic reactivity were recorded. While both groups achieved greater scores on forward-digit span in noise and poorer performance on backward digit-span in noise, groups differed substantially in terms of sympathetic reactivity. That is, when completing the more demanding cognitive task in noise, autistic adolescents demonstrated continuous increases in heart rate, which was at the detriment to task performance (Keith, Jamieson & Bennetto, 2019). Although this suggests that auditory input can be especially stressful for autistic children, it is important to note that not all children evidenced this effect. This, therefore, emphasizes once again the need to take an individual differences approach when investigating how the classroom sensory environment affects the ability of autistic and neurotypical children to stay on-task. Specifically, findings from this thesis indicate that sensory processing differences may be an important factor to consider.

7.1.3 *Current Study*

In summary, previous work suggests that the classroom sensory environment is an important factor to consider when thinking about children's off-task behaviour. Although there is evidence that visual and auditory input can impact pupil's behaviours, to date, research in these areas has often been siloed (Godwin, Erickson & Newman, 2019). That is, researchers have tended to focus on only the visual domain or only the auditory domain and neglected that the classroom is a rich multi-sensory space (Godwin, Erickson & Newman, 2019). There is a need therefore to conduct a holistic systematic investigation and consider the impact of both inputs, first separately and then together in a multi-sensory environment. Likewise, much of the literature has focused on the ability of neurotypical children to stay on-task and neglected that autistic children may be especially susceptible to off-task behaviour (Hanley et al., 2017). As such, there is also a need to probe if the prevalence and nature of off-task behaviours differ between autistic and neurotypical children.

The current study therefore developed a novel paradigm to investigate how aspects of the classroom sensory environment affect the ability of neurotypical and autistic children to stay on-task. Building on the work of Fisher, Godwin and Seltman (2014) and Hanley et al. (2017), children were asked to individually complete a reading task for 8 minutes in a bespoke pop-up classroom under four different environmental conditions; Baseline, Audio, Visual and Audio-visual. Two small cameras were placed inside the pop-up classroom to allow for children's behaviour to be continuously recorded and instances of on-task, off-task and supported engagement behaviours to be observed. The inclusion of supported engagement as a behaviour category aimed to represent classroom scenarios whereby a child was required to work independently but still might ask for help or a teacher might need to intervene after a prolonged period off-task. Once a child was deemed to be off-task, coders then classified the type of off-task behaviour as either Environmental Distraction, Self-Distraction, Gross Motor Distraction, Fine Motor Distraction and Experimenter Distraction. To investigate how individual differences might influence the ability to stay on-task, parents were asked to complete the Conners questionnaire (Conners, 2008; as a measure of children's inattention and hyperactivity), teachers were asked to complete the Sensory Profile School Companion (Dunn, 2014; to capture sensory processing differences), and children completed the WASI 2 (Wechsler, 2011; as a measure of estimated intelligence).

The first aim of this study was to examine if the percentage of time children spent off-task differed between sensory conditions (Baseline, Auditory, Visual and Audio-visual). Specifically, it was hypothesized that both groups would evidence the least amount of off-task behaviour in the Baseline condition relative to the three other conditions. However, predictions regarding off-task behaviour in the other conditions cannot be made as this is the first study, to the author's knowledge, to manipulate sensory environments in this manner (e.g., compare off-task behaviour in Visual, Audio and Audio-visual condition). Given the aforementioned attentional and sensory differences, it was also hypothesized that overall, autistic children would spend a significantly greater percentage of time off-task relative to neurotypical children.

The second aim of this study was to investigate if the types of off-task behaviour differed between sensory conditions and diagnostic groups. Five different types of off-task behaviour were coded; Environmental; Self-Distraction, Motor-Gross, Motor-Fine, and Experimenter Task-Irrelevant Engagement. Autistic children were predicted to spend a significantly greater percentage of time engaging in Environmental off-task behaviours relative to neurotypical children. Children in both groups however were predicted to evidence significantly more Environmental off-task behaviour in the Visual and Audio-visual condition relative to Baseline.

The final aim was to investigate if individual differences in cognitive, sensory, and attentional abilities predicted the percentage of time children spent on-task and in supported engagement. Due to Covid-19 and subsequent school closures, it was not possible to collect Conners questionnaire from the parents of autistic children. However, all other testing was complete prior to these school closures. Individual difference analyses were therefore undertaken for neurotypical and autistic children separately. For neurotypical children, it was hypothesized that younger age, lower IQ, and greater inattention and hyperactivity would predict more time off-task and in supported engagement. For autistic children, it was predicted that younger age, lower IQ, and greater sensory differences would predict more time off-task and in supported engagement.

7.2 Method

7.2.1 Ethics and GDPR

Ethical approval was granted by Durham Psychology ethics committee. Participating schools were provided with project packs, consisting of information sheets, consent forms, participant information sheets, and a privacy notice to send to parents (See Appendix G for these documents). If parents agreed for their child to participate, they were asked to return the consent form to school, and children provided assent prior to participation. For families recruited through social media, the above documentation was sent via email for parents to read. If parents agreed for their child to participate, they were then asked to complete paper copies of the forms at the Psychology Department when accompanying their child to the first testing session.

Data were collected in two formats- video footage and measures of performance (WASI 2 and questionnaire data). All data files (video and non-video) were given an anonymous code. For short term storage, after each testing session video footage was transferred from the camera memory card to a password protected computer and encrypted password protected external hard-drive. For long term storage, video footage was transferred to Durham University's secure research storage network. Performance data remains stored in a secure locked filing cabinet in Durham Psychology Department. In line with Durham University guidelines, both video footage and performance data will be kept for a period of ten years after any publication.

In terms of withdrawing data, caregivers were advised that after a period of two years all personally identifiable information linking to the non-video data would be deleted. Although the video footage was assigned an anonymous code for storage that did not link to the non-video data, by their nature, video data can never be fully anonymised (faces are personally identifiable). As such, caregivers were advised that if they wished to withdraw from the study all requests should be made within two years. After this period, caregivers were instructed that only video footage could be deleted.

7.2.2 Participants

23 neurotypical children and 31 autistic children were recruited. Neurotypical children were recruited through a) local links with mainstream schools in the North East of England and b) through advertisements placed on social media e.g. Twitter and Facebook. Neurotypical children were invited to take part if they were between the ages of 6 and 11 years and had no known neurodevelopmental conditions. Autistic children were recruited through SENCO networks and local links with a) Special schools b) Mainstream schools with Enhanced Provision C) ASD Specialist schools, in Merseyside and the North East. Autistic children were invited to take part if they were between the ages of 6 and 11 years and had a diagnosis of ASD. Children with co-occurring conditions such as ADHD were also eligible to take part. Parents were asked to confirm the presence or absence of an ASD diagnosis, and

any other co-occurring conditions via the Participant Information Sheet (See Appendix F). As noted in earlier chapters, this could be considered a limitation because researchers are having to rely on parent' understanding and openness when disclosing their child's diagnostic status. To be included in the final analysis, children needed to be able to complete at least 4 minutes (half) of each trial to ensure children were engaging with the task in a similar way across conditions.

Three autistic children were excluded from analyses as they were unable to complete four minutes of each trial. Trial length and demographic information for these children is shown in Table 7.1. It can be seen that all children had IQ in the Low-Average range and were able to complete the full duration of at least one trial. Examination of trial length and condition order indicates that it was during the second condition of a testing session that these children were unable to complete half of trial. Two other autistic children, both with co-occurring ADHD diagnoses, were excluded from analyses as one was unable to work independently and the second refused to complete the task. Lastly, one neurotypical child was excluded due to data becoming corrupted on the camera memory card.

Table 7.1 Demographic information for three autistic children excluded due to being unable to complete at least half of each trial (120 seconds). Duration is provided in seconds (Max Trial Length 480 seconds).

Case	Age	IQ	Additional Diagnosis	Order	Baseline Duration	Audio Duration	Visual Duration	AV Duration
1	7.93	85	None	Visual, AV, Baseline, Audio	480	***120***	480	480
2	8.82	87	None	Visual, AV, Baseline, Audio	480	456	339	***130***
3	7.59	81	ADHD	AV, Baseline, Audio, Visual	***164***	480	480	462

The final sample therefore included 26 autistic children and 22 neurotypical children. Autistic children (M=9.62 years, SD= 1.15) were significantly older than neurotypical children (M=8.35 years, SD=1.34), $t(46)=3.537$, $p=0.001$, with a large effect size Cohen's $d=1.025$. At a group level, although autistic and neurotypical children evidenced IQ scores within the average range, autistic children were found to have significantly lower FSIQ (M=95.00, SD=14.21) compared to neurotypical children (M=109.82, SD= 6.86), $t(37.286)= -4.708$, $p<0.001$, with a large effect size, Cohen's $d=1.293$. Neurotypical children (M=10.03, SD=1.91) and autistic children (M=8.98, SD=2.81) however were matched on verbal mental age at a group level $t(46)=1.486$, $p=0.144$, with a medium effect size Cohen's $d=0.430$. In terms of co-occurring conditions, five autistic children had an additional co-occurring condition (2 ADHD on medication, Dyslexia, Sensory Processing Disorder).

7.2.3 Measures and Materials

The Wechsler Abbreviated Scale of Intelligence- Second Edition (WASI 2) (Wechlser, 2011)

Estimated intellectual ability was assessed through the WASI 2. See Chapter 3 for an overview of the measure.

The School Companion Sensory Profile 2 (SCSP) (Dunn, 2014)

Sensory processing differences were assessed through teacher report using the SCSP. See Chapter 5 for an overview of the measure.

Conners 3 Parent Rating Scale (Conners, 2008)

The Conners 3 Parent Rating Scale is a 108-item questionnaire designed to assess behaviours reflective of ADHD, Conduct Disorder and Oppositional Defiant Disorder in children and adolescents aged 6 to 18 years old. Parents are asked to rank how frequently their child has demonstrated a particular behaviour in the last month on a four-point Likert Scale; 0= Not True at All (never or seldom happened), 1= Just a Little True (it happened occasionally), 2= Pretty Much True (it happened often or quite a bit), 3= Very Much True (it happened very often or very frequently). Example statement includes "*Blurts out answers before the question has been completed*", "*Actively refuses to do what adults tell him/her to do*", and "*Runs or climbs when he/she is not supposed to*". There are eleven scales; Inattention, Hyperactivity/Impulsivity, Learning Problems; Executive Functioning, Defiance/Aggression, Peer Relations, Conners 3 Global Index, DSM-5 Inattentive, DSM-5 Hyperactive-Impulsive, DSM-5 Conduct Disorder and DSM-5 Oppositional Defiant Disorder. However, in the current study only scores from the Inattention, Hyperactivity/Impulsivity scales were used. As ADHD type behaviours can differ by age and gender (e.g., younger children tend to be more hyperactive than older children) raw scores on these scales are then converted to T-scores by comparing the target student with same gender and age norms in the manual. T-scores have a standardized mean of 50 and a range of 40 to 90. T scores falling between 65 and 69 indicate that the child has elevated ADHD type behaviours, whereas scores greater than 70 indicate that the child has very elevated ADHD type behaviours, given their age and gender.

Experimental Stimuli

Children were asked to complete a reading worksheet in a square open-topped pop-up classroom (160x150x180cm) made using an aluminium frame. Four white curtain panels, which could be configured for different experimental conditions, were hung on the sides of the frame. In the Base condition, shown in Figure 7.1 the curtains were bare, and the child was asked to complete the task in silence. In the Auditory condition, the curtains remained bare, but classroom sounds were played from a Muzili Wireless Speaker, placed on the floor directly behind the front-curtain pane (See Figure 3 for classroom set up). Classroom sounds were sourced for free from '*Ambient Worlds',* an organization specializing in creating auditory stimuli on YouTube (See link https://www.youtube.com/watch?v=ApYyTBsn2K0). This soundtrack was cut and edited to an 8-minute track and included the sounds of multi-talker babble, furniture moving, and children working. As the soundtrack contained a variety of different noises, noise exposure varied from 50dB to 76dB, with an average of 62dB across the eight-minute period. In the Visual condition, shown in Figure 7.2. children completed the task in silence and the curtains were configured to display an array of educational posters and children's work on the front, left, and right panels (there were no displays on the door panel). Posters included illustrations of the solar system, times tables grids and names of fruits and animals. Examples of children's work were donated from a local primary school and included stories, drawings, and pamphlets. In the Audio-visual condition, classroom noises were played, and curtains were configured to display the educational posters.

Figure 7.1 Curtain configuration in Baseline and Audio conditions

Figure 7.2 Curtain configuration in Visual and Audio-visual conditions

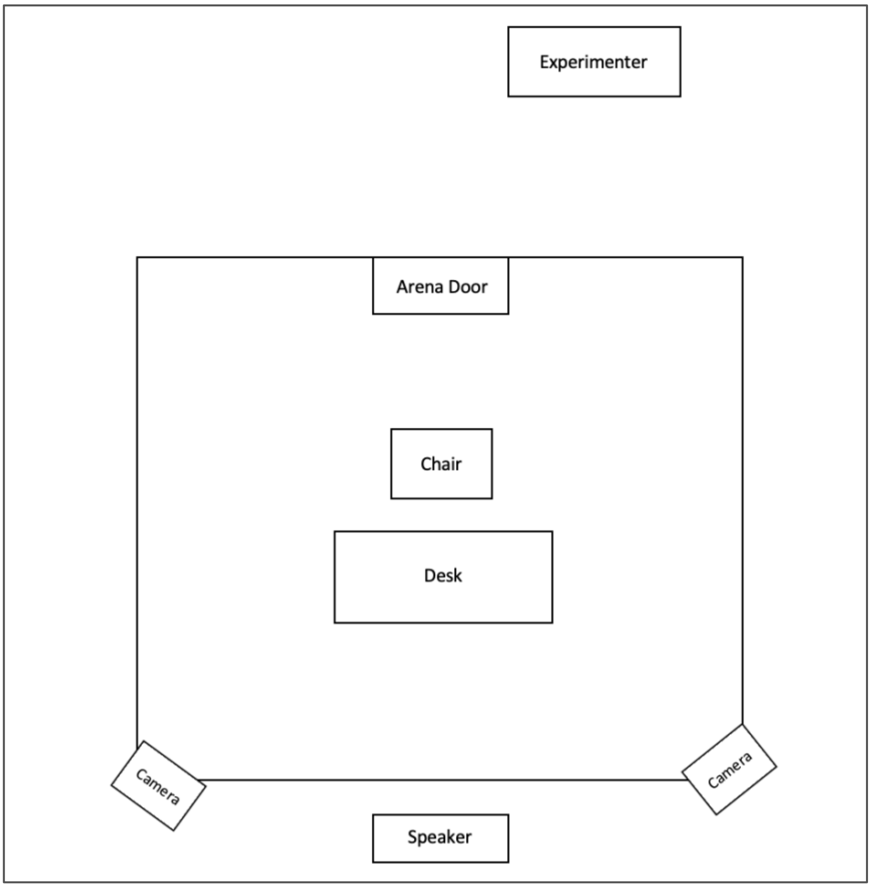


Figure 7.3 Pop-up classroom layout

The reading worksheets used in this study aimed to reflect a typical classroom activity that requires children to work independently. Whilst the aim was not to measure achievement on these worksheets, it was still critical that children were provided with a worksheet that was suitable for their mental age. This was to ensure that children were able to work independently and engage appropriately with the task (e.g., the worksheet couldn't be too hard or to too easy). Workbooks were sourced from a UK Educational Publisher (https://www.cgpbooks.co.uk). There were six workbooks available which corresponded to Year 1 up to Year 6 ability. For the younger years, workbooks included tasks such as tracking over words, putting pictures in the right order, and finishing speech bubbles with the correct word. In the older years, passages were longer, more complex, and children were required to complete tasks such as defining words, providing opinions, and describing characters.

7.2.4 On/Off Task Behaviour and Coding Strategy

To observe children's on/off-task behaviour, children were video recorded in each condition using two small Crosstour Action cameras (Model Number CT9000; Dimensions 59x41x25mm; Resolution 1080p) that were placed on the front left and right poles of the arena facing the child (See Figure 7.3 for a plan of the classroom set up). The height of the camera could be adjusted to ensure that the direction of eye gaze was visible when the child was sat down. In line with GDPR regulations, once the session had been recorded, data were transferred securely to Durham University's secure research storage network and erased off the camera memory card. Videos were then analysed using ELAN (Version 5.9) software.

An event-sampling strategy was used to code children's behaviour. Coders first assigned the behaviour as on-task, off-task or supported academic engagement. A child was deemed to be on-task if their eye gaze indicated that they were reading or writing independently (engaging with task materials). A child was classified as evidencing supported academic engagement if the experimenter was explaining or working through a question with the child after a) the child had asked for help b) the experimenter had offered help after a prolonged period of off-task behaviour. See Appendix H for a script used to respond to children's requests for help and prompts used to re-engage children with the task. A child was coded as off-task if they were not reading or writing independently or engaging with the task with the help of the experimenter. Coders classified the type of off-task behaviour as either Environmental Distraction (e.g., looking at or touching curtains or asking about classroom noises), Self-Distraction (e.g., engagement with one's own body or clothing), Motor-Gross Distraction (e.g., fidgeting in seat or walking around the classroom), Motor-Fine Distraction (e.g., playing or chewing pencil) or Experimenter Distraction (e.g., task-irrelevant engagement with the experimenter. See Appendix I for full coding scheme. Coders marked the onset and end of each on-task, off-task and supported engagement behaviour.

In total there were 192 videos (4 videos for each child). Three researchers coded the videos; EJ, JH and CH. EJ coded 100% of the videos and was not blind to hypothesis, condition, or child diagnosis as EJ had been present at every testing session. CH and JH together coded 50% of the videos. Although CH and JH were blind to diagnosis, they could not be blind to condition, as curtain configuration (displays or no displays) and the presence or absence of classroom noise was clear from the video footage. It should be noted that classroom configuration was also visible to coders in Fisher, Godwin and Seltman (2014). Therefore, the fact that researchers couldn't be blind to condition is not unique to this study. Cronabach Alpha scores indicated that there was excellent agreement between coders (CH and EJ =0.975, JH and EJ = 0.986).

7.2.5 Procedure

As detailed in Table 7.2 there were slight differences in the wider procedure dependent on whether testing took place in school or at the Psychology Department. Most notably, testing was split across three sessions across three separate days at school. The aim here was to minimize the amount of time a child was out of a lesson to take part in the study. Conversely, testing was split across two sessions, across two separate days at the Psychology Department, with the WASI 2 included in Session 1. The aim here being to minimize the number of visits to the Department. Another difference was that when testing took place at the Psychology Department, parents were provided with an additional consent form that asked for permission for researchers to contact the child's teacher inviting them to complete the Sensory Profile School Companion (Dunn, 2014). If consent was granted, the Sensory Profile School Companion (Dunn, 2014) was posted to the teacher, and they were instructed to return it to the researcher in the envelope provided. Aside from these differences, the procedure remained the same across both settings.

Table 7.2. Procedure for school and lab testing

	School	Psychology Department
Setting	Quiet Room e.g., school library	Quiet laboratory
N Sessions	3 sessions across 3 days	2 sessions across 2 days
Session 1	WASI 2 (30 minutes)	WASI 2 (30 minutes) Pop-up classroom (2 conditions)
Session 2	Pop-up classroom (2 conditions)	Pop-up classroom (2 conditions)
Session 3	Pop-up classroom (2 conditions)	NA

Having completed the WAS 2I (Wechsler, 2011), children were provided with a workbook appropriate for their mental age and introduced to the pop-up classroom. Children were asked to work through the workbook independently for eight minutes and informed that there would be a short break after this period. The researcher was sat outside of the arena but positioned so as to be able to observe the child (See Figure 7.3 for classroom layout). Although children were encouraged to work independently, they were told that if they really did need help, they could ask the researcher, who would be sat just outside of the arena. In such instances, the researcher would offer support, ensure the child was on-task and then leave the arena. After three occasions of requiring support within a condition, the researcher would emphasize that the child needed to try to answer as many of the questions on their own and would then suggest attempting a different question. See Appendix H for a list of prompts used by researchers to encourage independent work. If it became apparent that the child had become off-task for a prolonged period, the researcher would offer help and use prompts listed in Appendix H, to encourage the child back-on-task, after which the researcher would leave the arena. Whilst children were encouraged to complete the full 8 minutes, in situations where the child asked to finish or was unable get back on-task, the trial was finished early. During break periods, the child was asked to leave the area and sit while the researcher re-configured the curtains or set up the auditory stimuli. Children were then asked to re-enter the pop-up classroom and complete another 8 minutes, following the same procedure outlined above. At the end of the testing session, children were escorted back to their classroom or to their families in the Psychology Department. Each pop-up classroom session lasted approximately 25 minutes. Children then completed another two trials of the pop-up classroom, following the same procedure described above, in the second testing session.

7.2.6 Data Analysis Strategy

As outlined above, although children were encouraged to complete the full trial, there were some situations where the trial had to finish early. To ensure that there was no significant difference in trial length between conditions or group and to inform the subsequent analysis strategy, a Mixed Model ANOVA was undertaken. There was a within subject factor of condition (Baseline, Audio, Visual and Audio-visual) and between subject factor of group (ASD, NT). There was no main effect of condition $F(1.549, 71.246)= 0.942$, $p=0.422$, $\eta p^2=0.020$. There was no main effect of group $F(1,46)= 1.340$, $p=0.253$, $\eta p^2=0.028$. There was no significant interaction $F(1.549, 71.246)=0.055$, $p=0.908$, $\eta p^2=0.001$. Findings therefore indicate that there is no significant difference in trial length between conditions or group. Nevertheless, because there was variation in trial length, albeit not at a significant level, it was decided to use proportional values rather than absolute time.

7.3 Results

7.3.1 Descriptive Statistics

Table 7.3 below shows the percentage of time autistic and neurotypical children spent on-task, off-task and in supported engagement, averaged across the four conditions. It should be noted that the mean scores do not quite add up to 100% because the period from when the experimenter entered the pop-up classroom (to offer support) and walked towards the desk to offer the child support was not coded. Typically, this was one or two seconds.

Table 7.3 Percentage of time on-task, off-task and in supported engagement by group

Behaviour	Group	N	Mean	Min	Max	SD
% On-Task	ASD	26	76.65	42.48	99.80	15.35
	NT	22	92.34	73.49	99.29	6.58
% Off-Task	ASD	26	9.89	0.00	24.64	7.41
	NT	22	4.22	0.00	14.70	4.60
% Supported Engagement	ASD	26	11.37	0.00	41.04	10.89
	NT	22	2.82	0.00	21.21	4.63

Examination of the mean percentage of time spent on-tasks shows that both groups were engaged and on task for at least three quarters of the time. Although autistic children (M=9.89%) spent a greater percentage of time off-task relative to neurotypical children (M=4.22%), it can be seen that in both groups, there were some children who were never off-task and generally, for at least three quarters of the time on average, participants were on task. Further examination revealed that there were six children who evidenced no off-task behaviour across any of the conditions (3 Neurotypical children and 3 Autistic children). Demographic information for these children is presented below in Table 7.4. Apart from participant 2, who had an IQ of 120, all children had IQ in the Average range. There was a range of ages and an equal split of males and females.

Table 7.4 Demographic information for children evidencing no off-task behaviour

Participant	Diagnostic Group	Additional Diagnosis	Sex	IQ	Chronological Age
1	ASD	'Muscle Weakness'	Male	90	11.10
2	ASD	None	Male	120	10.63
3	ASD	None	Female	96	9.05
4	NT	None	Female	104	8.18
5	NT	None	Female	100	9.26
6	NT	None	Male	106	7.40

7.3.2 Does the classroom sensory environment affect the percentage of time autistic and neurotypical children spend off-task?

The first aim of this study was to examine if the percentage of time autistic and neurotypical children spent off-task differed between sensory conditions. As shown in Table 7.5, autistic children spent a greater percentage of time off-task in each condition compared to neurotypical children. Both groups however spent the greatest percentage of time off-task in the Visual condition (ASD M=16.84%, NT M=8.16%) followed by the Audio-visual condition (ASD M=12.77%, NT M=4.51%).

Table 7.5 Percentage of time autistic and neurotypical children spent off-task in each condition

Group	Condition	N	Mean %	Min %	Maximum %	SD
ASD	Baseline	26	4.24	0	22.09	5.39
	Audio		5.73	0	31.10	6.81
	Visual		16.84	0	77.42	18.12
	Audio-visual		12.77	0	40.91	12.94
	Mean		9.89			
NT	Baseline	22	2.29	0	11.66	3.25
	Audio		1.93	0	11.05	3.46
	Visual		8.16	0	38.37	12.51
	Audio-visual		4.50	0	18.46	6.17
	Mean		4.22			

To test the hypothesis that the percentage of time spent off-task would differ significantly between sensory conditions, and to examine potential group differences, a Mixed Model ANOVA was undertaken. There was a within-subject factor of condition (Baseline, Audio, Visual, Audio-visual) and a between subject factor of group (ASD, NT). Due to the novelty of this paradigm (e.g., considering Audio, Visual and Audio-visual input), there were no predictions in terms of how the percentage of off-task behaviour might differ between the Audio, Visual and Audio-visual conditions. Therefore, analysis comparing the percentage of off-task behaviour between these conditions is exploratory.

Equal variances were not assumed as Levene's Test for Equality of variances was significant for all conditions $p<0.005$, aside from the Visual condition $F(1,46)=1.609$, $p=0.211$. Mauchly's Test of Sphericity was also significant $W(5)=0.247$, $p<0.001$, therefore Greenhouse-Geisser correction was applied.

There was a main effect of condition $F(1.760, 80.953)=10.791$, $p<0.001$, $\eta p^2= 0.190$, with a medium effect size. There was also a main effect of group $F(1,46)=9.714$, $p=0.003$, $\eta p^2= 0.174$, with a medium effect size. As hypothesized, autistic children (M=9.89%) spent a significantly greater percentage of time off-task compared to neurotypical children (M=4.22%). There was no significant interaction between condition and group $F(1.760, 80.953)=1.571$, $p=0.216$, $\eta p^2=0.033$.

To unpick the main effect of condition, post-hoc pairwise comparisons (with Sidak adjustment applied for multiple comparison) were conducted. There was no significant difference in the percentage of time spent off-task in the Baseline condition (M=3.27%) compared to the Audio condition (M=3.83%), $p=0.982$. However, children spent a significantly greater percentage of time off-task in the Visual condition (M=12.50%) compared to the Baseline condition (M=3.27%), $p=0.001$. Children also spent a significantly greater percentage of time off-task in the Audio-visual (M=8.64%) condition relative to the Baseline condition (M=3.27%), $p=0.001$. There was a greater percentage of off-task behaviour in the Visual (M=12.50%) condition compared to the Audio condition (M=3.83%), $p=0.002$. Similarly, there was a greater percentage of off-task behaviour in the Audio-visual (M=8.64%) condition compared to the Audio condition (M=3.83%). . However, there was no significant difference in the percentage of time spent off-task in the Visual condition (M=12.50%) relative to the Audio-visual condition (M=8.64%), $p=0.584$.

In summary, findings from Aim 1 indicate that although autistic children spent a significantly greater percentage of time off-task relative to their neurotypical peers, both groups evidenced the same pattern of off-task behaviour across conditions. That is, both groups spent the greatest percentage of time off-task in the Visual and Audio-visual condition, and the smallest percentage of time off-task in the Audio and Baseline condition. However, on average both groups were engaged and on-task for at least three quarters of the time.

7.3.3 Does the nature of off-task behaviour differ between sensory conditions and are there differences between groups?

The second aim of this study was to investigate if the types of off-task behaviour evidenced by children, differed between sensory conditions and diagnostic groups. As emphasized above, on average both groups were engaged and on-task for at least three quarters of the time. However, it still important to examine what children were doing in the small amount of time that they were off task. Five different types of off-task behaviour were coded in this study; Environmental; Self-Distraction, Motor-Gross, Motor-Fine, and Experimenter Task-Irrelevant Engagement. Table 7.6 below shows the percentage of total task-time children spent evidencing each of these behaviours. In line with Fisher et al. (2014) as children spent less than 1% of task-time engaged in Self-Distraction, Motor-Fine or Experimenter Distraction, no further analyses were undertaken on these three off-task behaviours. Analysis therefore focused only on i) Environmental off-task behaviours and ii) Gross-Motor off-task behaviours.

Table 7.6 Percentage of task-time engaged in off-task behaviours by group and condition

Off-Task Behaviours	Group	N	Baseline	Audio	Visual	AV	Mean
Environmental	ASD	26	0.92	1.62	12.99	8.40	5.98
	NT	22	0.55	0.48	6.67	2.63	2.58
Self-Distraction	ASD	26	0.33	0.23	1.20	0.62	0.60
	NT	22	0.39	0.15	0.57	0.31	0.36
Motor-Gross	ASD	26	1.56	1.90	1.18	2.29	1.73
	NT	22	0.28	0.84	0.34	1.17	0.66
Motor-Fine	ASD	26	1.19	1.45	0.20	0.58	0.86
	NT	22	0.79	0.23	0.49	0.28	0.45
Experimenter	ASD	26	0.25	0.54	1.27	0.89	0.74
Task-Irrelevant Engagement	NT	22	0.28	0.24	0.09	0.12	0.18

7.3.3.1 Environmental off-task behaviours

A 4 x 2 Mixed Model ANOVA was first undertaken to investigate if the percentage of time spent engaging in Environmental off-task behaviours differed between sensory conditions and diagnostic groups. There was a between subject factor of condition (Baseline, Audio, Visual and AV). There was also a within-subject factor of group (ASD, NT). Equal variances were not assumed as Levene's Test for Equality of Variances was significant for the Audio condition $F(1,46)=8.267$, $p=0.006$ and in the AV condition $F(1,46)=16.115$, $p<0.001$. Mauchly's Test of Sphericity was also significant $W(5)=0.054$, $p<0.001$, therefore Greenhouse-Geisser correction was applied.

There was a main effect of condition $F(1.519, 46)=12.970$, $p<0.001$, with a large effect size $\eta p^2=0.220$. There was also a main effect of group $F(1,46)= 6.743$, p=0.013, with small effect size $\eta p^2=0.128$. Largely driven by findings from Aim 1, autistic children spent a significantly greater percentage of time engaging in

Environmental off-task behaviours compared to neurotypical children. There was however no significant interaction $F(1.519, 46)=1.665$, $p=0.201$, $\eta_p^2= 0.035$.

To unpick the main effect of condition, pairwise comparisons (Sidak adjusted for multiple comparisons) were next examined. There was no significant difference in the percentage of Environmental off-task behaviours between the Audio (M=1.05%) and Neutral (0.73%) condition $p=0.923$. However, children spent a significantly greater percentage of time engaging in Environmental off-task behaviours in the Visual condition (M=9.83%) compared to the Neutral condition (M=0.73%), $p=0.001$. Likewise, there was significantly more Environmental off-task behaviours in the Audio-visual (M=5.51%) relative to the Neutral condition (M=0.73%). Children also spent a significantly greater percentage of time evidencing Environmental off-task behaviours in the Visual condition (M=9.83%) compared to the Audio condition (M=1.05%), $p=0.001$ and also more in the Audio-visual condition (M=5.1%) relative to the Audio condition (M=1.05%) $p=0.002$. There was however no significant difference in the percentage of time engaging in Environmental off-task behaviours between the Visual (M=9.83%) and Audio-visual (M=5.51%) conditions, $p=0.323$.

7.3.3.2 Gross-Motor off task behaviours

A second 4 x 2 Mixed Model ANOVA was next undertaken to investigate if the percentage of time spent engaging in Gross-Motor off-task behaviours differed between sensory conditions and diagnostic groups. There was a within-subject factor of condition (Baseline, Audio, Visual and AV). There was also a between-subject factor of group (ASD, NT). Equal variances were not assumed as Levene's

Test for Equality of Variances was significant for the Neutral $F(1,46)=7.004$, $p=0.011$ and Visual $F(1,46)=13.783$, $p=0.001$. Mauchly's Test of Sphericity was also significant $W(5)= 0.614$, $p=0.001$, therefore Greenhouse-Geisser correction was again applied. There was no main effect of condition $F(2.384, 46)= 1.312$, $p=0.275$, $\eta p^2=0.028$. Likewise, there was no main effect of Group $F(1,46)= 3.690$, $p=0.061$, $\eta p^2= 0.074$. There was also no significant interaction $F(2.384, 46) = 0.054$, $p=0.966$, $\eta p^2=0.001$.

In summary, the second aim of this study was to investigate if the types of off-task behaviour evidenced by children, differed between sensory conditions and diagnostic groups. Autistic children spent a significantly greater percentage of time engaging in Environmental off-task behaviours relative to neurotypical children. Both groups however evidenced significantly more Environmental off-task behaviours in the Visual and Audio-visual condition relative to Baseline and Audio. There was however no significant difference between groups or sensory conditions in terms of Gross-Motor off-task behaviours.

7.3.4 Do individual differences in cognitive, sensory, and attentional abilities predict differences in the percentage of time spent off-task or in supported engagement?

The final aim of this study was to investigate if individual differences in cognitive, sensory, and attentional abilities predicted the percentage of time children spent off-task and in supported engagement. Due to Covid-19 and subsequent school closures, it was not possible to collect Connor's questionnaire from the parents of autistic children as planned. Therefore, individual difference analyses were undertaken for neurotypical and autistic children separately.

7.3.4.1 ASD Analysis

Descriptive statistics for Age, IQ and sensory differences are presented below in Table 7.7. There is substantial variability in sensory differences with scores ranging from 'Just Like the Majority' up to 'Much More Than Others', in all four quadrants.

Table 7.7 ASD individual differences descriptive statistics

	N	Mean	Minimum	Maximum	SD
FSIQ-4	26	95.00	67.00	124.00	14.21
Chronological Age	26	9.62	7.99	11.14	1.15
Seeking	24	20.00	8.00	38.00	7.91
Avoiding	24	31.46	14.00	47.00	10.20
Sensitivity	24	30.79	10.00	46.00	10.27
Registration	24	35.29	18.00	57.00	10.96
% Off-task	26	9.89	0.00	24.64	7.41
% Supported Engagement	26	11.37	0.00	41.04	10.89

Two sets of correlation analyses were undertaken to investigate if individual differences in age, IQ and sensory processing differences, as assessed through quadrant scores (Low Registration, Sensory Seeking, Sensory Sensitive, Sensory Avoiding) on the School Companion Sensory Profile, were associated with the percentage of time autistic children spent off-task and in supported engagement. For both sets of analyses, to reduce the likelihood of Type 1 error (due to small sample sizes and multiple comparisons) Bonferroni correction was applied and a new alpha value of $p<0.001$ set. Pearson (one-tailed) correlations were undertaken to investigate associations with the percentage of time spent on-task. Due to the percentage of time spent in supported engagement not being normally distributed

W(26)=0.859, *p*=0.002, Spearman correlations (one-tailed) were conducted to investigate associations with percentage of time spent in supported engagement. Results are presented below in Table 7.8.

Table 7.8 Associations between individual differences and percentage of time spent off-task and in supported engagement (ASD)

Individual Differences	Correlations	Mean Off-Task (Pearson)	Mean Supported Engagement (Spearman)
FSIQ-4 (N=26)	Correlation	-0.060	-0.339
	Sig. (1-tailed)	0.386	**0.045**
Chronological Age (N=26)	Correlation	-0.277	-0.056
	Sig. (1-tailed)	0.085	0.392
Avoiding (N=24)	Correlation	0.070	0.326
	Sig. (1-tailed)	0.372	0.060
Seeking (N=24)	Correlation	0.211	0.299
	Sig. (1-tailed)	0.161	0.078
Sensitivity (N=24)	Correlation	0.009	0.410
	Sig. (1-tailed)	0.483	**0.023**
Registration (N=24)	Correlation	0.029	0.351
	Sig.(1-tailed)	0.446	**0.046**

In contrast to predictions, there were no significant associations between IQ, age, sensory differences, and the mean percentage of time children spent off-task. However, as hypothesized greater IQ was associated with a smaller percentage of time spent in supported engagement $r_s(26)= -0.339$, $p=0.045$. However, this relationship was not significant following Bonferroni correction. Likewise, whilst greater Sensitivity $r_s(24)= 0.410$, $p=0.023$ and greater Registration $r_s(24)= 0.351$, $p=0.046$, were associated with a greater percentage of time in supported engagement, neither of these associations were significant following Bonferroni correction. As none of the above associations were significant following Bonferroni correction, regression analyses to examine if IQ, Age and Sensory differences predicted the percentage of time off-task and in supported engagement were not conducted.

7.3.4.2 Neurotypical analysis

Descriptive statistics for Age, IQ, hyperactivity, and inattention are shown below in Table 7.9. There is again substantial variability in Hyperactivity and Inattention with scores ranging from typical levels up to very elevated (suggestive of ADHD).

Table 7.9 Neurotypical individual differences descriptive statistics

	N	Mean	Minimum	Maximum	SD
FSIQ-4	22	109.82	97.00	121.00	6.86
Chronological Age	22	8.35	6.02	10.97	1.34
Hyperactivity T	19	53.63	40.00	82.00	12.99
Inattention T	19	51.32	40.00	80.00	12.94
% Off-task	22	4.22	0.00	14.70	4.60
% Supported Engagement	22	2.83	0.00	21.21	4.63

Two sets of correlation analyses were undertaken to investigate if individual differences in age, IQ, hyperactivity, and inattention (as assessed through the Conner's questionnaire) were associated with the percentage of time neurotypical children spent off-task and in supported engagement. For both set of analyses, to reduce the likelihood of Type 1 error, Bonferroni correction was applied and a new alpha value of 0.0125 set. Spearman correlations were undertaken for both analyses, as the percentage of time spent off-task was not normally distributed $W(22)=0.827$, $p=0.001$, and the percentage of time spent in supported engagement was also not normally distributed $W(22)=0.610$, $p<0.001$. Results are presented below in Table 7.10.

Table 7.10 Associations between individual differences and percentage of time spent off-task and in supported engagement (Neurotypical)

Individual Differences	Correlations	Mean Off-Task	Mean % Supported Engagement
FSIQ-4 (N=22)	Correlation	0.188	-0.169
	Sig. (1-tailed)	0.202	0.226
Chronological Age (N=22)	Correlation	**-0.357**	-0.010
	Sig. (1-tailed)	**0.051**	0.483
Hyperactivity (N=19)	Correlation	**0.414**	-0.073
	Sig. (1-tailed)	**0.039**	0.384
Inattention (N=19)	Correlation	0.038	-0.011
	Sig. (1-tailed)	0.438	0.482

As hypothesized, older age was associated with less time spent off-task, $r_s(22)= -0.357$, $p=0.051$. However, this relationship was not significant following Bonferroni correction. Likewise, although greater hyperactivity was associated with a greater percentage of time off-task $r_s(19)= 0.414$, $p=0.039$, this relationship was also not significant following Bonferroni correction. Also, in contrast to predictions, there was no significant association between IQ, Inattention, and mean percentage of time off-task. Finally, there were no significant associations, before or after Bonferroni correction, between IQ, Age, Inattention, Hyperactivity, and the mean percentage of time spent in supported engagement. As none of the above associations were significant following Bonferroni correction, regression analyses to examine if IQ, Age, Inattention and Hyperactivity predicted the percentage of time off-task and in supported engagement were not conducted

In summary, the final aim of this study was to investigate if individual differences in age, cognitive ability, sensory differences, and attention predicted the percentage of time children spent off-task and in supported engagement. For autistic children, lower IQ and greater Sensitivity and Registration were associated with a greater percentage of time spent in supported engagement. For neurotypical children, younger age and greater hyperactivity were associated with a greater percentage of time spent off-task. However, none of these associations were significant after Bonferroni correction. As such regression analyses were not undertaken.

7.4 Discussion

The current study sought to empirically investigate how aspects of the classroom sensory environment affect the ability of primary-aged children to stay on-task. By asking children to complete a reading task in a bespoke pop-up classroom, this study aimed to isolate and compare the effect of different sensory inputs on behaviour, in a systematic, controlled and more ecologically valid way. This approach was critical for several reasons. Notably, previous research has focused on only visual input or only the auditory input and neglected that the classroom is a rich multi-sensory space (Godwin, Erickson & Newman, 2019). The current study therefore developed a novel paradigm which allowed for the impact of visual and auditory inputs to be considered first in isolation, and then together in a multi-sensory environment. Second, to-date much of the research has focused on the ability of neurotypical children to stay on-task. Yet, autistic children tend to have attentional and sensory differences, which could make then especially susceptible to off-task behaviours, particularly in rich multi-sensory environments (Ames &

Fletcher, 2010; Smith & Sharp, 2013). As such, this study makes an important contribution to the literature by probing if the prevalence and nature of off-task behaviours shown by autistic and neurotypical children differ across sensory environments. In terms of applied impact, these findings could provide timely recommendations into how classrooms might be configured to meet a diverse range of sensory needs. Lastly, this study also examined how individual differences in cognitive, sensory, and attentional abilities affect the ability to stay on-task. Again, findings here could allow children who are at an increased risk of off-task behaviour to be identified, and for early tailored support to be implemented. This is important, because as discussed earlier, off-task behaviour can have substantial impacts on learning and achievement (Fisher, Godwin & Seltman, 2014; Carroll, 1963).

7.4.1 Off-task behaviour

In terms of overall off-task behaviour, as hypothesized, autistic children spent a significantly greater percentage of time off-task (9.89%) relative to neurotypical children (4.22%). Likewise, autistic children spent less time on-task (76.65%) compared to neurotypical children (92.34%) and also more time in supported engagement (11.37% versus 2.82% respectively). Findings therefore indicate that compared to neurotypical children, autistic children may need greater support to stay on-task and work independently in the classroom. It should be noted however, that the percentage of time neurotypical children spent off-task is much less than that reported by Godwin et al., (2016; 30%). However, in Godwin et al. (2016) children were observed in their actual classrooms with their peers as opposed to being asked work independently in a pop-up classroom for a very short period of time. It should be emphasized that adopting this experimental approach was critical for meeting the aims of the current study. Namely, it afforded systematic control and reduced the potential for confounds (e.g., impact of peers), to an extent that was not possible in previous studies, whilst also allowing for the effects of different environmental conditions to be isolated in a relatively ecological valid way. Even so, it needs to be considered that the absence of peers may have resulted in lower levels of off-task behaviour being observed relative to that seen in typical classrooms. Indeed, Godwin et al. (2016) found peer-distraction to be the most common source of off-task behaviour, particularly during independent work. Nonetheless, while peer-distraction was the most common source of off-task behaviour in these studies, there is some evidence that it was not the most detrimental to learning (Moffett & Morrison, 2020). Rather, it was environmental distraction that predicted fewer gains in reading comprehension (Moffett & Morrison, 2020). Consequently, while children in the current study may have spent a small percentage of time off-task, the types of off-task behaviours being captured (e.g., environmental distraction), are those suggested to have the greatest impact on learning (Moffett & Morrison, 2020).

Adopting a systematic controlled approach was especially important for Aim 1 of this study as the purpose here was to investigate if the percentage of time spent off-task differed between sensory conditions, and to also investigate potential group differences between autistic and neurotypical children. Although autistic children spent a greater percentage of time off-task relative to neurotypical children, both groups evidenced the same profile of off-task behaviour, such that off-task behaviour was greatest in the Visual and Audio-visual environment and lowest in the Baseline and Audio environment. It does need to be recognised however that the amount of time off-task was minimal in the current study, with both groups engaged and on-task for at least three quarters of the time. Even so, in Aim 2, it was found that the nature of the off-task behaviour differed between sensory conditions, such that both groups spent a significantly greater percentage of time evidencing Environmental off-task behaviours in the Visual and Audio-Visual condition relative to Baseline and Audio. Taken together, findings thus emphasize that while the classroom sensory environment may impact the ability of all children to stay on-task, autistic children may be especially susceptibility to off-task behaviour when learning in these types of stimulating spaces.

7.4.2 Visual stimulation in the classroom

Considering the effects of visual stimulation first, neurotypical children were found to spend 6.1% more time off-task in the Visual condition (8.2%) compared to Baseline (2.3%) and 6.3% more time off-task in the Visual condition (8.2%) relative to Audio (1.9%). Importantly, this replicates the work of Fisher, Godwin and Seltman (2014) where it was found that neurotypical children evidenced 10% more off-task behaviour when learning in a classroom heavily decorated with visual displays compared to a sparsely decorated classroom. By including a wider age range of children (6-11 years) the current study also extends Fisher, Godwin and Seltman (2014) and emphasizes that classroom visual stimulation is an important consideration for all primary classes, not just those in Key Stage 1.

At the same time however, findings highlight that consideration of visual stimulation may be especially important when thinking about the learning and behavioural needs of autistic children (Hanley et al., 2017). Indeed, autistic children spent

12.6% more time off-task in the Visual condition (16.8%) relative to Baseline (4.2%) and 11.1% more time off-task in the Visual condition (16.8%) compared to Audio (5.7%). Moreover, Environmental distraction was found to be greatest in the Visual and Audio-visual condition. This supports the work of Hanley et al. (2017) in which the presence of visual displays were found to impact the attention and learning of all children, but especially those with a diagnosis of ASD. One explanation for this increased susceptibility, could be that a lack of social prioritising (Riby & Hancock, 2008) may result in visual displays more readily capturing the attention of autistic children. Moreover, once attention has been directed towards these displays, difficulties in attentional shifting, could prevent autistic children orienting their attention back towards the task or teacher (Elsabbagh et al., 2013; Sacrey et al., 2014). Findings from Mo et al. (2019) do appear to lend some support for this position. In that study age-matched autistic and neurotypical children were asked to complete the gap-overlap paradigm. In this paradigm, a central fixation stimulus is first presented. During overlap conditions, the central fixation stimulus stays on screen whilst peripheral stimuli are presented. However, during gap conditions, the central fixation stimulus disappears, and then peripheral stimuli appear. In Mo et al. (2019), the central stimuli were neutral pictures of landscapes and peripheral stimuli were either objects related to circumscribed interests, objects not related to circumscribed interests or social objects (faces). Eye-tracking data revealed that compared to neurotypical children, autistic children took significantly longer disengaging from the central stimuli to any of the peripheral stimuli (during overlap conditions) (Mo et al., 2019). Whereas autistic children were found to disengage quicker when the peripheral stimuli related to circumscribed interests, neurotypical children disengaged more quickly when peripheral stimuli were social, in nature

(Mo et al., 2019). Findings thus suggest that a lack of social prioritizing alongside difficulties in re-orienting attention once it has been captured, may underlie autistic children's increased susceptibility to visual distraction (Riby & Hancock, 2008; Sacrey et al., 2014, Hanley et al., 2017).

Nevertheless, it could be argued that because children only spent 8 minutes in each condition, the effects of visual stimuli on behaviour are underpinned by novelty such that with longer exposure, both groups would habituate to these displays and become less susceptible to distraction (Imuta & Scarf, 2014). There are two reasons however that this account seems unlikely. Firstly, conditions were counterbalanced. Secondly, it was found in Godwin et al. (2016) that environmental distraction increased over the school year. This suggests that rather than habituating, children become increasingly susceptible to environmental distraction throughout the school year (Godwin et al., 2016). This increase is of concern because even at short exposure there is evidence to suggest high levels of visual stimulation can impact cognitive processes that are important for learning. This can be highlighted by the work of Rodrigues and Pandeirada (2018) where 64 neurotypical children were asked to complete two attention tasks (go/no-go and choice reaction time) and two memory tasks (Corsi block tapping and Rey complex figure) in high and low visual stimulation conditions. During high stimulation conditions, children completed the tasks sat at a desk enclosed by panels decorated in visual displays. In the low-stimulation conditions, these displays were removed, and panels remained bare. Overall, children achieved greater performance (significantly faster reaction times, higher percentage of correct responses, and significantly better immediate recall) when asked to complete tasks in the low-load visual condition (Rodrigues & Pandeirada, 2018). Thus, emphasizing that exposure to highly stimulating visual displays, even for a short-amount of time, can affect children's ability to stay on-task and impact cognitive processes known to be important for learning (Hanley et al., 2017; Rodrigues & Pandeirada, 2018; Fisher, Godwin & Seltman, 2014).

In terms of considering implications for the classroom, critically this does not mean that classrooms should be stripped of all visual stimulation. Indeed, Barrett et al. (2015) found a curvilinear relationship between visual complexity and academic progress, indicating that both too much and too little visual stimulation can be detrimental to children's learning. As such, one way to reduce off-task behaviour, and potentially improve learning for both autistic and neurotypical children, would be to reduce, not eliminate visual displays in the classroom (Barrett et al., 2015). This stands in contrast however to the recommendations recently proposed by Remington et al. (2020). This study modified the task developed by Hanley et al. (2017) to investigate if attending to the background as opposed to the teacher, was detrimental for autistic and neurotypical children's learning. Children watched videos of a teacher delivering a story against a blank background, a background containing task-relevant visual displays, and a background with task-irrelevant visual displays. At the end of the lesson, children were asked questions about both the story and the displays (despite not being told to direct attention towards the displays). When the displays were relevant, autistic and neurotypical children could recall information about the story, in addition to information about the background information. However, when the background information was irrelevant, autistic children were able to answer more questions about the displays compared to neurotypical children, and critically this was not at the detriment to performance on the story task. Although perceptual load was not assessed in Remington et al. (2020), this pattern of results was interpreted within an enhanced perceptual capacity framework (See Chapter 6 for an outline of load theory and enhance perceptual capacity). That is spare perceptual capacity allowed autistic children to process information about the relevant and irrelevant visual displays without impacting the ability to learn about the story. Consequently, the authors propose that findings "*challenge the prevailing view that learning environments should be made as simple as possible for those on the autistic spectrum*" (Remington et al., 2020;20).

It should be considered, however, that this task represents a narrow and specific type of learning activity in the classroom; namely, recall following teacher-led instruction. Yet, children engage in a variety of learning activities, including small group work, whole-group work, and independent pupil-driven tasks (Godwin et al., 2016). While visual displays may not have impacted autistic pupils' accuracy on the story task following teacher-led instruction, current findings emphasize that visual displays can certainly affect the ability of autistic individuals to stay on-task when required to work independently. It seems, therefore, that when thinking about how best to adapt the classroom visual environment, minimizing displays may still be the preferred option in terms of reducing off-task behaviour across instructional formats (Barrett et al., 2015). However, future research is needed to test this hypothesis using a more ecologically valid paradigm. For instance, one approach could be manipulating the number of visual displays in a school setting (as opposed to a lab) to examine potential effects on off-task behaviour and learning (Fisher, Godwin & Seltman, 2014).

7.4.3 Auditory stimulation in the classroom

In terms of auditory distraction, the fact there was no significant difference in off-task behaviour between Baseline and Audio nor Visual and Audio-visual was a somewhat unexpected finding. Indeed, within the neurotypical literature, there is evidence that noise generated from both outside the classroom (e.g., noise from a flight path or a busy road) and within the classroom (children's babble) can affect a range of academic skills (Klatte, Bergstrom & Lachmann, 2013; Clark & Paunovic, 2018). Emphasizing this are the findings of Dockrell and Shield (2006) who found neurotypical children achieved poorer scores on literacy and spelling when children were babbling. Speech in particular appears to be especially detrimental to reading and recall performance (Klatte, Bergstrom & Lachmann, 2013). Two mechanisms have been proposed to explain this effect. The first, referred to as the deviation effect, suggests that attention is captured by unexpected changes in irrelevant speech and diverted away from the task at hand, resulting in poorer performance (Clark & Paunovic, 2018). The second mechanism, referred to as interference by process, suggests that changes in irrelevant speech are processed automatically and this interferes with working memory and associated rehearsal processes (Clark & Paunovic, 2018). Thinking about these mechanisms, it could be that auditory stimulation does disrupt learning, but this is less through overt off-task behaviours (as seen with visual stimulation) and is instead driven by interference with internal cognitive processes such as working memory (Clark & Paunovic, 2018). Future research is therefore needed to explore this hypothesis by investigating both learning outcomes and off-task behaviour across different sensory environments.

For autistic children, however, findings from Chapter 4, do suggest that auditory input can disrupt learning by causing overt off-task behaviour. Indeed, parents and teachers reported that stimuli such as fire-alarms and chatter in group work could lead to distraction, alongside physical and emotional reactions including meltdowns and leaving the classroom (Jones, Hanley & Riby, 2020). As such, it was predicted that the percentage of off-task behaviour would be greater in the Audio environment relative to Baseline. Moreover, given reports that sensory processing differences are most challenging in multi-sensory environments, off-task behaviour was also predicted to be greater in the Audio-Visual environment relative to the Visual condition (Smith & Sharp, 2013; Marco et al., 2011).

Qualitative insights from late-diagnosed autistic females in Chapter 5 of this thesis, alongside findings from Robertson and Simmons (2013), emphasize however, that not all auditory input is perceived as distressing. Rather, stimulus properties including predictability, control, and single versus multiple channels of input, are reported to influence whether a stimulus is perceived as distressing or enjoyable (Robertson & Simmons, 2013; Smith & Sharp, 2013). That is, challenges are most likely to arise when there is a mixture of competing sounds, which are unpredictable and hard to control (Smith & Sharp, 2013). While the auditory stimuli presented in this study may have captured some typical classroom noises such as babble and furniture moving, it did not contain complex and unpredictable sounds such as fire-alarms or the school bell. Moreover, stimuli were presented at 65dB, which is slightly lower than typical noise exposure (although in line with Dockrell and Shield, 2006), and only for 8 minutes. This, therefore, raises the possibility, that with longer and louder exposure to more complex and unpredictable stimuli, auditory input would affect the ability to stay on-task. Qualitative insights do appear to support this position and emphasize the need to consider both auditory and visual stimulation in tandem when thinking how best to reduce off-task behaviour in the classroom (Godwin, Erickson & Newman, 2019).

7.4.4 Individual Differences

The final aim of this study was to examine how individual differences in cognitive, sensory, and attentional abilities affected the percentage of time children spent off-task and in supported engagement. Notably, there was vast heterogeneity both within and between diagnostic groups in terms of children's ability to stay on-task. Indeed, in the autistic group the percentage of time spent off-task ranged from 0% up to 25% whereas in the neurotypical group this ranged from 0-15%. Although findings from a series of correlation analyses, undertaken for autistic and neurotypical children separately did indicate that individual differences were associated with task behaviour, none of these associations were significant following Bonferroni correction. There is a need therefore to replicate and examine these associations in further detail with a larger sample size.

Taking into consideration this limitation, for neurotypical children, there was some indication that greater hyperactivity was related to a greater proportion of time off-task. Notably, mean hyperactivity was in the typical range and far below the threshold for a clinical consideration of ADHD. The finding that hyperactivity but not inattention was related to the percentage of time off-task was unexpected. However, behaviours typically associated with hyperactivity, such as fidgeting or pacing, may be more overt compared to behaviours reflective of inattention (daydreaming, missing teacher instructions) and critically it was these more overt behaviours that were used to conceptualize off-task behaviour in the current study (Motor-Gross, Motor-Fine; Finn, Pannozzo & Voelkl, 1995). Future research is therefore needed to ensure inattentive off-task behaviours are also captured in the coding scheme.

There was also some evidence that in our sample of 6–11-year-olds, age was positively associated with the percentage of time spent off-task. Again, although caution is needed due to this relationship not being significant following Bonferroni correction, it does support the proposed developmental trajectory of selective sustained attention (Gaspelin, Margett-Jordan & Ruthruff 2015). Indeed, it is suggested that across development (particularly between the ages of 3-8; Steele et al., 2012; Pozuelos et al., 2014), children become better able to inhibit irrelevant distractors and are able to exert voluntary control over attention for longer (Gaspelin, Margett-Jordan & Ruthruff 2015). Consequently, more mature selective attention abilities may have allowed older children in this study to filter out auditory and visual distractions and not go off-task (Gaspelin, Margett-Jordan & Ruthruff, 2015). This has important implications for classroom design because it is often in the younger years where classrooms are most vibrant and stimulating. It seems, therefore, that while adapting the classroom sensory environment may be beneficial for all primary aged children, it may be particularly beneficial for younger children, who despite having less sustained selective attention abilities, often learn in the most sensory-rich and stimulating environments (Barrett et al., 2015; (Gaspelin, Margett-Jordan & Ruthruff, 2015).

For autistic children, there was some evidence that lower IQ and greater sensory differences (Sensitivity in particular) were associated with a greater percentage of time spent off-task and in supported engagement. This does appear to offer some support for the findings of Chapter 6 of this thesis in which greater Sensitivity positively predicted a small but significant amount of variance in reading achievement. Three potential mechanistic pathways were discussed, one of which was that Sensitivity may have promoted reading achievement through disruptive classroom behaviours. It was suggested that for Sensors who typically have a passive response to hypersensitivity disruptive behaviours could alert the teacher quickly to a problem, enabling them to receive support and get back on-task (Finn, Pannozzo & Voelkl, 1995; Tymms & Merrell, 2011). This scenario is reflective of supported engagement and suggests that children with greater Sensitivity may need more support from teachers to stay on-task in busy classroom environments. However, to examine this proposed mechanism, future research examining how different patterns of sensory differences relate to the amount of support needed and offered by teachers in the classroom is needed.

7.4.5 Limitations and Conclusions

Several limitations of this study need to be considered. Foremost, although the pop-up classroom was designed to be as ecological-valid as possible, as discussed, it did not replicate a real classroom scenario due to the absence of peers. As peer distraction was found to be the most common source of distraction in Godwin et al. (2016) it may be beneficial to examine how the classroom sensory environment impacts peer-distraction in future studies. It also needs to be considered that the experimental manipulation, was “all or nothing” such that there were lots of visual displays or none at all, which was the same approach as that taken by Hanley et al (2017). As the findings of Barrett et al. (2015) suggest that there is an optimal level of visual stimulation in the classroom, there is a need to investigate the effect of moderate visual stimulation on behaviour. This could be achieved by increasing the number of visual displays in increments from Baseline. One strength of this study was that the pop-up classroom was portable and therefore allowed children in different areas, in different schools supporting different needs and abilities, to take part. However, this meant that stimuli external to the experiment, such as light and temperature- factors suggested to influence behaviour and learning, differed across sites (Barrett et al., 2015). This, therefore, raises the small possibility that factors external to the experimental manipulation impacted behaviour. Lastly, this study only examined how the classroom sensory environment impacted behaviour and did not consider the impact on learning outcomes. As discussed, this may be a particular issue when considering the impact of auditory stimulation, therefore future research is needed where both off-task behaviour and achievement are assessed.

In summary, the current study aimed to conduct a timely and systematic investigation into how aspects of the classroom sensory environment affect the ability of autistic and neurotypical children to stay on-task. To this end, a bespoke pop-up classroom was developed that allowed children to work independently under four sensory conditions: Baseline, Audio, Visual, and Audio-Visual. Children were video-recorded in each condition and coders observed incidents of on-task, off-task, and supported engagement behaviours in each condition. In the first aim of this study, it was found that autistic children spent a significantly greater proportion of time off-task and in supported engagement relative to neurotypical children. It should be noted however, that both groups were engaged on-task for at least three quarters of the time. In the second aim of this study, it was found that although autistic children evidenced more off-task behaviour, autistic and neurotypical demonstrated the same pattern of off-task behaviour across conditions. Indeed, both groups demonstrated significantly more off-task behaviour in the Visual and Audio-visual conditions relative to Baseline and Audio. Moreover, both groups evidenced significantly more environmental distractions in Visual and Audio-Visual condition relative to Baseline and Audio. In terms of implications for the classroom, results, therefore, suggest that minimizing the number of displays may improve the on-task behaviour of both autistic and neurotypical children. This is a critical finding because the visual aspect of the classroom is easily adapted and therefore easy to intervene with, potentially even at a national level. Findings from Aim 4 indicate that this approach may be particularly beneficial for younger neurotypical children and autistic children with greater levels of sensory sensitivity. Overall, findings emphasize that the classroom sensory environment is an important source of off-task behaviour for all children but particularly for children with a diagnosis of ASD.

Chapter 8: General Discussion

8.1 Introduction

This thesis adopted a mixed-method, multi-informant approach to investigate the relationship between sensory processing differences, classroom behaviour, and academic achievement for autistic pupils. The thesis began by exploring the evidence for sensory processing differences in ASD. One clear finding from the review was that sensory differences in autism are highly prevalent and highly variable (Uljarevic et al., 2017; Ben-Sasson et al., 2019). In Chapter 2, the importance of understanding these differences within an educational context was emphasized. It was highlighted that despite a range of reforms, there are still considerable inequalities in the availability and quality of support offered to autistic children attending schools in the UK (Henshaw, 2016; Van Herwegen, Ashworth & Palikara, 2018). The academic achievement of autistic pupils was also reviewed in Chapter 2, with the literature indicating that at a group level, autistic pupils demonstrate lower levels of achievement compared to their neurotypical peers (Keen, Webster & Ridley, 2016). Moreover, there was some evidence that factors beyond IQ might be influencing the achievement of autistic pupils (Kim, Bal & Lord, 2018; Chen et al., 2019; Estes et al., 2011). Drawing on previous work, it was argued that sensory differences might be an important factor when thinking about autistic pupils' academic achievement, and their classroom behaviour and school life more broadly (Ashburner, Ziviani & Rodger, 2008; Howe & Stagg, 2016).

The first empirical aim of the thesis was to investigate the relationship between IQ and academic achievement for autistic and neurotypical pupils (Chapter 3). This first investigation was key because although previous research has identified potential IQ-achievement discrepancies in ASD, the prevalence and direction of these discrepancies was unclear (Kim, Bal & Lord, 2018, Mayes et al., 2020). Likewise, a lack of suitable comparison group, meant it was not possible to ascertain if these achievement profiles were restricted to autism or reflected those seen in neurotypical development (Jones et al., 2009; Mayes et al., 2020). Findings from Chapter 3 indicated that although IQ-achievement discrepancies exist in neurotypical development, the nature of these discrepancies differs to those seen in autism. Indeed, 18% of autistic children overachieved in Reading compared to 40% of neurotypical pupils. Likewise, in Maths, 40% of autistic children were found to be underachieving compared to only 5.3% of neurotypical pupils. Given these different profiles, it was suggested that the factors underlying the IQ-achievement discrepancies may be different in ASD and in NT. Importantly, it is only by comparing NT and ASD within one study in which such conclusion can be drawn. This makes an important contribution to the thesis by indicating different factors may need to be targeted when thinking how best to support autistic and neurotypical academic achievement at school. Drawing on previous literature, it was suggested that Working Memory might be contributing towards neurotypical pupil's academic achievement whereas sensory processing differences were predicted to have a unique and important role for autistic pupil's academic achievement (Alloway & Alloway, 2010; Ashburner, Ziviani & Rodger, 2008).

The aim of Chapter 4 was to therefore gather insights from parents and teachers via an online questionnaire, to explore their views on if, and how, sensory differences might impact the learning and classroom behaviour of autistic pupils

(Jones, Hanley & Riby, 2020). Parents and teachers perceived sensory differences as having a substantial impact on learning, namely through causing distraction, distress, anxiety, and reducing participation within the classroom. Importantly, it was auditory, tactile, and visual stimuli that were perceived to be most impactful on learning. However, parents and teachers explained that increased predictability, school resources and appropriate classroom design could reduce these potential negative impacts. While these insights were incredibly valuable, it was also critical to understand these issues from the perspective of autistic individuals. As previous evidence had suggested increased sensory differences in autistic females, in Chapter 5 late-diagnosed autistic females were asked to reflect back on their sensory experiences at school (Lai et al., 2015). These rich qualitative reflections supported the views of parents and teachers in Chapter 4, thereby ensuring validity of these findings, and also provided novel insights into the relationship between social and sensory challenges at school. Critically, by drawing together findings from Chapters 4 and 5, this thesis demonstrates the value of adopting a multi-perspective approach, with all three central parties emphasizing the potential challenges and impact of sensory differences on autistic pupils learning, behaviour and well-being at school.

Building on these qualitative insights, Chapter 6 used standardized questionnaires and assessments to examine the relationship between sensory processing differences, academic achievement, and classroom behaviour. Importantly, this study asked teachers, and not parents, to reflect on pupil's sensory differences. This was vital because previous work had shown that the nature and severity of sensory differences is often context-dependent (Brown & Dunn, 2010; Smith &

Sharp, 2013). Given the findings of previous chapters, it was predicted that greater sensory differences would be associated with poorer academic achievement and poorer classroom behaviour. Although greater sensory differences were associated with greater levels of hyperactivity and poorer peer-relations, unexpectedly Sensitivity was positively related to Reading achievement. Moreover, hierarchical regression revealed that Sensitivity accounted for a small (7.5%) but significant amount of variance in scores. While caution is needed due to small sample sizes, it was argued that a range of cognitive, perceptual, and behavioural explanations could account for this unexpected finding (Liss et al., 2006; Remington et al., 2019; Tymms & Merrell, 2011). Importantly, this finding emphasizes positive aspects of sensory differences and illustrates that in some circumstances, sensory differences may actually benefit the academic achievement of autistic pupils.

Up to this point in the thesis, the focus had largely been on children's sensory differences with limited consideration of how sensory features of the classroom environment might impact those sensory characteristics and also impact children's learning and behaviour. However, key to the Nordic Relational Model of Disability is consideration of both the person and the environment (Tossebro, 2014, Gustavsson et al., 2005). Therefore, in Chapter 7, a novel experimental paradigm was developed to examine how Audio, Visual and Audio-visual classroom stimuli impact the ability of autistic and neurotypical children to stay on-task while completing a reading comprehension activity. Developing this novel pop-up classroom was vital for ensuring rigorous manipulation and for isolating and comparing the effect of different sensory inputs on behaviour in a systematic and controlled way. The study also makes an important contribution to the thesis by examining learning and off-task behaviour using observation as opposed to standardized assessments and questionnaires. Thus, ensuring a holistic and broader understanding of how sensory differences and the classroom sensory environment impact the educational outcomes of autistic pupils. Using this pop-up classroom, it was found, across all conditions, autistic pupils spent significantly more time off-task compared to neurotypical pupils. Both groups however demonstrated the same pattern of off-task behaviour such that off-task behaviour was greatest in the Visual and Audio-visual condition and lowest in the Audio and Baseline condition. This was somewhat unexpected as teachers and parents in Chapter 4 had identified Audio stimuli as particularly distracting and impactful on learning. Several explanations, including the role of predictability, were offered to account for these contradictory findings. The source of off-task behaviour across conditions was also explored and it was found that Environmental distraction was greatest in the Visual and Audio-visual condition and lowest in Audio and Baseline. Thus, indicating that the high levels of off-task behaviour in the Visual and Audio-visual condition were largely being driven by Environmental Distraction, namely looking at and engaging with the displays present in the classroom environment.

Taken together, findings from this thesis can be used to develop a framework to understand how, and under which circumstances, sensory processing differences impact the academic achievement and classroom behaviour of autistic pupils. This framework is shown below in Figure 1. Illustrated in grey, Figure 1 shows that there are several pathways by which sensory differences can impact autistic children at school. This includes, exacerbating social challenges, reducing participation, increasing distraction/off-task behaviour and heightening anxiety. These pathways are presented in the white boxes in Figure 8.1 below. At the same time however, it is clear that the school context is key in shaping this relationship. In line with the Nordic Relational Model of Disability, findings indicate that factors such as predictability and control, classroom design, school resources and staff knowledge moderate this relationship and can determine whether or not sensory differences have an impact on achievement and behaviour. These external impacts are represented in the blue outside edge of Figure 8.1.

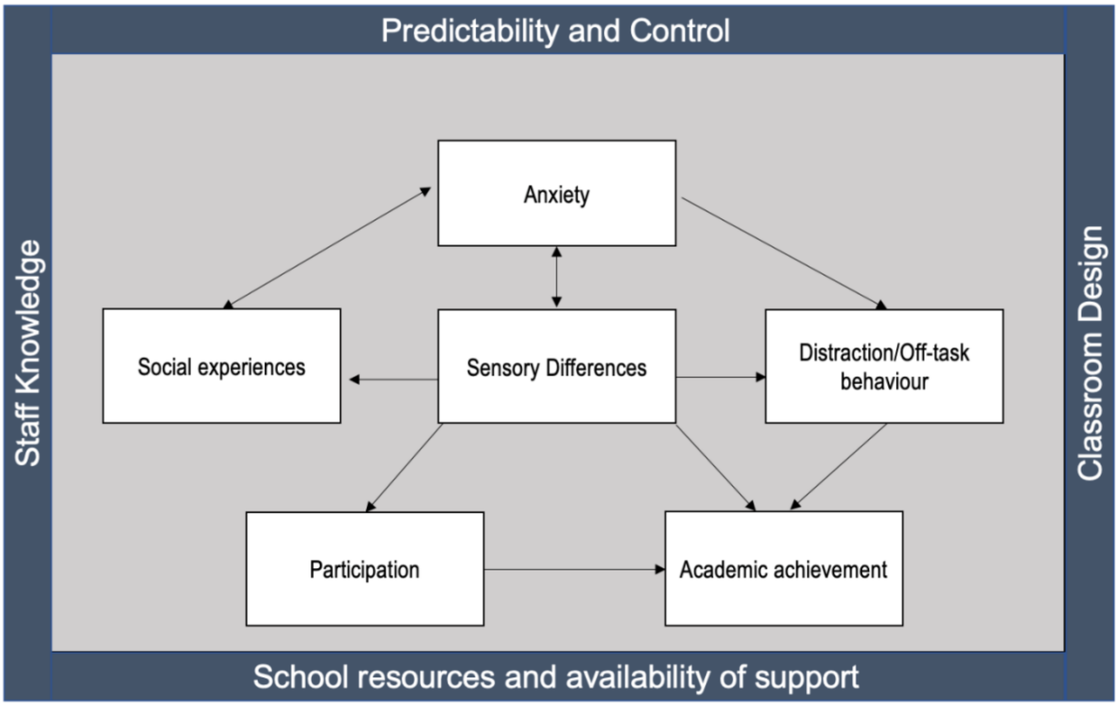


Figure 8.1: A framework to visualise how, and under which circumstances, sensory differences impact the educational outcomes of autistic pupils.

In this final chapter, each component of this framework will be discussed in turn, with a focus on highlighting what this means for our theoretical understanding of sensory differences and also our applied understanding of how best to support autistic pupils at school. Lastly, this chapter will evaluate the strengths and limitations of the thesis and present several directions for future research.

8.2 What are the nature of sensory differences at school?

The first component of this framework that we will consider is the nature and severity of autistic pupil's sensory differences at school. As emphasized in Chapter 1, although sensory processing differences are well documented in ASD, and indeed are listed as part of the diagnostic criteria, very little research has considered the nature of sensory differences within an educational setting (APA, 2013; Keen, Webster & Ridley, 2016; Uljarevic et al., 2017). However, there is some suggestion that sensory differences are, to some extent situational, meaning that the presentation and severity of these differences is influenced by the environment in which an individual is placed (Brown & Dunn, 2010; Smith & Sharp, 2013). Framed within a Nordic Relational Model Disability, it was suggested that sensory differences might be particularly severe and impactful within a classroom context as this space in especially stimulating and multi-sensory in nature (Tøssebro, 2004; Donohue et al., 2012).

Quantitative and qualitative evidence, gathered from multiple informants throughout this thesis, support this view and make an important contribution to the literature by providing a holistic account of the nature and severity of sensory differences at school. Quantitative findings from Chapter 6 indicate that the majority of autistic children are experiencing substantial hypersensitivity at school, with 91% of children evidencing 'Avoiding' behaviours 'Much More Than Others' and 74% evidencing ‘Sensitivity’ behaviours ‘Much More Than Others’ (as reported by teachers via the Sensory Profile School Companion). The high levels of hypersensitivity reported here are in line with previous work that has indicated that hypersensitivity best distinguishes ASD from typical development and other neurodevelopmental disorders (Ben-Sasson, et al., 2019). From an applied perspective, such high levels of hypersensitivity seem to indicate the need to reduce levels of sensory stimulation within the school environment. Qualitative insights captured in Chapters 4 and 5 provide clear examples of the types of stimuli that could be targeted if such an approach were to be taken. In support of the findings of Howe & Stagg (2016), parents and teachers in Chapter 4 identified Auditory, Tactile and Visual stimuli as most impactful on learning and school life. In terms of auditory stimuli, loud and unpredictable noises such as fire-alarms and hand-dryers were identified as being problematic, as were low intensity noises such as the pen on a whiteboard. Late-diagnosed autistic females in Chapter 5 provided further insights and explained that multiple streams of competing auditory input were more challenging than a single stream of auditory input, although again there were vast individual differences. Autistic adults in a focus group conducted by Smith and Sharp (2013) have also identified predictability and competing streams as key factors in influencing whether sensory input is perceived as enjoyable or adverse. This has important implications for the classroom, because although findings from the current thesis strongly suggest the need to minimize loud and unpredictable stimuli at school, the world at large is not a predictable and quiet place. Creating an almost artificial environment, characterized by minimal and predictable input may thus be detrimental to autistic individuals in the long term, as it won’t afford the opportunity to learn about new stimuli nor learn how to manage potential adverse sensory events (Neil et al., 2016; Boulter et al, 2014; South & Rodgers, 2017). The findings of Kirkby, Dickie and Baranek (2015) highlight the importance of such experiences. In this study, autistic children (Mean age= 8.3 years) reported using strategies such as deep breathing and self-talk when faced with potentially distressing sensory stimuli. For instance, one child who did not like the sounds of toilets flushing stated "*I took deep breaths, I was like, 'K', that was it, not more flushing*" (p.322, Kirkby, Dickie & Baranek, 2015). Collectively, these findings emphasize that there is a need to balance the sensory needs of pupils whilst simultaneously preparing children to be able to manage hypersensitivity and unpredictable input outside of the school environment (South & Rodgers, 2017).

A complete reduction of sensory stimulation could also be detrimental because it is clear that many autistic children also experience high levels of hyposensitivity in school. Again, this emphasizes the heterogeneity in sensory differences and highlights the need to move away from a one size fits all approach and for individual differences to be considered. Indeed, in Chapter 6, 39% of autistic children were demonstrating Seeking behaviours 'Much More Than Others' (as reported by teachers via the Sensory Profile School Companion) and 43% were evidencing 'Bystander' behaviours 'Much More Than Others'. Although the prevalence is less than that seen for hypersensitivity, it is important to note that behaviours linked to hypersensitivity (e.g., covering ears when hearing a loud noise) tend to be more overt and noticeable than behaviours linked to hyposensitivity (Dickie et al., 2009). Therefore, while the prevalence and severity of hyposensitivity documented in this thesis is high, it is important to recognize that this may still be an underestimation.

Acknowledging this limitation is important for both theoretical and applied reasons. First it emphasizes that sensory differences in ASD are heterogeneous and can be experienced across modalities and in both directions of responsivity. From an applied perspective, this means a balanced approach to intervention incorporating hyper- and hyposensitivity is needed. Emphasizing this are qualitative findings from Chapter 4 in which parents and teachers were asked to identify tactile experiences encountered by autistic pupils at school. Compared to auditory experiences, tactile experiences were much more diverse, in that some children would seek out input like '*hugs and kisses'* (indicative of sensory seeking) while at the same time becoming distressed by unexpected touch in the corridor (perhaps indicative of hypersensitivity). In line with the findings of Robertson and Simmons (2015), it was argued that the ability to control the stimulus explained the difference between these two situations, such that when children felt they had agency, there were able to seek and interact with stimuli in positive ways. Teachers in Chapter 4 offered several examples of how they were supporting seeking behaviours at school, for example "*Giving the students time to explore a room completely and look at things before they are expected to work*" (Teacher, mainstream) and "*Creating their own sensory experiences, such as mixing paint in the water trough*" (Teacher, mainstream). Thus, illustrating that a second approach to improving sensory experiences at school is to provide children with the agency and freedom to seek out explore different sensory stimuli at their own pace. Taken together, the findings discussed above illustrate that sensory differences at school are prevalent, severe, and heterogeneous for autistic pupils. One common theme, however, is that stimulus properties such as predictability and control largely determine the perception (adverse or enjoyable) and impact of different sensory inputs for autistic pupils.

8.3 How do sensory differences impact social experiences?

Thinking next about the impact of these sensory differences, one clear finding that emerged from this thesis is that there is a strong interplay between social and sensory experiences at school. As discussed in Chapter 1, to date, much of the behavioural research on RRBI and social experiences in autism has been siloed, meaning that the more prevailing theories of autism share the limitation of being unable to account for all aspects of the condition (Happé & Frith, 2020). This has led to the suggestion that perhaps multiple accounts are needed to explain multiple components of autism; an idea known as fractionation (Happé, Ronald & Plomin, 2006; Brundson & Happé, 2014). Other researchers have however, argued that the relationship between sensory and social behaviours in ASD is stronger that suggested in traditional models, and may in fact, be bidirectional and inter-dependent (Ronconi, Molteni & Casartelli, 2016; Gilga, 2014; Thye et al., 2018). Novel quantitative and qualitative evidence gathered in this thesis certainly seem to support this position.

Focusing first on quantitative evidence, in Chapter 6 it was found that greater sensory differences (as assessed through the Sensory Profile School Companion) were associated with poorer peer-relation in the classroom (as assessed through Connor's Teacher questionnaire). Although the Sensory Profile School Companion can confound attentional, sensory, and social difficulties, meaning this finding could in part be explained by shared variance, it is line with previous work that has explored this relationship using observation, rather than questionnaire methods (DuBois et al., 2017; Hughes, 2014; Damiano-Goodwin et al., 2018), therefore, mitigating the risk of shared variance (Hughes, 2014). Highlighting this is the work of Damiano-Goodwin et al. (2018), who first assessed toddlers sensory seeking and social orienting behaviours using the Sensory Processing Assessment at 18 months and then assessed social symptomatology using the ADOS when toddlers were 36months. It was found that children with greater seeking behaviours at 18 months also had greater social difficulties at 36 months (Damiano-Goodwin et al., 2018). Thus, supporting the findings of Chapter 6 and emphasizing that the association between sensory and social differences is closer than previously conceptualized in the more traditional models of autism e.g., ToM and WCC (Baron-Cohen, Leslie & Frith, 1985; Frith & Happé, 1994).

Nevertheless, these quantitative insights provide little clarity into *how* sensory differences might interact and influence the social experiences of autistic pupils. Capturing qualitative evidence from late-diagnosed autistic females in Chapter 5 was therefore vital for exploring such mechanisms and also in developing our understanding of the autism-female phenotype. A clear theme that emerged from Chapter 5 was that autistic females faced a difficult social experience at school. This is line with several other studies that have shown autistic females appear to be especially vulnerable to bullying and social isolation at school (Cook, Ogden & Winstone, 2018; Tomlinson, Bond & Hebron, 2020; Gray et al., 2001). Findings from Chapter 5 build on these findings and make an important contribution to the literature by demonstrating how sensory differences can exacerbate an already difficult social world. Late-diagnosed autistic females explained that their reactions to distressing sensory stimuli e.g., covering their ears when hearing a loud unpredictable noise often led to further teasing and name calling by peers. Social spaces such as assemblies were also over-stimulating, meaning that although females may have had high motivations for friendships, they were unable to access spaces that would have afforded them the opportunity to create and maintain these relationships. Instead, participants reported a preference for spaces such as the library or shaded areas outside; spaces characterized by reduced stimulation and solitude.

Collectively, findings from Chapters 5 and 6 have several important implications. Focusing first on our understanding of the autism female phenotype, findings illustrate that many females have strong motivations for friendship. When considered alongside the work of Cook et al. (2012) and Sedgewick (2016), this provides a direct challenge to the Social Motivation Theory of autism and emphasizes that this account cannot be applicable to all autistic individuals. Findings also support the hierarchal model of Williams and Shellenberger (1994), introduced in Chapter 1 of this thesis, in which sensory differences early in life are theorized to cascade into challenges in other cognitive and behaviour domains. Lastly, findings suggest that supporting the sensory needs of pupils may also benefit social experiences at school.

8.4 How do sensory differences impact anxiety?

Thinking next about the third component of the framework, a clear theme that emerged from chapters 4 and 5 is that the school sensory environment can be a substantial source of anxiety for autistic pupils. Indeed, one teacher from mainstream school explained "*I have seen heightened anxiety and increasingly more challenging behaviours in many pupils who have not had their sensory needs met*." In addition to impacting the wellbeing of autistic children at school, anxiety related to sensory differences was also perceived to disrupt the learning experiences of autistic children. One parent explained "*She either appears anxious or angry. How can you possibly learn with all that adrenaline rushing through you? It's like asking someone to do long division when they're free falling from a plane. It's Not going to happen*". This supports the work of McDougal, Riby and Hanley (2020) in which teachers were asked to identify the factors most important for autistic children's learning in the classroom. Anxiety was identified as a key barrier to learning as it often prevented children from concentrating and being able to engage with the task at hand. Understanding and reducing anxiety related to sensory differences is therefore potentially critical for both the wellbeing and achievement of autistic pupils at school (McDougal, Riby & Hanley, 2020; Howe & Stagg, 2018; Humphrey & Lewis, 2008).

Focusing first on our theoretical understanding, there is strong evidence that sensory differences contribute to the development and maintenance of the anxiety experienced by autistic individuals (South & Rodger, 2017; Green et al., 2012; Hwang et al., 2020). Highlighting this relationship is the work of Green et al. (2012) who undertook a longitudinal study of 149 toddlers (Mean Age=28.3 months) and found that hyperreactivity predicted an increase in anxiety over time, indicating that sensory hyperreactivity emerges earlier in development than anxiety. In terms of maintenance, autistic adults have previously explained that high levels of anxiety can result in heightened sensitivities, which in turn results in greater anxiety and further sensory sensitivities; a process referred to as the ‘Sensory Avalanche’ (Smith & Sharp, 2013).

Findings from this thesis indicate that the same mechanisms are at play within the school environment, with unpredictable and uncontrollable stimuli such as fire-alarms and sirens reported to be most anxiety provoking and distressing for autistic pupils. This supports the Intolerance of Uncertainty framework discussed in Chapter 4 and emphasizes once again, the need to gradually expose children to uncertain and novel situations, rather than shielding or flooding them with these types of stimuli (South & Rodgers, 2017; Boulter et al., 2014). One intervention that has been developed to do just that is the ‘Coping with Uncertainty in Everyday Situations CUES’ program (Rodgers et al., 2019). In this intervention, parents attend eight group sessions to learn about strategies and tools that can be implemented to help their child develop a more flexible and confident approach to uncertainty. Findings from early evaluation work suggests this intervention is feasible and acceptable to parents (Rodgers et al., 2019). One potential avenue for future work could therefore be modifying this intervention to focus on teachers rather than parents and embedding this within a school environment.

A second approach to intervention, and one that could be implemented nationally, might be to raise awareness amongst school staff of the relationship between sensory differences and anxiety. Although the majority of parents and teachers in chapter 4 recognised this relationship, the work of Adams, Simpson and Keen (2020) emphasizes that this is not always the case. In this study, 113 autistic children between the ages of 6 and 14 were asked to share their experiences of anxiety at home, school, and community settings (e.g., activities outside home or school, such as clubs and sports). Nearly all children reported experiencing anxiety in at least one of these environments. Prevalence was greatest in school (83.2%), followed by home (75.9%) and then the community (58.4%). However, only 50% of children felt that teachers were able to recognize when they were anxious at school (Adams, Simpson & Keen, 2020). This is a critical issue because without this identification, children cannot be supported in the classroom and this could have substantial impacts on both the wellbeing and achievement of pupils (McDougal, Hanley & Riby, 2020; Howe & Stagg, 2016).

Findings from Chapter 5 suggest that recognizing anxiety related to sensory differences may be especially challenging in autistic females. Indeed, many autistic females reported camouflaging their anxiety until they got one home, with one participant explaining "*I wasn't permitted to do things like stimming or publicly melting down or expressing anxiety, so I tried to keep it all inside and just got exhausted later*"*.* Although autistic males can and do camouflage, evidence suggests that these types of behaviours are more common in females (Hull, Petrides & Mandy, 2020). This has led to several researchers identifying camouflaging as a key feature of the female autistic phenotype (Lai et al., 2017; Wood-Downie et al., 2021; Hull, Petrides & Mandy, 2020). Autistic individuals have explained that there are several benefits to camouflaging, such as assimilation and connecting with others (Hull et al., 2017). However, camouflaging behaviours have also been associated with increased mental health difficulties (e.g., Hull et al., 2019b) and are viewed as a risk marker for suicidality (Cassidy et al., (2018). Future work is therefore needed to explore teachers understanding of camouflaging in autistic females and to evaluate whether specific training on recognizing anxiety in this group is needed.

8.5 How do sensory differences impact school participation?

As illustrated in Figure 1, the fourth pathway by which sensory differences can impact the educational outcomes of autistic pupil's is by restricting classroom participation. As highlighted in Chapter 1, discourse surrounding inclusion and provision remains contentious (All Party Parliamentary Report on Autism, 2017). One growing consensus however is that participation and inclusion means more than merely sitting in class (Hodges et al., 2020; Simpson, Imms & Keen, 2021; Imms et al., 2016). Indeed, Imms et al. (2016) has suggested that participation is comprised of two essential components: attendance and involvement. Attendance is defined as "being there" and is measured as the frequency of attending and/or the range of diversity of activities" (Imms et al., 2016; 36). Involvement is defined as "the experience of participation while attending, including elements of motivation, persistence, social connection, and affect" (Imms et al., 2016; 36). Findings from Chapter 4 indicate that unsupported sensory differences can impact both components of participation. First, in line with the findings of Piler and Pfeiffer (2015), sensory differences can impact 'attendance' by limiting the ability of autistic children to engage with certain tasks in the classroom e.g., arts and crafts, music lessons. Moreover, unsupported sensory differences can result in children having to withdraw from class or being unable to attend school altogether. Emphasizing this is the following extract from a parent in Chapter 4 who explained "*He begs us to home school him. He misses a lot of lessons, often just getting the worksheet, then withdrawing from class to work elsewhere."* Sensory differences can also impact involvement by triggering emotional and physical reactions such as "*meltdowns, tears, screaming, tantrum like behaviours*". Findings thus indicate that sensory differences can be a risk factor to the successful participation of autistic children at school (Piller & Pfeiffer, 2015).

Again however, this needs to be understood within a given context, as many teachers used a range of strategies to support the sensory needs and participation of autistic pupils in class. One such strategy was ensuring that staff had knowledge of autism and also specific knowledge of each child's sensory needs. For example, one parent explained "*My child's school is a special school, and they are fully aware of his and all the other kids in the class's sensory profiles. When they allocate groups, this is primary concern".* The importance of staff knowledge in enabling participation has been highlighted previously in the work of Hodges et al. (2020). In this study, parents and teachers were asked to identify the factors most important for promoting autistic children's participation in the classroom. A critical factor that emerged from these discussions was 'Being expected to participate'. Underpinning this factor was the sense amongst parents and teachers that some educators did not know their autistic pupils well enough to make judgments on the pupil's capability or willingness to participate (Hodges et al., 2020). Taken together, these findings emphasize the importance of building knowledge of autism and supporting teachers to become experts in their pupil's sensory differences and needs. This could involve asking caregivers to complete a sensory questionnaire, observing a child in class, asking children directly about the things they do and don't like in the classroom and seeking support from other professionals such as educational psychologists and occupational therapists. Supporting such an approach are the findings from an All-Party Parliamentary Group survey in which 60% of autistic young people said that the key thing that would make school better is having a teacher who understands autism (All Party Parliamentary Report on Autism, 2017).

A second strategy adopted by teachers and parent in Chapter 4 was to offer a range of occupational tools such as ear defenders, weighted blankets, and sensory diet programmes to autistic pupils. This approach aligns with the second key factor identified in Hodges et al. (2020) in which parents and teachers explained that access to appropriate supports were key to maximizing pupils' school participation. However, there was a perception amongst parents and teachers in Chapter 4 that these resources were much more readily available in special education provision than in mainstream schools. This reflects a much wider issue of variability in the support and provision available to autistic pupils across the UK (Henshaw, 2016; Van Herwegen, Ashworth & Palikara, 2018; All Party Parliamentary Report on Autism, 2017). Acknowledging this variability is important because although teachers in the current thesis were able to demonstrate an understanding of sensory differences and outline a range of practices to support these differences, this may not be representative of teachers across the UK. Indeed, we know that not all local authorities invest in centralized educational psychology services which could impact the ability of teachers to access occupational therapy tools in certain areas (All Party Parliamentary Report on Autism, 2017). Likewise, we know that specialist input from professionals is not always available when conducting EHCP assessments, meaning that teachers can be left unsupported to manage complex sensory needs in the classroom All Party Parliamentary Report on Autism, 2017).

Therefore, while findings from the current thesis emphasize that focusing on factors such as teacher knowledge and classroom design will likely benefit the educational outcomes of autistic pupils, systematic changes at institutional level are also needed if autistic pupils are to be supported to reach their full academic potential at school.

8.6 How do sensory differences impact distraction/on-task behaviour?

By adopting a Nordic Relational Model of Disability, this thesis has made an important contribution to the literature by demonstrating how a child's sensory differences, the classroom sensory environment, and the interaction between these two, impact the ability of pupils to stay on-task. This relationship has been illustrated in the framework proposed in Figure 1. In doing so, it has emphasized the interconnectedness of sensory and attentional differences and has provided important insights on how best to adapt classroom stimuli to meet the learning needs of both autistic and neurotypical pupils. Key to building this understanding was the use of multiple methods, namely, standardized questionnaires, qualitative insights, and a novel experimental method.

Focusing first on quantitative insights, it was found in Chapter 6 that greater levels of Sensory Seeking (as reported by teachers via the Sensory Profile School Companion) were associated with greater levels of Hyperactivity (as reported by teachers via Connors Questionnaire) and accounted for 49.5% of the variance in scores. Likewise, greater Bystander scores were associated with greater levels of Inattention and accounted for 36% of the variance in scores. This does seem to offer a degree of support to the model proposed by Dunn (1997; 2014). In this framework, it was proposed that a child with high levels of sensory seeking might be identified by behaviours such as making noises while working, chewing objects, and touching furniture. It was suggested that all of these behaviours might represent strategies to increase levels of sensory stimulation to meet high neurological threshold (Dunn, 1997; 2014). Such behaviours could also be interpreted as Hyperactivity. Conversely, it was proposed that those with high levels of Bystander/Registration might miss more sensory cues than others, for example, missing teacher instructions. This too, could be interpreted as Inattention in the classroom. While there are some potential strengths associated with Seeking and Registration profiles (see Chapter 1) it is important to note that Hyperactivity and Inattention have strongly been associated with poorer academic achievement (Rabiner et al., 2000; Rodriguez et al., 2007; Merrell & Tymms, 2001). Highlighting this is the work of Merrell and Tymms (2001) who assessed the Reading and Maths achievement 4184 neurotypical children at the start of formal education (ages 4-5) and then one year later at the end of Key Stage 1 (ages 6-7). Teachers were asked to report on children's inattention, hyperactivity and impulsivity using a behaviour rating scale. Importantly, Hyperactivity and Inattention were found to be significantly associated with poorer academic achievement at the end of Key Stage 2. In terms of the mechanisms underlying this relationship, it was suggested that Inattention and Hyperactive behaviours might impact the ability of children to plan responses and remain on-task (Merrell & Tymms, 2001).

Qualitative insights gathered in Chapters 4 and 5 do offer some support for this view and also indicate the types of stimuli that are most likely to lead to off-task behaviour and distraction in the classroom. Visual sources of distraction included bright classroom displays whereas distracting auditory stimuli included the noise of peers chatting, the school bell, and noises outside the classroom including traffic and children playing on the school year. Teachers interpreted auditory distraction to be caused by an inability to "*to tune out the noises they don't need affecting their ability to listen to instructions/input*". This supports the work of Ashburner, Ziviani and Rodger (2008) in which auditory filtering differences (as assessed through the Sensory Profile) were found to negatively impact autistic pupils reading achievement.

Building on these insights, the aim of Chapter 7 was to examine how the classroom sensory environment impacted children's on-task behaviour using an experimental paradigm. Adopting an experimental design with a rigorous manipulation was important for isolating and comparing the effect of different sensory inputs on behaviour in a systematic and controlled way. This approach was critical for several reasons. Notably, previous research had focused on only visual input or only the auditory input and neglected that the classroom is a rich multi-sensory space (Godwin, Erickson & Newman, 2019; Hanley et al., 2017; Fisher, Godwin & Seltman, 2014). Second, much of the previous research had focused on the ability of neurotypical children to stay on-task (Fisher, Godwin & Seltman, 2014; Moffett & Morrison, 2020). However, as indicated in Chapters 4, 5 and 6, the sensory and attentional differences experienced by autistic pupils may make them especially susceptible to off-task behaviours, particularly in rich multisensory environments. Findings from Chapter 7 support this view and make an important contribution to the literature by providing timely recommendations on how classrooms might be configured to meet a diverse range of sensory needs.

A key finding from this study was that across all conditions, autistic children spent significantly more time off-task compared to neurotypical pupils. However, the profile of off-task behaviour was the same across conditions such that both groups of children spent significantly more time off-task in the Visual and Audio-visual condition and this effect was largely driven by Environmental Distraction. This is in line with Hanley et al. (2017) who found that although visual displays impacted attention for all children, this effect was particularly pronounced for autistic children. Likewise, Fisher, Godwin and Seltman (2014) found that neurotypical children spent significantly more time off-task in a decorated classroom as opposed to a sparse classroom, and this led to poorer learning outcomes. Taken together, these findings indicate that one approach to reducing off-task behaviour and improving the educational outcomes of both autistic and neurotypical pupils would be to reduce levels of visual stimulation in the classroom (Hanley et al., 2017; Fisher, Godwin & Seltman, 2014).

Importantly, the work of Barrett et al. (2015) emphasizes that this should be a reduction, not an elimination of visual displays. Indeed, Barrett et al. (2015; 122) found that that the relationship between complexity, defined as "*the degree to which the classroom provides appropriate visual diversity"* and academic achievement was curvilinear. Thus, suggesting that there is optimal amount of visual stimulation in the classroom, with both too little and too much stimulation negatively impacting children's progress (Barrett et al., 2015). Finding this balance is especially important given the high levels of severe hypersensitivity and hyposensitivity reported in Chapter 6 and also when considering the vast individual differences present in a classroom of upwards of twenty children. One avenue for future experimental and intervention work could therefore be to examine the impact of moderate amounts of visual stimulation (as opposed to all or nothing) on children on-task behaviour. It needs to be acknowledged however, that while a reduction in visual stimulation may benefit the educational outcomes of both autistic and neurotypical pupils, this intervention cannot be implemented in isolation. As emphasized throughout this chapter and in Figure 1, predictability and control, staff knowledge and resources are also key, albeit trickier, factors to focus on. Highlighting this is the finding that there was no significant difference in the percentage of off-task behaviour between the Auditory and Baseline condition in Chapter 7. This finding was unexpected because auditory input has consistently been identified as a source of anxiety, distress, and distraction throughout this thesis. However, it was argued that while the audio stimuli used in Chapter 7 reflected classroom background noise, it was not unpredictable nor particularly loud in nature; two properties identified as key in influencing the perception and impact of a stimulus (Smith & Sharp, 2013; Robertson & Simmons). This, therefore, highlights that adapting the school environment to meet the sensory needs of pupils means more than simply reducing levels of sensory stimulation. Instead, a package of work centred on staff knowledge, classroom design, predictability, and control. and school resources is needed.

8.7 What does this mean for academic achievement?

The framework outlined in Figure 1 provides a novel and holistic understanding of how, and under which circumstances, sensory processing differences might impact the academic achievement of autistic pupils. As emphasized in Chapter 2, understanding the factors that contribute to autistic pupil's academic achievement is important for two key reasons. First, at a group level autistic pupils tend to attain lower levels of academic achievement compared to their neurotypical pupils (Keen, Ridley & Webster, 2016). This is an issue because academic achievement has been associated with an array of future life outcomes including, employment, health, and financial security (Burgess & Gutstein, 2007). Second, there is some suggestion that factors beyond IQ might be influencing the academic achievement of autistic pupils (Jones et al., 2009; Mayes et al., 2020; Estes et al., 2011). Chapter 3 sought to explore these issues further by using standardized assessments to assess the relationship between IQ and Reading and Maths achievement in a group of autistic and neurotypical pupils matched for age and cognitive ability. It was found that IQ predicted Reading and Maths achievement in both groups and accounted for a significant amount of variance in scores. Significant IQ-achievement discrepancies were identified in both groups. However, the nature of the discrepancies differed between groups such that 18% of autistic children overachieved in reading compared to 40% of neurotypical pupils. Likewise, in Maths, 40% of autistic children were found to be underachieving compared to only 5.3% of neurotypical pupils. Given these different profiles, it was suggested that the factors underlying the IQ-achievement discrepancies may be different in ASD and in NT. Drawing on previous literature, it was suggested that Working Memory may be influencing the achievement of neurotypical pupils whereas sensory differences may be contributing towards the underachievement of autistic pupils (Alloway & Alloway, 2010; Ashburner, Ziviani & Rodger, 2008).

As emphasized above, qualitative findings of Chapters 4 and 5 certainly did seem to align with this view. It was, however, also important to examine this relationship quantitatively in Chapter 6 using standardized assessments to quantify the severity of impact. Although Ashburner, Zivinani and Rodger (2008) and Butera et al. (2020) had previously demonstrated that sensory processing differences negatively impact autistic pupil's academic achievement, critically, both studies had asked parents, and not teachers to reflect on children's sensory differences. Given the somewhat situational nature of sensory differences, it is argued that the severity and impact of sensory differences on achievement may have been underestimated in both of these studies. However, when asking teachers to report on sensory differences in Chapter 5, unexpectedly, Sensitivity scores were positively related to Reading achievement and accounted for a small (7.5%) but significant amount of variance in scores. Moreover, sensory differences were not related to autistic pupil's Maths's achievement, and therefore did not seem to offer an adequate explanation for the high levels of underachievement identified in Chapter 3.

However, when interpreting these findings using the framework proposed in Figure 1 and embedding this within a Nordic Relational Model of Disability, we can begin to see how context may moderate the relationship between sensory processing differences and academic achievement. Thinking first about the school resources, children in Chapter 6 attended special school, meaning they may have had better access to occupational therapy tools and specialist support compared to children attending mainstream or enhanced provision (All Party Parliamentary Report on Autism, 2017; Henshaw, 2016; Van Herwegen, Ashworth & Palikara, 2018). Likewise, teachers working in a special school may have a more thorough understanding of autism than teachers working in other provisions (Henshaw, 2016). Furthermore, small class sizes may have allowed teachers to become experts on each child's sensory profile allowing them to offer tailored support to pupils. This understanding may have also influenced how they designed the classroom e.g., number of visual displays and how they supported children to manage unpredictable events. Collectively, these strategies and behaviours may have limited the impact of sensory differences on participation, social experiences, distraction, and anxiety and enabled children to fulfil their academic potential at school. It should be emphasized that such practices are not limited to special schools and indeed we see from Chapter 4 that teachers across provisions are implementing some of these strategies. However, it is also clear that not all schools are taking/are able to take such an approach and under these circumstances, sensory differences can have a substantial and far-ranging impact on autistic pupil's well-being, learning and behaviour at school.

This has important implications for how we might think about sensory differences and autism moving forward. First, findings strongly argue against the medical model of autism as it's clear that wider social and environmental factors influence the sensory behaviours and experiences of autistic individuals (Goodley & Runswick-Cole, 2012; Milton, 2012). Indeed, rather than hypersensitivity and hyposensitivity being static traits that reside entirely within an individual, they appear to be more dynamic and are shaped by the environment in which an individual is placed. Findings thus support a move towards a Nordic Relational Model of Disability when thinking about autism and sensory differences (Wendelborg & Tøssebro, 2010; Tøssebro, 2014). Such a shift is also taking place when thinking about social differences in autism, with a recent focus on ‘Double Empathy’ (Milton, 2012; Mitchell, Sheppard & Cassidy, 2021). Rather than placing cause on the autistic individual, as is the case with ToM, Double Empathy emphasizes that communication is two-way and that a lack of understanding/empathy from neurotypical individuals also contribute to the social differences seen in ASD (Mitchell, Sheppard & Cassidy, 2021; Crompton et al., 2021). Approaching autism from Nordic Relational Model of Disability as opposed to a medical model, means that sensory differences are no longer seen as a ‘deficit’ that needs to be cured, but are instead something to be celebrated, supported, and understood in relation to the environment (Tøssebro, 2014). Consequently, interventions are not focused on changing the child but are instead focused on creating a match between the environment and an individual’s sensory needs. This has been illustrated throughout this discussion with suggested interventions largely focusing on increasing staff knowledge, ensuring access to resources, and reducing sensory stimulation in the classroom.

8.8 Strengths and Limitations

Thus far this General Discussion has identified key themes from the thesis to present a framework for understanding how, and under which circumstances, sensory processing differences impact the educational outcomes of autistic pupils. Focus will now turn to discussing the strengths and limitations of the thesis. Although each chapter has previously identified specific limitations, the aim of this section is to discuss limitations more broadly, paying particular attention to methodology and challenges associated autism research.

8.8.1 Measurement and Methodology

A key strength of this thesis is that it has adopted a multi-method approach to explore the nature and impact of sensory differences on autistic pupils' educational outcomes. As highlighted in the sections above, collecting quantitative evidence was vital for measuring the severity of sensory differences and quantifying impacts on classroom behaviour and achievement. Conversely, qualitative evidence was vital for unpicking the pathways by which sensory differences could impact achievement and also for building a holistic understanding of the nature of sensory differences at school. By combining methods, the advantage and disadvantage of each individual method becomes more balanced when looking at the thesis as a whole and has allowed multiple perspectives to be captured. There are, however, several limitations to consider, particularly in the approach taken to measuring achievement and sensory processing differences.

Focusing first on achievement, in Chapter 3 and 6, the WIAT was used as a standardized measure of children's reading and maths ability. While this measure permitted a direct comparison of achievement across pupils and schools, the nature of this assessment meant that not all children were able to take part (Howse, 2019; Hughes, 2014). For instance, minimally verbal autistic children were unable to participate in this task as several subscales require a verbal response (Wechsler, 2005; Hughes, 2014). Findings therefore cannot be generalized to the autistic population as a whole. It should be noted that minimally verbal, and autistic individuals with intellectual disability are often excluded from autism research so much so that this has been identified as a priority area for future work (Happé & Frith, 2020). Highlighting this is the work of Russell et al. (2019) who examined 301 autism papers published in 2016 and found that 94% of all participants had IQ in the average range. However, an estimated 50-55% of the autistic population have intellectual disability, meaning that a lot of autism research, including that presented in the current thesis, is only generalizable to a subset of the autistic population (Russell et al., 2019)

Moreover, there is criticism amongst teachers that standardized assessments do not allow for small aspects of academic progress, that are just as important to parents and pupils, to be captured (Howell, Langdon & Bradshaw, 2020). Emphasizing this is the work of Howell, Langdon and Bradshaw (2020) who undertook focus groups with teachers and found that learning behaviours such as attention skills, readiness to learn and social skills were viewed just as important as subject knowledge when considering achievement as a whole. For instance, one teacher explained "*We've had some children that won't even come into the class then you look, say, six months later they're in the class…that is progress*" (Howell, Langdon & Bradshaw, 2020; 12), Therefore, while the use of standardized assessments may have excluded some autistic children from taking part, it is important to note that the thesis did attempt to use wider indicators of achievement, namely observing on-task behaviour in Chapter 7 and asking for teacher insights in Chapter 4. This varied approach is certainly a strength especially when comparing to the work of Ashburner et al., (2008) and Butera et al. (2020) who only used questionnaires.

Thinking next about the measurement of sensory processing differences, this thesis largely relied upon the Sensory Profile School Companion (Dunn, 2014).

Although there are several questionnaires available to measure sensory processing differences, the Sensory Profile School Companion was selected as on key strength of this measure is that it was specifically designed for understanding sensory differences as they presented within the school context (DuBois et al., 2017; Dunn, 2014). There are, however, several limitations associated with this questionnaire and Dunn's Model of Sensory Processing more broadly (Hughes, 2014). Foremost, this questionnaire was not designed specifically for the autistic population. This is an issue because the presentation of sensory differences and motivations for a particular behaviour may differ to that seen in neurotypical development. It may therefore have been more valid to use a measure such as the Glasgow Sensory Questionnaire, which was designed specifically for autistic individuals (Robertson & Simmons, 2013). Second, many of the questions included on the Sensory Profile overlap with items on autism diagnostic instruments. For example, one item is "I do not get jokes as quickly as others". This relates to a wider issue of the School Sensory Profile often confounding social, sensory, and attentional differences (Hughes, 2014). This appears to be especially acute on the Avoiding scale as illustrated by the following items: "*interacts or participates in groups less than same-aged children*"; "*is distressed by changes in plans, routines, or expectation*" and "*is sensitive to criticisms*". While some of these items could reflect sensory processing differences, they could equally reflect social and RRBI differences that are characteristic of autism. This overlap could explain why the severity of Avoiding differences was so high in Chapter 6. A third issue is that within Dunn's Framework sensory seeking is thought to represent a strategy to manage hyposensitivity (Dunn, 1997; 2014).. However, there is some evidence that behaviours indicative of sensory seeking could actually reflect a strategy to manage hypersensitivity (Boyd et al., 2009; Joosten & Bundy, 2010). For example, some children may seek out predictable and controllable input to create a more ordered environment in the wake of severe hypersensitivity (Joosten & Bundy, 2010; Uljarevic et al., 2017). Lastly, the Sensory Profile does not consider how contextual factors, such as the emotional state of the child, classroom design and school resources can influence the presentation and severity of sensory differences. It is because of these limitations that moving away from such a rigid framework and capturing the first-hand accounts of autistic females was so important in Chapter 5.

8.8.2 Sample Size and Selection

Another important strength of this thesis is that it captured the views of multiple informants from across the UK. For instance, in Chapter 4 parents and teachers from across school provisions shared their views on the nature and impact of sensory differences in the classroom. Likewise, in Chapter 5 late-diagnosed autistic females shared first-hand accounts that supported the views of parents and teachers and also provided novel insights into the interplay between sensory and social differences at school. The use of a portable pop-up classroom in Chapter 7 also meant that a more representative group of children were able to take part than would have been possible had the classroom been fitted in a university building. Also key to ensuring a representative sample was permitting autistic children with co-occurring conditions to participate in the research. Including this group of children was important because autism rarely occurs in isolation (Mannion & Leader, 2013). Indeed, research by Simonoff et al. (2008) found that 30% of autistic children between the ages of 10 and 14 also had an ADHD diagnosis. While the inclusion of these children was important for capturing some of the variability seen in ASD, there is the possibility that the sensory and school challenges experienced by pupils with an autism and an ADHD diagnosis is very different to children only with an ASD diagnosis. For example, there is evidence that children with ADHD are most likely to underachieve academically in school and so recognizing and examining differences between these two groups of children could be an important avenue for future research (Mayes et al., 2020).

It also needs to be acknowledged that this thesis has relied on parent- or self-report to confirm a diagnosis of ASD. This is a limitation because it relies on individuals understanding what it meant by an ‘official diagnosis’. For example, it is possible that some participants in Chapter 5 were self-diagnosed. This possibility could have been avoided if researchers had conducted an independent autism assessment such as the ADOS. However, there in an on-going debate within the literature as to whether it is ethical to ‘redo’ a formal diagnosis for research purposes (Bishop, 2011). Moreover, it has been argued that the time, training, and space needed to conduct these assessments is often not practical when conducting small scale PhD research (Bishop, 2011). As such, a more common approach, and one taken by Hanley et al., (2017), is to use scores from the Social Responsiveness Scale (SRS; Constantio and Gruber, 2005) to confirm that all children in the ASD group had difficulties with reciprocal social behaviour. Although this thesis attempted to adopt this approach, return rates for this questionnaire were very limited, meaning SRS scores have not been included in all chapter of the thesis. Therefore, given these circumstances researchers felt that relying on parent- or self-report was the most appropriate approach when confirming a diagnosis of ASD.

8.8.3 Future Directions

Findings from this thesis suggest several directions for future research. One interesting finding that emerged from Chapter 4 was parents and teachers believed special schools might be more readily available to support the sensory needs of autistic pupils. One avenue for future research would be to compare the relationship between sensory differences and academic achievement across different school provisions (e.g., special schools versus mainstream schools). Linked to this investigation would be a comparison of the classroom sensory environment across different provisions. For example, using the framework developed by Barret et al., (2015) to explore levels of visual and auditory stimulation across mainstream and special schools. The experimental paradigm developed in Chapter 7 also offers several avenues for future research. One possibility would be to ask several children to complete the independent reading task at once to explore how the sensory environment impacts peer-distraction. As discussed in Chapter 7, a second important strand of research would be to use 'unpredictable' auditory input and examine how this stimuli impacts children's learning and off-task behaviour. Building on the work of Remington et al. (2009) another important piece of research would be to examine how moderate amounts of visual stimulation (as opposed to lots or no stimulation) impact on-task behaviour of pupils. This could then be extended to explore how varying amounts of visual stimulation impact the learning and on-task behaviour of pupils in actual classrooms, as opposed to a lab setting. Finally, there is a need to understand from the perspective of current autistic pupils how sensory differences impact school life and academic achievement (Uljarevic et al., 2017). Although late-diagnosed females were able to offer incredibly value insights when asked to report back on their time at school, it is important to recognise that this may not reflect the experience of males. Likewise, the introduction of legislation such as the Children and Families Act (2014) may have improved access to support for autistic pupils currently at school compared to that available a decade ago. Although previous studies such as Howe and Stagg (2016) have aimed to capture the perspective of current autistic pupils, they have tended to focus on secondary school children and used traditional methods such as questionnaires or semi-structured interviews (Ashburner et al., 2013).The use of more innovative methods such as diaries, photographs and drawings however could allow a wider group of autistic children to take part and provide novel insights into the nature and impact of sensory differences at school (Ha & Whittaker, 2016).

8.9 Conclusion

This thesis has provided a significant contribution to our understanding of how sensory differences can impact the academic achievement, school life, and classroom behaviour of autistic pupils. The multi-method, multi-informant approach adopted within this thesis permitted a rich investigation and allowed for a framework detailing the different pathways by which sensory differences can impact educational outcomes, and under which circumstances, to be developed. These pathways include limiting participation, heightening anxiety, increasing distraction, and exacerbating social difficulties. At the same time however, it is clear that the school context is key in shaping this relationship. In line with the Nordic Relational Model of Disability, findings indicate that factors such as stimulus predictability and control, classroom design, school resources and staff knowledge moderate this relationship and can determine whether or not sensory differences have an impact on achievement and behaviour. Left unsupported, sensory differences can have a substantial impact on autistic pupil's educational outcomes. It is therefore vital that this framework is used to develop interventions and to ensure autistic pupils are supported to achieve and thrive at school. Taken together, this thesis has therefore provided a comprehensive and valuable insight into the nature and impact of sensory differences at school and outlined clear directions for future research.

Appendices

Appendix A: Chapters 3 and 6 Information Sheet, Consent Form and Demographic Questionnaire

Durham University

Department of Psychology

Sensory Processing and Classroom Achievement

Parent Research Booklet

Dear caregiver,

Our research group in the Department of Psychology at Durham University is running a study that aims to understand the relationship between sensory experiences and classroom behaviour. We all need to be able to understand information from our sensory world, for example through touch, sight, or smell. School can often be a very busy sensory experience with lots of bright lights and colourful displays on the wall. In this project, we are interested in the relationship between sensory patterns (e.g. whether people seek out sensory information or shy away from sensory information) and academic behaviour in the classroom. This project will inform parents, teachers and researchers about the impact of sensory issues in the classroom, and importantly will hopefully feed into training and workshops for schools. In this booklet, you will find our information sheet, privacy notice, consent form and demographic questionnaire. Please read through this information carefully.

If you would like to take part in this research, please complete the consent form and demographic questionnaire (separate to this booklet) and return to school in the envelope provided by XXX.

Yours sincerely,
Liz Jones

Before you decide whether to agree for your child to take part it is important for you to understand why the research is being done and what participation will involve. Please read the following information carefully. Please contact us using the contact details shown at the bottom of the sheet if there is anything that is not clear or if you would like more information.

What is the purpose of the study?

The aim of this study is to examine the relationship between different sensory experiences and classroom behaviour and how this might relate to academic achievement. Previous research has suggested that sensory processing might be related to classroom engagement (e.g., paying attention to an academic task while there is loud noise or bright stimulating information on the walls distracting attention). However, we would like to study these issues in a large sample of children with Autism Spectrum Disorders to understand the relationship between sensory preferences and academic behaviours in more detail.

Why have I been asked to take part?

You have been asked to take part in this study because either your child's school is taking part in this study and they our helping us to recruit autistic/neurotypical {delete as appropriate} children. Your child's school has not passed on any information to us about your child, but simply has passed on these information sheets to you on our behalf. We are recruiting children aged 6-11 years

PARENT INFORMATION SHEET

Parents/Caregivers

You will be asked to complete two standardised questionnaires. The first questionnaire asks 86 questions about your child's sensory experiences whereas the second questionnaire asks 65 questions about your child's social behaviour and ability. Each questionnaire will take between 15 and 20 minutes to complete and if you want to split this over several days in your own time, that is fine. For both questionnaires, any questions you don't want to answer can be left blank. We also ask that you complete the Participant Information Questionnaire, which simply asks you to confirm that your child has a diagnosis of autism. We will provide anonymous codes on the questionnaire, so you do not have to write your child's name on them.

Teachers

Teachers will also be asked to complete two short, standardized questionnaires. One questionnaire will ask about your child's sensory experiences in school and the second will ask about your child's classroom behaviour and attention. This data will only be linked to the other information that is collected by anonymous codes and the information will be confidential.

Children

Children will complete an ability measure and an assessment of mathematical and reading achievement. These are standard assessments of academic achievement and intellectual functioning that are regularly used in developmental psychology research. For example, they involve tasks such as the child being presented with a geometric pattern and asked to reproduce this pattern using small two-coloured cubes. These tasks will be completed across two 45-minute sessions. The tasks described above will not be completed at one go. We will complete them on separate days to minimise the amount of time that children are out of class at any one time. We will explain everything to your child clearly, and if they do not wish to take part, we will take them back to class

PARENT INFORMATION SHEET

What are the benefits of taking part in the study?

We hope that this study will be a fun experience for everyone who takes part, and it will help the research team gain a greater understanding of the links between sensory experiences and academic achievement. In our experience, children really enjoy taking part in our research as the tasks are like fun games. Your child will be presented with a certificate for taking part.

What are the disadvantages of taking part in the study?

Since this study will be completed during the school day, your child will leave class to participate in data collection. We have divided the experiment into two sessions, which should last no more than 45 minutes each. We will take care to make sure to minimize the time your child spends out of class.

Do I have to take part?

Participation in this study is entirely voluntary and you will be free to withdraw your consent at any time after participation. Please note that after 12 months, all data will be anonymised.

What will happen to the data?

All data will be kept strictly confidential and secure in accordance with Data Protection Legislation. If we seek to publish the paper, the results from each participant will remain entirely anonymous and no individually identifiable information would be published. We will retain the research data for a period of 10 years after any publication. With your permission, we would like to share your child's ability achievement scores with the school but this is the only information that we would share on an individual level.

CHILD INFORMATION SHEET

LEARNING IN THE SENSORY WORLD

Our senses- smell, sound, touch work as a team to help us know what is going on in the world. The classroom can be a really **fun**, **colourful** and **noisy** place. Some children might really like all of this sound and colour but other children might find it hard to concentrate. We want to look at how your sensory experiences are related to how well you can learn in class.

What the teachers will do:

Teachers will answer some questions about your behaviour at school.

What parents will do:

Parents will answer some questions about your sensory behaviours at home

.

What you will do:

We would like to you to do some fun reading and maths tasks in school. We would also like you to try some thinking games and a few puzzles in class.

If you would like to help us with our work then that's great, please check with your parents or the person who looks after you. If you ever change your mind then don't worry that's ok, just tell someone and you can stop whenever you want to.

Privacy Notice

PART 1 – GENERIC PRIVACY NOTICE

Durham University's responsibilities under data protection legislation include the duty to ensure that we provide individuals with information about how we process personal data. We do this in a number of ways, one of which is the publication of privacy notices. Our privacy notices comprise two parts – a generic part and a part tailored to the specific processing activity being undertaken.

Data Controller: The Data Controller is Durham University. If you would like more information about how the University uses your personal data, please see the University's Information Governance webpages.

Data Protection Office: The Data Protection Officer is responsible for advising the University on compliance with Data Protection legislation and monitoring its performance against it. If you have any concerns regarding the way in which the University is processing your personal data, please contact the Data Protection Officer.

Retention: The University keeps personal data for as long as it is needed for the purpose for which it was originally collected. Most of these time periods are set out in the University Records Retention Schedule.

Your rights in relation to your personal data

Privacy notices and/or consent: You have the right to be provided with information about how and why we process your personal data. Where you have the choice to determine how your personal data will be used, we will ask you for consent. Where you do not have a choice (for example, where we have a legal obligation to process the personal data), we will provide you with a privacy notice. A privacy notice is a verbal or written statement that explains how we use personal data. Whenever you give your consent for the processing of your personal data, you receive the right to withdraw that consent at any time. Where withdrawal of consent will have an impact on the services we are able to provide, this will be explained to you, so that you can determine whether it is the right decision for you.

Accessing your personal data: You have the right to be told whether we are processing your personal data and, if so, to be given a copy of it. This is known as the right of subject access. You can find out more about this right on the University's Subject Access Requests webpage.

Right to rectification: If you believe that personal data we hold about you is inaccurate, please contact us and we will investigate. You can also request that we complete any incomplete data. Once we have determined what we are going to do, we will contact you to let you know.

Right to erasure: You can ask us to erase your personal data in any of the following circumstances: We no longer need the personal data for the purpose it was originally collected; You withdraw your consent and there is no other legal basis for the processing; You object to the processing and there are no overriding legitimate grounds for the processing; The personal data have been unlawfully processes; The personal data have to be erased for compliance with a legal obligation; The personal data have been collected in relation to the offer of information society services (information society services are online services such as banking or social media sites). Once we have determined whether we will erase the personal data, we will contact you to let you know.

Right to restriction of processing. You can ask us to restrict the processing of your personal data in the following circumstances: You believe that the data is inaccurate and you want us to restrict processing until we determine whether it is indeed inaccurate; The processing is unlawful and you want us to restrict processing rather than erase it; We no longer need the data for the purpose we originally collected it but you need it in order to establish, exercise or defend a legal claim and You have objected to the processing and you want us to restrict processing until we determine whether our legitimate interests in processing the data override your objection. Once we have determined how we propose to restrict processing of the data, we will contact you to discuss and, where possible, agree this with you.

Making a complaint
If you are unsatisfied with the way in which we process your personal data, we ask that you let us know so that we can try and put things right. If we are not able to resolve issues to your satisfaction, you can refer the matter to the Information Commissioner's Office (ICO).

PART 2 – TAILORED PRIVACY NOTICE
This section of the Privacy Notice provides you with the privacy information that you need to know before you provide personal data to the University for the particular purpose(s) stated below.

Type(s) of personal data collected and held by the Department of Psychology and method of collection:
We will collect personal data on your child through the Participant Information Sheet questionnaire (date of birth, school, diagnostic information). If you consent, your child's ability scores and reading and maths scores will be shared with the school.

How personal data is stored by Department of Psychology: Each participant will be assigned an anonymous code at the beginning of the study. A password-protected list will be created that that links personal data and anonymous codes. This file will be kept separate from the anonymised data and will not be available to anyone outside the research team. After 12 months, this list will be destroyed and all data will become fully anonymised and cannot therefore be withdrawn because it will be impossible to identify who provided the data. Hardcopies will be kept locked in the supervisor's office at the Department of Psychology and all computer data will be stored in a password protected computer. If we seek to publish the paper, the results from each participant will remain entirely anonymous and no individually identifiable information would be published. We will retain the research data for a period of 10 years after any publication.

How personal data is processed by Department of Psychology: The personal data that we will collect through the participant information sheet will be used to confirm your child's age at the time of testing, and whether or not they have a diagnosis of a neurodevelopmental disorder. Once we have collected this information we will enter it into a data sheet, and 12 months after data collection these data will be completely anonymised and the original participant information sheet will be destroyed (this will happen at 12 months after data collection because at this point all data for the study will have been collected).

How long personal data is held by Department of Psychology: We will hold this data for 12 months from the point of data collection, after which it will be anonymised.
How to object to Department of Psychology processing your personal data:
If you have any issues with the processing of your personal data, please contact the lead researcher.

Informed Consent Form

Sensory processing and classroom achievement

Please read each of the following statements, and sign your initials after each to indicate that you have read and understood each one:

• I have read and understood the attached Information Sheet and Privacy Notice.

____

• I have been given full information regarding the aims of the research and have been provided with contact details should I require further information.

____

• I understand that any responses provided by me or my child will be anonymized and confidential.

____

• I understand that data from this study may be published in a scientific journal, or presented at a conference, but that no individually identifiable information will be revealed through these processes

____

• I give consent for my child to participate in this study.

____

• I understand that both myself and my child are free to withdraw from this study without having to give a reason to withdraw, and without any adverse result of any kind, up until the point at which the data are anonymized (within 12 months), after which we will not be able to identify the individual who provided the data.

____

- I consent to my child's ability scores and reading and maths scores being shared with the school. Yes/No _________

Parent/Caregiver's name:____

Parent/Caregiver's signature:_____________________________________

Date:_________

Participant Information Sheet Questionnaire

Please complete and return with the consent form and privacy notice.

Name of Parent/Guardian	
Name of child	
Name of school	
Child School Year	
Child DOB	
Does your child have any known neurological or developmental disorders? If yes please state diagnosis here:	

Appendix B: Chapter 4 Parent Questionnaire

Demographic Information

- What is your gender?
- What is your age?
- How old is your child with a diagnosis of an Autism Spectrum Disorder?
- What type of school does your child attend currently – please give as much detail as possible? (e.g. Mainstream/Special etc, and Primary/Secondary school, and any hours of one- to-one support?)
- In which country or countries did/does your child attend school?

Main Body

1) Are you familiar with the phrase ***hyper-reactivity*** to sensory input?

Yes	No

1a) If yes, how would you describe it to someone unfamiliar with the term?

2)Are you familiar with the phrase ***hypo-reactivity*** to sensory input?

Yes	No

2a) If yes, how would you describe it to someone unfamiliar with the term?

3) Does your child usually show unusual reactions or sensitivities to sensory information?

Yes	No

3a) If yes, please rate how frequently this occurs

Very Rare	Rarely	Occasionally	Frequently	Everyday

4) Can you describe a recent time during which your child had an **enjoyable** sensory experience (please provide as much detail as possible)?

5) Can you describe a time during which your child had a **negative** sensory experience (please provide as much detail as possible)?

6) What makes you believe that it is the sensory environment impacting these situations (for example is it a particular way your child reacts, or a particular stimulus that is always present)?

7) What strategies/techniques do you use to manage reactions to sensory information at home?

8) Do you believe your child's response to sensory information affects their life at school?

Very Rare	Rarely	Occasionally	Frequently	Everyday

8a) If so, how and what makes you believe this?

9) Are there any sensory experiences you believe your child might wish to **avoid** at school? What makes you think this – for example do they respond in a certain way?

10) Are there any sensory experiences you believe your child might **seek out** at school? What makes you think this – for example do they respond in a certain way?

11) Do you think your child's sensory experiences affect his/her ability to learn in the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

11a) If so, why do you think this and how do you think it affects **learning**?

12) Which modality do you think is most likely to affect learning for your child?

Sight	Smell	Touch	Taste	Hearing

13) The school environment is compatible with my child's sensory needs.

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

14) School is aware that my child might experience and react to sensory information differently

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

15) Teachers have received sufficient training and guidance to support pupils on the Autism Spectrum who may have different experiences and reactions to sensory information

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

16) School works closely with parents and pupils to support the sensory needs of the individual in class

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

17) My child's sensory needs are supported in school

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

18) Are there aspects of your child's school environment that you believe are **helpful** for your child's sensory needs (multisensory rooms, small class sizes etc)?

19) Are there aspects of your child's school environment that you believe are **not helpful** for your child's sensory needs (multisensory rooms, small class sizes etc)?

20)Finally, what do you think could (and should) be done to support pupils on the Autism Spectrum who have different sensory experiences at school and within the classroom?

Appendix C: Chapter 4 Teacher Questionnaire

Demographic Information

- What is your gender?
- How many years teaching experience do you have?
- What type of school's have you taught at (mainstream/special etc, primary or secondary)?
- In which country or countries have you taught pupils on the Autism Spectrum?
- Approximately how many pupils on the Autism Spectrum have you taught?

Main Body

1) Are you familiar with the phrase ***hyper-reactivity*** to sensory input?

Yes	No

1a) If yes, how would you describe it to someone unfamiliar with the term?

2) Are you familiar with the phrase ***hypo-reactivity*** to sensory input?

Yes	No

2a) If yes, how would you describe it to someone unfamiliar with the term?

3) Have you taught pupils on the Autism Spectrum who seemed to have different sensory experiences/reactions?

Yes	No

4) Thinking about the pupils that you have taught, what percentage of pupils with an ASD that you have taught, do you think experienced sensory issues in the classroom?

<10%	10-25%	26-50%	51%-75%	76%-90%	>90%

5) Can you describe a time during which a pupil on the Autism Spectrum seemed to have a **positive sensory experience** – tell us a little about the pupil and the experience?

6)Can you describe a time during which a pupil on the Autism Spectrum seemed to have a **negative sensory experience** - tell us a little about the pupil and the experience?

7) What makes you believe that it is the sensory environment impacting these situations?

8) Do you believe these types of sensory experiences/reactions affect pupil's **life at school**?

Not at all	Rarely	Sometimes	Frequently	All the time

8a) If so, how and what makes you believe this?

9) What behaviours are most indicative of a pupil having difficulty with sensory input?

10) Do you think sensory differences affect pupil's ability to **learn** within the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

11) More specifically, do you think that different experiences/reactions to ***auditory stimuli*** affect pupil's ability to learn within the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

11a) If so, how do you think it affected learning?

11b) Are there any lessons or activities in which this is a particular issue? For example, in p.e or group work?

11c) Do you use any strategies/techniques to manage these reactions?

12) Do you think that different experiences/reactions to ***visual stimuli*** affect pupil's ability to learn within the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

12a) If so, how do you think it affected learning?

12b) Are there any lessons or activities in which this is a particular issue? For example, in p.e or group work?

12c) Do you use any strategies/techniques to manage these reactions?

13) Do you think that different experiences/reactions to ***taste*** affect pupil's ability to learn within the classroom?

13a) If so, how do you think it affected learning?

13b) Are there any lessons or activities in which this is a particular issue? For example, in p.e or group work?

13c) Do you use any strategies/techniques to manage these reactions?

14) Do you think that different experiences/reactions to ***touch*** affect pupil's ability to learn within the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

14a) If so, how do you think it affected learning?

14b) Are there any lessons or activities in which this is a particular issue? For example, in p.e or group work?

14c) Do you use any strategies/techniques to manage these reactions?

15) Do you think that different experiences/reactions to ***smell*** affect pupil's ability to learn within the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

15a) If so, how do you think it affected learning?

15b) Are there any lessons or activities in which this is a particular issue? For example, in p.e or group work?

15c) Do you use any strategies/techniques to manage these reactions?

Based on your experiences at school, we would like you to indicate your agreement with the following statements.

16) I have received sufficient information and training to support pupils on the Autism Spectrum who may have different sensory experiences/needs.

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

17) I am not confident in my ability to teach pupils on the Autism Spectrum who have different sensory experiences.

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

18) My school works closely with parents and pupils to support the sensory needs of the individual in class.

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

19) Schools and teachers need more guidance to support pupils on the Autism Spectrum who might have different sensory experiences.

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

20) Are there aspects of the school environment that you believe are **helpful** for pupils' sensory needs (multisensory rooms, small class sizes etc)?

21) Are there aspects of the school environment that you believe are **not helpful** for pupils' sensory needs (multisensory rooms, small class sizes etc)?

22) Finally, what do you think could be done to support pupils on the Autism Spectrum with different sensory reactions/experience at school and within the classroom?

Appendix D: Chapter 5 Autistic Adult Questionnaire

We would like you to think back about your time in school. What was your favourite part of school and why?

Did you face any difficulties at school? If so, what were they?

We would like you to think about your reactions to the sights, smells, tastes, touch and the sounds you experienced at school. Can you describe a time when you had an enjoyable sensory experience at school? How did this make you feel?

Can you describe a time when you had a negative sensory experience at school? How did this make you feel?

Do you feel your experiences/ reactions to the sensory environment affected your life at school?

Not at all	Rarely	Sometimes	Frequently	All the time

5a) If so, how did it affect your life at school?

Were there any sensory experiences you wished to avoid at school? What were they?

Were there any sensory experiences you sought out at school? What were they?

Do you think your sensory experiences affected your learning within the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

More specifically, do you think that different experiences/reactions to auditory stimuli impacted your ability to learn within the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

9a) If so, how do you think it affected learning?

9b) Were there any lessons or activities in which this was a particular issue? For example, in p.e or group work?

9c) Did you use any strategies/techniques to manage this situation?

Do you think that different experiences/reactions to visual stimuli impacted your ability to learn within the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

10a) If so, how do you think it affected learning?

10b) Were there any lessons or activities in which this was a particular issue? For example, in p.e or group work?

10c) Did you use any strategies/techniques to manage this situation?

Do you think that different experiences/reactions to taste impacted your ability to learn within the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

11a) If so, how do you think it affected learning?

11b) Were there any lessons or activities in which this was a particular issue? For example, in p.e or group work?

11c) Did you use any strategies/techniques to manage this situation?

Do you think that different experiences/reactions to touch impacted your ability to learn within the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

12a) If so, how do you think it affected learning?

12b) Were there any lessons or activities in which this was a particular issue? For example in p.e or group work?

12c) Did you use any strategies/techniques to manage this situation?

Do you think that different experiences/reactions to smell impacted your ability to learn within the classroom?

Not at all	Rarely	Sometimes	Frequently	All the time

13a) If so, how do you think it affected learning?

13b) Were there any lessons or activities in which this was a particular issue? For example in p.e or group work?

13c) If so, how do you think it affected learning?

Based on your experiences at school, we would like you to indicate your agreement with the following statements

The school environment was compatible with my sensory needs.

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

Teachers at my school were aware that pupils might have different sensory experiences/needs.

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

Teachers at my school supported pupils who might have different sensory experiences/needs.

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

Teachers need more guidance to support pupils with sensory experiences

Strongly Disagree	Disagree	Somewhat	Agree	Strongly Agree

Were there any aspects of your school environment that you believe were helpful for your sensory needs (multisensory rooms, small class sizes etc)?

Were there any aspects of your school environment that you believe were not helpful for your sensory needs (multisensory rooms, small class sizes etc)?

Finally, what do you think could be done to support pupils with different sensory experiences at school and within the classroom.

Appendix E: Chapter 6 The School Companion Sensory Profile 2 Cut-Off Scores

Table 1: *Sensory Profile School Companion Cut-Off Scores*

Section	Scale	Much Less Than Others	Less Than Others	Just Like the Majority of Others	More Than Others	Much More Than Others
Quadrant	Seeking	0	1-6	7-19	20-25	26-40
	Avoiding	0-1	2-7	8-21	22-27	28-60
	Sensitivity	0-2	3-9	10-23	24-30	31-55
	Bystander	0	1-9	10-28	29-37	38-65
Sensory	Auditory	0-1	2-5	6-15	16-19	20-35
	Visual	**	0-5	6-17	18-23	24-35
	Touch	0	1-4	5-15	16-20	21-40
	Movement	0	1-5	6-17	18-23	24-40
	Behaviour	0-1	2-8	9-22	23-29	30-55

Appendix F: Chapter 6 The Social Responsiveness Scale T-Score Range Description

Table 1: The Social Responsiveness Scale T-Score Range Description

T Scores	Clinical Range	Description
59 or below	Within normal limits	Not associated with clinically significant Autism Spectrum Disorders
60 to 65	Mild Range	Indicate deficiencies in reciprocal social behaviour that are clinically significant and may lead to mild or moderate interference with everyday social interactions
66 to 75	Moderate Range	Indicate deficiencies in reciprocal social behaviour that are clinically significant and lead to substantial interference with everyday social interactions. Such scores are typical for children with ASD of moderate severity
76 or higher	Severe range	Indicate deficiencies in reciprocal social behaviour that are clinically significant and lead to severe interference with everyday social interactions. Such scores are strongly associated with clinical diagnosis of autism spectrum disorder.

Appendix G: Chapter 7 Research Booklet

Durham University

Department of Psychology

Learning in the sensory world

Parent Research Booklet

ESRC ECONOMIC & SOCIAL RESEARCH COUNCIL

Dear caregiver,

School can often be a very busy sensory experience, with lots of bright lights, colourful wall displays and the noisy chatter of children! Previous research has suggested that this type of environment might be distracting for pupils and deter from learning. Our research group in the Psychology Department at Durham University would like to investigate this issue in a large sample of autistic and neurotypical pupils in a controlled environment. This will allow us to understand how different sensory inputs impact children's ability to concentrate and stay on task, before extending our findings into the classroom.

For this project we are inviting children, aged between 6-10 years with a diagnosis of Autism Spectrum Disorder, to complete a reading task under four different sensory conditions. This will take place at school on two separate days. Children will be video recorded in each condition so that we can examine how different sensory inputs affect children's ability to concentrate on an academic task. Parents will also be asked to complete two short questionnaires. Both testing sessions will take approximately 20 minutes and children will receive a certificate and a small gift for taking part. We would really like for you to take part in this study as findings will be used to develop training for teachers on the impact of sensory experiences in the classroom.

In this pack, you will find our information sheet and privacy notice. Please read through this information carefully and **if you would like to take part please return the consent form and participant questionnaire to school in the envelope provided.**

Parent Information Sheet

Before you decide whether to agree for your child to take part it is important for you to understand why the research is being done and what participation will involve. Please read the following information carefully. Please contact us using the details shown at the bottom of the sheet if there is anything that is not clear or if you would like more information.

What is the purpose of the study?

The aim of this study is to examine how different sensory inputs impact children's ability to concentrate and stay on task. Previous research has suggested that classroom design might be related to classroom engagement (paying attention to an academic task while there is bright stimulating information on the walls). However, we would like to study these issues in large sample of autistic and neurotypical children, in a controlled environment, before extending out findings into the classroom.

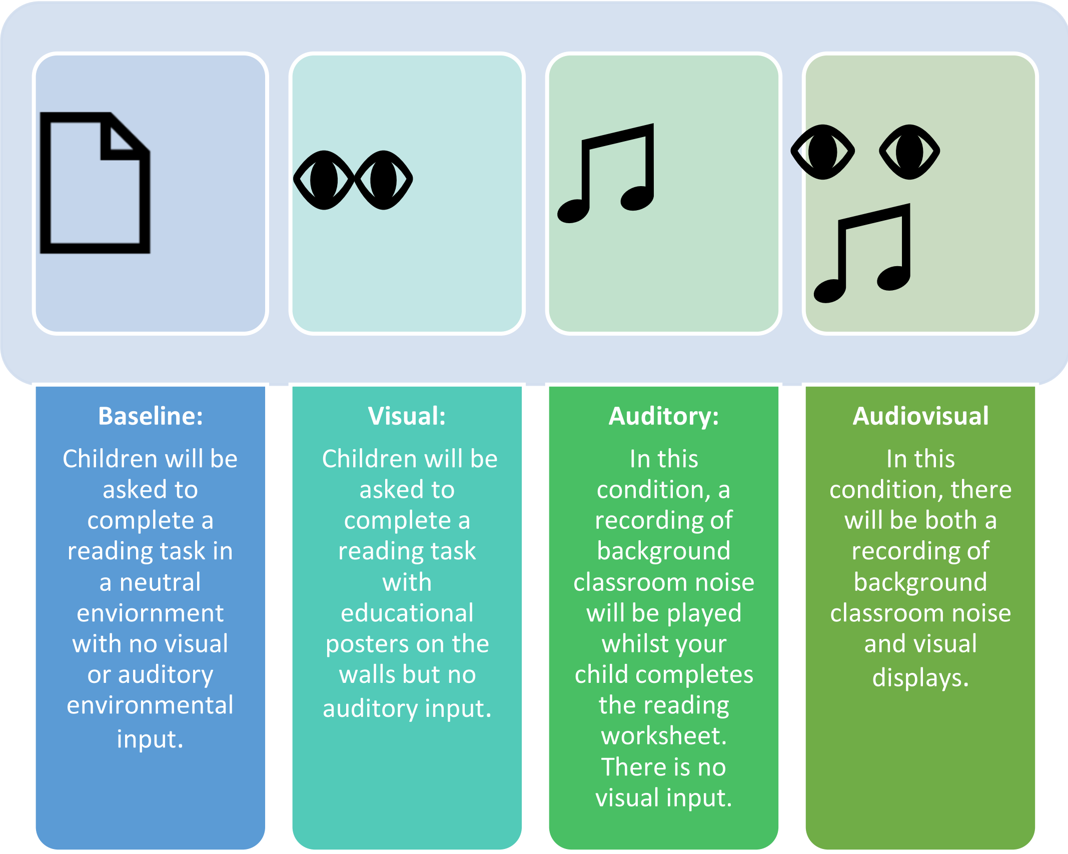
Why have I been asked to take part?

You have been asked to take part in this study because your child's school is participating in this project. Your child's school has not passed on any information to us about your child. We are recruiting children between the ages of 6 and 10 with a diagnosis of Autism Spectrum Disorder.

What will the study involve?

a) Children

Children will be invited to complete a reading tasks under four different environmental conditions at school. Children will be video recorded in each condition so that we can examine how different sensory inputs affect children's ability to concentrate on the reading task. Each session will last 20 minutes, and a member of the research team will be sat with your child throughout. A description of the four conditions is shown



Children will also be asked to complete a measure of intellectual functioning. This a standardized assessment that is regularly used in developmental psychology research. This assessment involves tasks such as the child being presented with a geometric pattern and asked to reproduce this pattern using small two-coloured cubes. This task will take 20 minutes to complete.

Parents/Caregivers

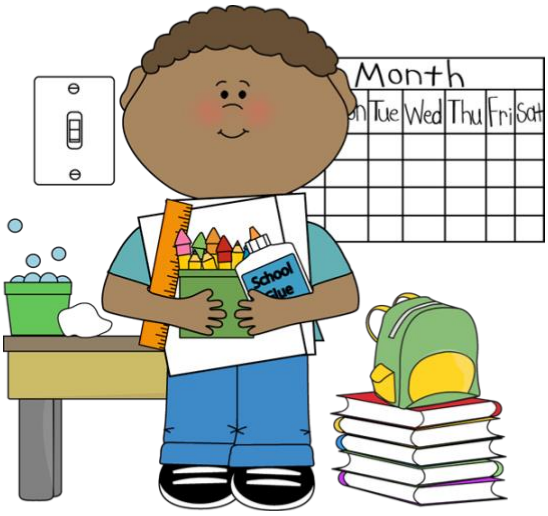
You will be asked to complete a standardized questionnaire that asks about your child's attention and behaviour. This questionnaire will take approximately 10-15 minutes to complete. Any question that you don't want to answer can be left blank and you are able to complete this questionnaire in your own time. We also ask that you complete the Participant Information Questionnaire, which simply asks you to confirm your child's diagnostic status. We will provide an anonymous code on the questionnaire, so you do not have to write your child's name on them.

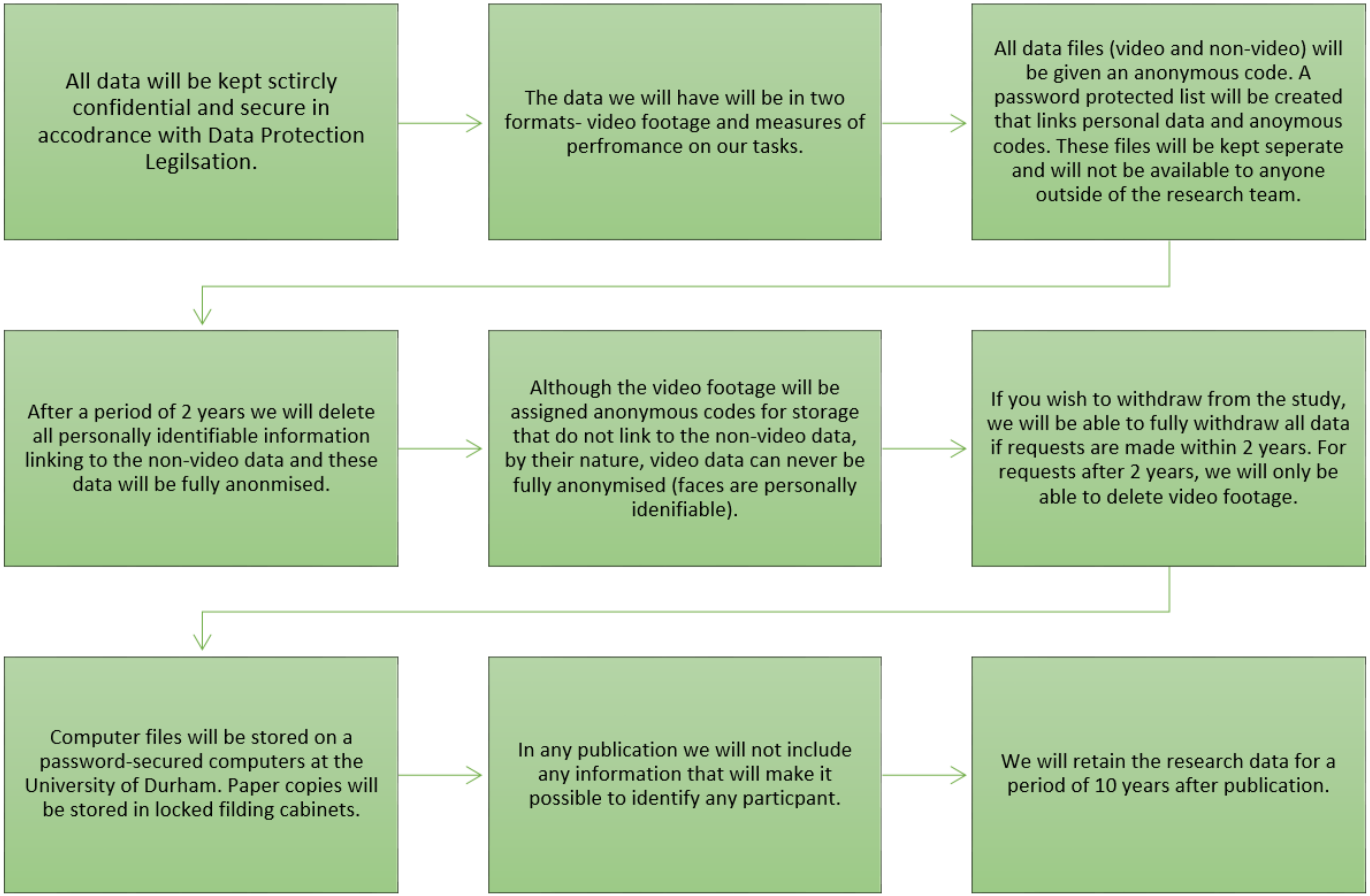
What are the benefits of taking part in the study?

We hope that this study will be a fun experience for everyone who takes part. In our experience, children really enjoy taking part in our research as the tasks are like fun games. Your child will be presented with a certificate and a small prize for taking part. Findings from this study will also help the research team develop workshops and training for schools on the relationship between classroom design, sensory experiences and behaviour in the classroom.

Do I have to take part?

Participation in this study is entirely voluntary. If you wish to withdraw from the study, we will be able to fully withdraw all data if requests are made within 2 years. For requests after 2 years, we will only be able to delete video footage.




All data will be kept sctircly confidential and secure in accodrance with Data Protection Legilsation.
The data we will have will be in two formats- video footage and measures of perfromance on our tasks.
All data files (video and non-video) will be given an anonymous code. A password protected list will be created that links personal data and anoymous codes. These files will be kept seperate and will not be available to anyone outside of the research team.
After a period of 2 years we will delete all personally identifiable information linking to the non-video data and these data will be fully anonmised.
Although the video footage will be assigned anonymous codes for storage that do not link to the non-video data, by their nature, video data can never be fully anonymised (faces are personally idenifiable).
If you wish to withdraw from the study, we will be able to fully withdraw all data if requests are made within 2 years. For requests after 2 years, we will only be able to delete video footage.
Computer files will be stored on a password-secured computers at the University of Durham. Paper copies will be stored in locked filding cabinets.
In any publication we will not include any information that will make it possible to identify any particpant.
We will retain the research data for a period of 10 years after publication.

What will happen to my data?

The data we will have will be in two formats- video footage and measures of performance on our tasks. We need to keep both types of data for enough time to allow us to analyse and publish the research, as well for a period of time thereafter to allow the data to be checked if needed (our University recommends a period of 10 years). All data files (video and non-video) will be given an anonymous code. After a period of 2 years we will delete all personally identifiable information linking to the non-video data and these data will be fully anonymised. Although the video footage will be assigned anonymous codes for storage that do not link to the non-video data, by their nature, video data can never be fully anonymised (faces are personally identifiable). If you wish to withdraw from the study, we will be able to fully withdraw all data if requests are made within 2 years. For requests after 2 years, we will only be able to delete video footage.

After each testing session, video footage will be transferred from the camera's memory card to an encrypted external hard-drive and will also be stored on a password protected computer in the Psychology Department. Two research assistants will then watch the footage and code your child's behaviour. Long term, video footage will be stored on Durham University's secure research storage network. This storage supports encryption and is suitable for storing data classified as personal or commercially confidential. We will maintain this footage for 10 years after publication. Access to video footage will be restricted to the research team (Liz Jones, Dr Mary Hanley, Professor Debbie Riby and two research assistants). Parents will be asked if they would like to consent to their child's footage being shown in conferences, presentations and for teaching material.

Child Information Sheet

LEARNING IN THE SENSORY WORLD

Our senses- seeing, hearing, smelling, tasting and touching, all work as a team to help us know what is going on in the world. The classroom can be a really fun, colourful and noisy place. Some children might really like all of this sound and colour but other children might find it hard to concentrate. We want to look at which environment helps you concentrate best!

What parents will do:

Parents will answer some questions about your sensory experiences and behaviour at home.

What you will do:

We would like you to complete some fun reading and thinking game on two separate days at school. If you would like to help us with our work that's great, please check with the person who looks after you. If you ever change your mind then don't worry that's ok, just tell someone and you can stop whenever you want to.

Privacy Notice

PART 1 – GENERIC PRIVACY NOTICE

Durham University has a responsibility under data protection legislation to provide individuals with information about how we process their personal data. We do this in a number of ways, one of which is the publication of privacy notices. Organisations variously call them a privacy statement, a fair processing notice or a privacy policy.

To ensure that we process your personal data fairly and lawfully we are required to inform you:

- Why we collect your data
- How it will be used
- Who it will be shared with

We will also explain what rights you have to control how we use your information and how to inform us about your wishes. Durham University will make the Privacy Notice available via the website and at the point we request personal data.

Our privacy notices comprise two parts – a generic part (ie common to all of our privacy notices) and a part tailored to the specific processing activity being undertaken.

Data Controller

The Data Controller is Durham University. If you would like more information about how the University uses your personal data, please see the University's Information Governance webpages or contact Information Governance Unit:

Information Governance Unit also coordinate response to individuals asserting their rights under the legislation. Please contact the Unit in the first instance.

Data Protection Officer

The Data Protection Officer is responsible for advising the University on compliance with Data Protection legislation and monitoring its performance against it. If you have any concerns regarding the way in which the University is processing your personal data, please contact the Data Protection Officer:

Your rights in relation to your personal data

Privacy notices and/or consent
You have the right to be provided with information about how and why we process your personal data. Where you have the choice to determine how your personal data will be

used, we will ask you for consent. Where you do not have a choice (for example, where we have a legal obligation to process the personal data), we will provide you with a privacy notice. A privacy notice is a verbal or written statement that explains how we use personal data.

Whenever you give your consent for the processing of your personal data, you receive the right to withdraw that consent at any time. Where withdrawal of consent will have an impact on the services we are able to provide, this will be explained to you, so that you can determine whether it is the right decision for you.

Accessing your personal data
You have the right to be told whether we are processing your personal data and, if so, to be given a copy of it. This is known as the right of subject access. You can find out more about this right on the University's Subject Access Requests webpage.

Right to rectification
If you believe that personal data we hold about you is inaccurate, please contact us and we will investigate. You can also request that we complete any incomplete data.

Once we have determined what we are going to do, we will contact you to let you know.

Right to erasure
You can ask us to erase your personal data in any of the following circumstances:

- We no longer need the personal data for the purpose it was originally collected
- You withdraw your consent and there is no other legal basis for the processing
- You object to the processing and there are no overriding legitimate grounds for the processing
- The personal data have been unlawfully processed
- The personal data have to be erased for compliance with a legal obligation
- The personal data have been collected in relation to the offer of information society services (information society services are online services such as banking or social media sites).

Once we have determined whether we will erase the personal data, we will contact you to let you know.

Right to restriction of processing
You can ask us to restrict the processing of your personal data in the following circumstances:

- You believe that the data is inaccurate and you want us to restrict processing until we determine whether it is indeed inaccurate
- The processing is unlawful and you want us to restrict processing rather than erase it
- We no longer need the data for the purpose we originally collected it but you need it in order to establish, exercise or defend a legal claim and

- You have objected to the processing and you want us to restrict processing until we determine whether our legitimate interests in processing the data override your objection.

Once we have determined how we propose to restrict processing of the data, we will contact you to discuss and, where possible, agree this with you.

Retention

The University keeps personal data for as long as it is needed for the purpose for which it was originally collected. Most of these time periods are set out in the University Records Retention Schedule.

Making a complaint

If you are unsatisfied with the way in which we process your personal data, we ask that you let us know so that we can try and put things right. If we are not able to resolve issues to your satisfaction, you can refer the matter to the Information Commissioner's Office (ICO).

PART 2 – TAILORED PRIVACY NOTICE

This section of the Privacy Notice provides you with the privacy information that you need to know before you provide personal data to the University for the particular purpose(s) stated below.

Project Title: Learning in the Sensory World

Type(s) of personal data collected and held by the researcher and method of collection:

We will collect personal data on your child through the Participant Information Sheet questionnaire (date of birth, gender and diagnostic information). We will also collect personal data through audio and video recordings of your child completing the four reading tasks.

Lawful Basis
Collection and use of personal data is carried out under the University's public task, which includes teaching, learning and research.

How personal data is stored:
The data we will have will be in two formats- video footage and measures of performance on our tasks. All data files (video and non-video) will be given an anonymous code. A password-protected list will be created that links personal data and anonymous coded. This file will be kept separate from the anonymous data and will not be available to anyone outside the research team. After a period of 2 years we will delete all personally identifiable information linking to the non-video data and these data will be fully anonymised. Although

the video footage will be assigned anonymous codes for storage that do not link to the non-video data, by their nature, video data can never be fully anonymised (faces are personally identifiable). If parents wish to withdraw from the study, we will be able to fully withdraw all data if requests are made within 2 years. For requests after 2 years, we will only be able to delete video footage. Paper copies of the questionnaire will be stored in locked filing cabinets securely in the Department of Psychology. Video footage of the reading tasks will be transferred at the end of each testing session to an encrypted external hard-drive and then to a password protected computer at the Psychology Department.. Long-term video files will be stored on Durham University research storage network. This storage supports encryption and is suitable for storing data classified as personal or commercially confidential. We will retain the research data for a period of 10 years after any publication.

How personal data is processed:

The personal data that we will collect through the participant information sheet will be used to confirm your child's age at the time or testing, and whether or not they have a diagnosis of Autism Spectrum Disorder. Once we have collected this information, we will enter it into a data sheet. Video footage of the reading tasks will be transferred from the camera SD card at the end of each testing session to an encrypted password protected computer external hard-drive and then to a password- protected computer in the Psychology Department.. All data files (video and non-video) will be given anonymous codes. After a period of 2 years we will delete all personally identifiable information liking to the non-video data and these data will be fully anonymised. Although the video footage will be assigned anonymous codes for storage that do not link to the non-video data, by their nature, video data can never be fully anonymised (faces are personally identifiable). If you wish to withdraw from the study, we will be able to fully withdraw all data if requests are made within 2 years. For requests after 2 years, we will only be able to delete video footage. We need to keep both types of data for enough time to allow us to analyse and publish the research, as well for a period of time thereafter to allow the data to be checked if needed (our University recommends a period of 10 years).

Withdrawal of data

If you wish to withdraw from the study, we will be able to fully withdraw all data if requests are made within 2 years. For requests after 2 years, we will only be able to delete video footage.

Who the researcher shares personal data with:

Personal data will not be shared with anyone outside of the research team.

How to object to the processing of your personal data for this project:

If you have any concerns regarding the processing of your personal data, or you wish to withdraw your data from this project, contact the researchers below:

Learning in the Sensory World

Informed Consent Form

Please read each of the following statements, and sign your initials after each to indicate that you have read and understood each one:

• I have read and understood the attached Information Sheet and Privacy Notice.

____

• I have been given full information regarding the aims of the research and have been provided with contact details should I require further information.

____

• I understand that any responses provided by me or my child will be anonymized and confidential.

____

• I understand that data from this study may be published in a scientific journal, or presented at a conference, but that no individually identifiable information will be revealed through these processes

____

• I give consent for my child to participate in this study.

____

• I understand that both myself and my child are free to withdraw from this study without having to give a reason to withdraw, and without any adverse result of any kind. If you wish to withdraw from the study, we will be able to fully withdraw all data if requests are made within 2 years. For requests after 2 years, we will only be able to delete video footage________

I consent to my child's video footage being shown in conference, presentations and in teaching material. All care will be taken that no third-party recordings will be made of this material. Footage remains for the researchers use only to illustrate the study's findings________

Parent/Caregiver's name:____

Parent/Caregiver's signature:____________________________________ Date:_________

Child's Name____

Additional Consent

We would really like to hear from teachers about your child’s sensory experiences at school. This will help us understand how sensory experiences might relate to the ability to concentrate on an academic task. As such, we would like to contact your child’s teacher asking them to complete a questionnaire that asks about your child sensory reactions in the classroom. Your **child can still participate in the experiment even if you don’t consent to researchers contacting the teacher.**

I consent to researchers contacting my child’s teacher asking them to complete the School Companion Sensory Profile. ____

If you have consented, please complete the following questionnaire.

Name of School	
Name of Child	
Name of teacher and school year	

Appendix H: Chapter 7 Script and Prompts

Child asks for help.

1st time

Offer support with question and praise.

- You're working really hard, I'm really impressed, shall we have a look at this together? Make sure child is back on task then leave.

2nd time

Offer support and praise

- That was a hard one, but this next one might be easier, shall we do it together? Complete question then leave

3rd time

- I really want to see how well you can do these questions for yourself, remember if you're not sure you can leave it blank. Let's do it together for one last time. Complete question then leave

4th time

- Good work, but you need to try this question for yourself. Don't help.

5th time

- You're working so well, but you need to this question by yourself. Why don't you try the next one? Don't help.

Reference to poster

Example- My favourite food is / colour/ pet/ animal/ number is, what about yours?

- Oh, that's a good choice, mine is XXX! How are you getting on with the story! That's looks like excellent work so far, keep on going!

Auditory references

What's that noise? / I don't like that noise

- We want to understand which types of classrooms help children learn best! These are some of the noises you might hear in your usual classroom. How are you getting on with the story? You're working very hard, keep on going!

Appendix I: Chapter 7 Coding Scheme

OFF-TASK

Environmental Distraction	Looking at walls (experimenter not present) Looking at walls in presence of experimenter Pointing at walls Asking about noise Out of seat looking at walls experimenter not present Out of seat looking at walls presence of experimenter Touching walls Camera Distraction
Self-Distraction	Playing with hair Playing with clothes Rubbing hands/face
Motor-Gross	Moving Table Swinging Seat Waving Fidgeting in seat Out of seat not looking at walls Left arena
Motor-Fine Object Based	Playing with pen Chewing pen
Experimenter Distraction	Talking to experimenter not relevant to task Looking for experimenter
Supported Academic Engagement	Child asks for help Experimenter Intervene to offer help Supported engagement
Independent Academic Engagement	Reading and writing without experimenter present

References

Achenbach, T. M., & Rescorla, C. A. (2001). Manual for the ASEBA school-aged forms and profiles. Burlington: University of Vermont, Research Center for Children, Youth and Families

Adams, D., Simpson, K., & Keen, D. (2020). Exploring anxiety at home, school, and in the community through self-report from children on the autism spectrum. *Autism Research*, *13*(4), 603-614.

All Party Parliamentary Group on Autism. (2017). *Autism and education in England 2017*. London: The National Autistic Society.

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of experimental child psychology*, *106*(1), 20-29.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)*. American Psychiatric Pub.

Anderson, A. H., Stephenson, J., Carter, M., & Carlon, S. (2019). A systematic literature review of empirical research on postsecondary students with autism spectrum disorder. *Journal of autism and developmental disorders*, *49*(4), 1531-1558.

Ashburner, J., Bennett, L., Rodger, S., & Ziviani, J. (2013). Understanding the sensory experiences of young people with autism spectrum disorder: A preliminary investigation. *Australian occupational therapy journal*, *60*(3), 171-180.

Ashburner, J., Ziviani, J., & Rodger, S. (2008). Sensory processing and classroom emotional, behavioral, and educational outcomes in children with autism spectrum disorder. *American journal of occupational therapy*, *62*(5), 564-573.

Asperger, H., & Frith, U. T. (1991). 'Autistic psychopathy' in childhood.

Assouline, S. G., Nicpon, M. F., & Dockery, L. (2012). Predicting the academic achievement of gifted students with autism spectrum disorder. *Journal of autism and developmental disorders*, *42*(9), 1781-1789.

Ausderau, K. K., Furlong, M., Sideris, J., Bulluck, J., Little, L. M., Watson, L. R., & Baranek, G. T. (2014). Sensory subtypes in children with autism spectrum disorder: latent profile transition analysis using a national survey of sensory features. *Journal of Child Psychology and Psychiatry*, *55*(8), 935-944.

Ausderau, K. K., Sideris, J., Little, L. M., Furlong, M., Bulluck, J. C., & Baranek, G. T. (2016). Sensory subtypes and associated outcomes in children with autism spectrum disorders. *Autism Research*, *9*(12), 1316-1327.

Ayres, A. J. (1972b). Sensory integration and learning disorders. Los Angeles: Western Psychological Services.

Bae, Y. S., Chiang, H. M., & Hickson, L. (2015). Mathematical word problem solving ability of children with autism spectrum disorder and their typically developing peers. *Journal of autism and developmental disorders*, *45*(7), 2200-2208.

Baker, A. E., Lane, A., Angley, M. T., & Young, R. L. (2008). The relationship between sensory processing patterns and behavioural responsiveness in autistic disorder: A pilot study. *Journal of Autism and Developmental Disorders*, *38*(5), 867-875.

Baranek, G. T., Carlson, M., Sideris, J., Kirby, A. V., Watson, L. R., Williams, K. L., & Bulluck, J. (2019). Longitudinal assessment of stability of sensory features in children with autism spectrum disorder or other developmental disabilities. *Autism Research*, *12*(1), 100-111.

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. *Journal of Child Psychology and Psychiatry*, *47*(6), 591-601.

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.

Baron-Cohen, S. (2000). Theory of mind and autism: A fifteen year review. *Understanding other minds: Perspectives from developmental cognitive neuroscience*, *2*, 3-20.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"?. *Cognition*, *21*(1), 37-46.

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., and Plumb, I. (2001). The "Reading the Mind in the Eyes" test revised version: a study with normal adults, and adults with Asperger syndrome or high−functioning autism. *J. Child Psychol. Psychiatry* 42, 241–251.

Barrett, P., Davies, F., Zhang, Y., & Barrett, L. (2015). The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis. *Building and Environment*, *89*, 118-133.

Barrett, P., Zhang, Y., Moffat, J., & Kobbacy, K. (2013). A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning. *Building and environment*, *59*, 678-689.

Ben-Sasson, A., Gal, E., Fluss, R., Katz-Zetler, N., & Cermak, S. A. (2019). Update of a meta-analysis of sensory symptoms in ASD: A new decade of research. *Journal of autism and developmental disorders*, *49*(12), 4974-4996.

Ben-Sasson, A., Hen, L., Fluss, R., Cermak, S. A., Engel-Yeger, B., & Gal, E. (2009). A meta-analysis of sensory modulation symptoms in individuals with autism spectrum disorders. *Journal of autism and developmental disorders*, *39*(1), 1-11.

Berkowitz, R., Moore, H., Astor, R. A., & Benbenishty, R. (2017). A research synthesis of the associations between socioeconomic background, inequality, school climate, and academic achievement. *Review of Educational Research*, *87*(2), 425-469

Bishop, D. (2011). Are our 'Gold Standard'Autism Diagnostic Instruments Fit for Purpose

Boesley, L., & Crane, L. (2018). 'Forget the Health and Care and just call them Education Plans': SENCO s' perspectives on Education, Health and Care plans. *Journal of Research in Special Educational Needs*, *18*, 36-47.

Bonner, A., & Tolhurst, G. (2002). Insider-outsider perspectives of participant observation. *Nurse Researcher (through 2013)*, *9*(4), 7.

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.

Boyd, B. A., McBee, M., Holtzclaw, T., Baranek, G. T., & Bodfish, J. W. (2009). Relationships among repetitive behaviors, sensory features, and executive functions in high functioning autism. *Research in autism spectrum disorders*, *3*(4), 959-966.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research In Psychology*, *3*(2), 77-101.

Brede, J., Remington, A., Kenny, L., Warren, K., & Pellicano, E. (2017). Excluded from school: Autistic students' experiences of school exclusion and subsequent re-integration into school. *Autism & Developmental Language Impairments*, *2*, 2396941517737511.

Brinkert, J., & Remington, A. (2020). Making sense of the perceptual capacities in autistic and non-autistic adults. *Autism*, 1362361320922640.

Brock, J., Brown, C.C., Boucher, J., Rippon, G., 2002. The temporal binding deficit hypothesis of autism. Dev. Psychopathol. 14 (2), 209–224

Brown, H. M., Oram-Cardy, J., & Johnson, A. (2013). A meta-analysis of the reading comprehension skills of individuals on the autism spectrum. *Journal of autism and developmental disorders*, *43*(4), 932-955

Brown, N. B., & Dunn, W. (2010). Relationship between context and sensory processing in children with autism. *American Journal of Occupational Therapy*, *64*(3), 474-483.

Brown, T., Leo, M., & Austin, D. W. (2008). Discriminant validity of the Sensory Profile in Australian children with autism spectrum disorder. *Physical & occupational therapy in pediatrics*, *28*(3), 253-266.

Brunsdon, V. E., & Happé, F. (2014). Exploring the 'fractionation' of autism at the cognitive level. *Autism*, *18*(1), 17-30.

Bullen, J. C., Swain Lerro, L., Zajic, M., McIntyre, N., & Mundy, P. (2020). A Developmental Study of Mathematics in Children with Autism Spectrum

Disorder, Symptoms of Attention Deficit Hyperactivity Disorder, or Typical Development. *Journal of Autism and Developmental Disorders*, 1-14

Burgess, A. F., & Gutstein, S. E. (2007). Quality of Life for People with Autism: Raising the Standard for Evaluating Successful Outcomes. *Child and Adolescent Mental Health*, *12*(2), 80–86

Butera, C., Ring, P., Sideris, J., Jayashankar, A., Kilroy, E., Harrison, L., & Aziz-Zadeh, L. (2020). Impact of Sensory Processing on School Performance Outcomes in High Functioning Individuals with Autism Spectrum Disorder. *Mind, Brain, and Education*, *14*(3), 243-254.

Calvert, G., Spence, C., & Stein, B. E. (Eds.). (2004). *The handbook of multisensory processes*. MIT press.

Calvin, C. M., Fernandes, C., Smith, P., Visscher, P. M., & Deary, I. J. (2010). Sex, intelligence and educational achievement in a national cohort of over 175,000 11-year-old schoolchildren in England. *Intelligence*, *38*(4), 424–432.

Carroll, J. B. (1963). A model of school learning. Teachers College Record, 64, 723– 733.

Cascio, C. J., Woynaroski, T., Baranek, G. T., & Wallace, M. T. (2016). Toward an interdisciplinary approach to understanding sensory function in autism spectrum disorder. *Autism Research*, *9*(9), 920-925.

Cassidy, S., Bradley, L., Shaw, R., & Baron-Cohen, S. (2018). Risk markers for suicidality in autistic adults. *Molecular autism*, *9*(1), 42.

Chen, L., Abrams, D. A., Rosenberg-Lee, M., Iuculano, T., Wakeman, H. N., Prathap, S.,& Menon, V. (2019). Quantitative analysis of heterogeneity in academic achievement of children with autism. *Clinical Psychological Science*, *7*(2), 362-380.

Chevallier, C., Kohls, G., Troiani, V., Brodkin, E. S., & Schultz, R. T. (2012). The social motivation theory of autism. *Trends in cognitive sciences*, *16*(4), 231-239.

Chiang, H. M., & Lin, Y. H. (2007). Mathematical ability of students with Asperger syndrome and high-functioning autism: A review of literature. *Autism*, *11*(6), 547-556.

Clements, C. C., Zoltowski, A. R., Yankowitz, L. D., Yerys, B. E., Schultz, R. T., & Herrington, J. D. (2018). Evaluation of the social motivation hypothesis of autism: a systematic review and meta-analysis. *JAMA psychiatry*, *75*(8), 797-808.

Cole, T., McCluskey, G., Daniels, H., Thompson, I., & Tawell, A. (2019). Factors associated with high and low levels of school exclusions: Comparing the English and wider UK experience. *Emotional and Behavioural Difficulties*, *24*(4), 374-390.

Conners, C. K. (2008). Conners third edition (Conners 3). *Los Angeles, CA: Western Psychological Services*.

Conners, C. K. (1997). Conners' Rating Scales—Revised technical manual. New York: Multi-Health Systems

Constantino, J. N., & Gruber, C. P. (2012). *Social responsiveness scale: SRS-2*. Torrance, CA: Western Psychological Services.

Cook, A., Ogden, J., & Winstone, N. (2018). Friendship motivations, challenges and the role of masking for girls with autism in contrasting school settings. *European Journal of Special Needs Education*, *33*(3), 302-315.

Cosbey, J., Johnston, S. S., & Dunn, M. L. (2010). Sensory Processing Disorders and Social Participation. *American Journal of Occupational Therapy*, *64*(3), 462–473.

Cosbey, J., Johnston, S. S., Dunn, M. L., & Bauman, M. (2012). Playground behaviors of children with and without sensory processing disorders. *OTJR: Occupation, Participation and Health*, *32*(2), 39-47.

Crane, L., Goddard, L., & Pring, L. (2009). Sensory processing in adults with autism spectrum disorders. *Autism*, *13*(3), 215-228.

Craston, M., Thom, G. & Spivack, R. (2015) Evaluation of SEND Pathfinder Programme: Processes and Implementation. London: Department for Education

Crompton, C. J., DeBrabander, K., Heasman, B., Milton, D., & Sasson, N. J. (2021). Double Empathy: Why Autistic People Are Often Misunderstood. *Frontiers for Young Minds*, *9*.

Damiano-Goodwin, C. R., Woynaroski, T. G., Simon, D. M., Ibañez, L. V., Murias, M., Kirby, A., & Cascio, C. J. (2018). Developmental sequelae and neurophysiologic substrates of sensory seeking in infant siblings of children with autism spectrum disorder. *Developmental cognitive neuroscience*, *29*, 41-53.

Deary, I. J., Strand, S., Smith, P., & Fernandes, C. (2007). Intelligence and educational achievement. *Intelligence*, *35*(1), 13–21.

DeBoth, K. K., & Reynolds, S. (2017). A systematic review of sensory-based autism subtypes. *Research in autism spectrum disorders*, *36*, 44-56.

Dellapiazza, F., Michelon, C., Vernhet, C., Muratori, F., Blanc, N., Picot, M. C., & Baghdadli, A. (2020). Sensory processing related to attention in children with ASD, ADHD, or typical development: results from the ELENA cohort. *European child & adolescent psychiatry*, 1-9.

Department for Education & Department of Health (2015) Special Educational Needs and Disability Code of Practice: 0–25 years. London: Crown Copyright.

Department for Education. (July 2020). Statistics: Special educational needs

Department for Education/Department of Health. (January 2015). Special Educational Needs and Disability Code of Practice: 0 to 25 years

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. *American Journal of Occupational Therapy*, *63*(2), 172-181.

Donohue, S. E., Darling, E. F., & Mitroff, S. R. (2012). Links between multisensory processing and autism. *Experimental brain research*, *222*(4), 377-387.

DuBois, D., Lymer, E., Gibson, B. E., Desarkar, P., & Nalder, E. (2017). Assessing sensory processing dysfunction in adults and adolescents with autism spectrum disorder: a scoping review. *Brain sciences*, *7*(8), 108.

Dunn, W. (1997). The impact of sensory processing abilities on the daily lives of young children and their families: A conceptual model. *Infants and young children*, *9*, 23-35.

Dunn, W. (1999). *Sensory profile: User's manual*. San Antonio, TX: Psychological Corporation.

Dunn, W. (2014). Sensory Profile 2 Manual. The Psychological Corporation

Dunn, W., Little, L., Dean, E., Robertson, S., & Evans, B. (2016). The state of the science on sensory factors and their impact on daily life for children: A scoping review. *OTJR: Occupation, Participation and Health*, *36*(2_suppl), 3S- 26S.

Dwyer, S. C., & Buckle, J. L. (2009). The space between: On being an insider-outsider in qualitative research. *International journal of qualitative methods*, *8*(1), 54-63.

Easterbrooks-Dick, O., May-Benson, T., & Teasdale, A. (2020). What's the Prognosis? Longitudinal Follow-Up of Children With Sensory Processing Challenges 8 to 32 Years Later. *American Journal of Occupational Therapy*, *74*(4_Supplement_1), 7411520507p1-7411520507p1.

Eaves, L. C., & Ho, H. H. (1997). School Placement and Academic Achievement in Children with Autistic Spectrum Disorders. *Journal of Developmental and Physical Disabilities*, *9*(4), 15

Erickson, L. C., Thiessen, E. D., Godwin, K. E., Dickerson, J. P., & Fisher, A. V. (2015). Endogenously and exogenously driven selective sustained attention: Contributions to learning in kindergarten children. Journal of Experimental Child Psychology, 138, 126-134.

Estes, A., Rivera, V., Bryan, M., Cali, P., & Dawson, G. (2011). Discrepancies between academic achievement and intellectual ability in higher-functioning school-aged children with autism spectrum disorder. *Journal of autism and developmental disorders*, *41*(8), 1044-1052.

Everitt, B. S., Landau, S., Leese, M., & Stahl, D. (2011). Cluster analysis 5th ed.

Fanning, P. A., Hocking, D. R., Dissanayake, C., & Vivanti, G. (2018). Delineation of a spatial working memory profile using a non-verbal eye-tracking paradigm in young children with autism and Williams syndrome. *Child Neuropsychology*, *24*(4), 469-489.

Fernández-Andrés, M. I., Pastor-Cerezuela, G., Sanz-Cervera, P., & Tárraga-Mínguez, R. (2015). A comparative study of sensory processing in children with and without autism spectrum disorder in the home and classroom environments. *Research in developmental disabilities*, *38*, 202-212

Finn, J. D., Pannozzo, G. M., & Voelkl, K. E. (1995). Disruptive and inattentive-withdrawn behavior and achievement among fourth graders. *The Elementary School Journal*, *95*(5), 421-434

Fisher, A. V., Godwin, K. E., & Seltman, H. (2014). Visual environment, attention allocation, and learning in young children: When too much of a good thing may be bad. *Psychological science*, *25*(7), 1362-1370.

Fletcher-Watson, S., & Happé, F. (2019). *Autism: A new introduction to psychological theory and current debate*. Routledge.

Foss-Feig, J.H., Kwakye, L.D., Cascio, C.J., Burnette, C.P., Kadivar, H., Stone, W.L., Wallace, M.T., 2010. An extended multisensory temporal binding window in autism spectrum disorders. Exp. Brain Res. 203 (2), 381–389

Fraley C., Raftery A. E., Murphy T. B. and Scrucca L. (2012) mclust Version 4 for R: Normal Mixture Modeling for Model-Based Clustering, Classification, and Density Estimation. *Technical Report* No. 597, Department of Statistics, University of Washington

Frith, U. (1989). Autism: Explaining the enigma. Oxford: Basil Blackwell.

Frith, U. (1991). Asperger and his syndrome. *Autism and Asperger syndrome*, *14*, 1-36.

Frith, U., & Happé, F. (1994). Autism: Beyond “theory of mind”. *Cognition*, *50*(1-3), 115-132.

Gaspelin, N., Margett-Jordan, T., & Ruthruff. (2015). Susceptible to distraction: Children lack topdown control over spatial attention capture. Psychonomic Bulletin & Review, 22(2), 461-468.

Gathercole, S. E., Lamont, E. M. I. L. Y., & Alloway, T. P. (2006). Working memory in the classroom. In *Working memory and education* (pp. 219-240). Academic Press.

Geary, D. C. (2004). Mathematics and learning disabilities. *Journal of learning disabilities*, *37*(1), 4-15.

Geary, D. C., Hamson, C. O., & Hoard, M. K. (2000). Numerical and arithmetical cognition: A longitudinal study of process and concept deficits in children with learning disability. *Journal of experimental child psychology*, *77*(3), 236-263.

Georgiades, S., Szatmari, P., & Boyle, M. (2013). Importance of studying heterogeneity in autism. *Neuropsychiatry*, *3*(2), 123.

Georgiades, S., Szatmari, P., Boyle, M., Hanna, S., Duku, E., Zwaigenbaum, L., & Pathways in ASD Study Team. (2013). Investigating phenotypic heterogeneity in children with autism spectrum disorder: a factor mixture modeling approach. *Journal of Child Psychology and Psychiatry*, *54*(2), 206-215.

Gernsbacher, M. A., & Yergeau, M. (2019). Empirical Failures of the Claim That Autistic People Lack a Theory of Mind. *Archives of scientific psychology*, *7*(1), 102.

Giarelli, E., Wiggins, L. D., Rice, C. E., Levy, S. E., Kirby, R. S., Pinto-Martin, J., et al. (2010). Sex differences in the evaluation and diagnosis of autism spectrum disorders among children. Disability and Health Journal, 3(2), 107–116.

Gliga, T., Jones, E. J., Bedford, R., Charman, T., & Johnson, M. H. (2014). From early markers to neuro-developmental mechanisms of autism. *Developmental Review*, *34*(3), 189-207.

Godwin, K. E., Erickson, L. C., & Newman, R. S. (2019). Insights from crossing research silos on visual and auditory attention. *Current directions in psychological science*, *28*(1), 47-52

Goldman, D. Z., Shapiro, E. G., & Nelson, C. A. (2004). Measurement of vigilance in 2-year-old children. *Developmental neuropsychology*, *25*(3), 227-250.

Goodley, D., & Runswick-Cole, K. (2012). Reading Rosie: The postmodern disabled child. *Educational and child psychology*, *29*(2), 53.

Grandin, T. (2009). Visual abilities and sensory differences in a person with autism. *Biological Psychiatry*, *65*(1), 15-16.

Grapel, J. N., Cicchetti, D. V., & Volkmar, F. R. (2015). Sensory features as diagnostic criteria for autism: Sensory features in autism. *The Yale journal of biology and medicine*, *88*(1), 69

Gray, L., Bownas, E., Hicks, L., Hutcheson-Galbraith, E., & Harrison, S. (2021). Towards a better understanding of girls on the Autism spectrum: educational support and parental perspectives. *Educational Psychology in Practice*, 1-20.

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.

Guez, A., Panaïotis, T., Peyre, H., & Ramus, F. (2018). Predictors of the IQ-achievement gap in France: A longitudinal analysis. *Intelligence*, *69*, 104-116.

Gustavsson, A., J. Tøssebro, and R. Traustadóttir. 2005. Introduction: Approaches and pespectives in Nordic disability research. In Resistance, reflection and change: Nordic disability research, ed. A. Gustavsson, J. Sandvin, R. Traustadóttir and J. Tøssebro, 23–44. Lund: Studentlitteratur.

Ha, V. S., & Whittaker, A. (2016). 'Closer to my world': Children with autism spectrum disorder tell their stories through photovoice. *Global public health*, *11*(5-6), 546-563.

Habib, A., Harris, L., Pollick, F., & Melville, C. (2019). A meta-analysis of working memory in individuals with autism spectrum disorders. *Plos one*, *14*(4), e0216198.

Hallmayer, J., Cleveland, S., Torres, A., Phillips, J., Cohen, B., Torigoe, T., & Risch, N. (2011). Genetic heritability and shared environmental factors among twin pairs with autism. *Archives of general psychiatry*, *68*(11), 1095-1102.

Hanley, M., Khairat, M., Taylor, K., Wilson, R., Cole-Fletcher, R., & Riby, D. M. (2017). Classroom displays—Attraction or distraction? Evidence of impact on attention and learning from children with and without autism. *Developmental psychology*, *53*(7), 1265

Happé, F. (1999). Autism: cognitive deficit or cognitive style?. *Trends in cognitive sciences*, *3*(6), 216-222.

Happé, F. (2005). The weak central coherence account of autism. *Handbook of autism and pervasive developmental disorders*, *1*, 640-649.

Happé, F., & Frith, U. (2020). Annual Research Review: Looking back to look forward–changes in the concept of autism and implications for future research. *Journal of Child Psychology and Psychiatry*, *61*(3), 218-232.

Happé, F., Ronald, A., & Plomin, R. (2006). Time to give up on a single explanation for autism. *Nature neuroscience*, *9*(10), 1218-1220.

Henshaw, P. (2016). Parents still face 'uphill struggle' to get satisfactory SEN support. *Seced*, *2016*(21), 1-1.

Her Majesty's Stationery Office (2009) *Autism Act 2009*. London: The Stationery Office.

Her Majesty's Stationery Office (2014) *Children and Families Act.* London: The Stationery Office.

Hill, E. L. (2004). Executive dysfunction in autism. *Trends in cognitive sciences*, *8*(1), 26-32.

Hiller, R. M., Young, R. L., & Weber, N. (2014). Sex Differences in Autism Spectrum Disorder based on DSM-5 Criteria: Evidence from Clinician and Teacher Reporting. Journal of Abnormal Child Psychology

Hodgen, J., & Marks, R. (2013). The Employment Equation: Why our young people need more maths for today's jobs.

Hodges, A., Joosten, A., Bourke-Taylor, H., & Cordier, R. (2020). School participation: The shared perspectives of parents and educators of primary school students on the autism spectrum. *Research in developmental disabilities*, *97*, 103550.

Hollocks, M. J., Lerh, J. W., Magiati, I., Meiser-Stedman, R., & Brugha, T. S. (2019). Anxiety and depression in adults with autism spectrum disorder: a systematic review and meta-analysis. *Psychological medicine*, *49*(4), 559-572.

Howe, F. E., & Stagg, S. D. (2016). How sensory experiences affect adolescents with an autistic spectrum condition within the classroom. *Journal of Autism and Developmental Disorders*, *46*(5), 1656-1668.

Howse, J. (2019). *The achievement gap: The discrepancy between intellectual ability and academic achievement in children with autism* (Doctoral dissertation, UCL (University College London).

Hughes, A. (2014). *A Case Study Investigation into the Sensory Needs of Children and Young People with Autistic Spectrum Condition (ASC) within an Educational Context*(Doctoral dissertation, University of Manchester)

Hull, L., Petrides, K. V., & Mandy, W. (2020). The female autism phenotype and camouflaging: A narrative review. *Review Journal of Autism and Developmental Disorders*, 1-12.

Hull, L., Petrides, K. V., Allison, C., Smith, P., Baron-Cohen, S., Lai, M. C., & Mandy, W. (2017). “Putting on my best normal”: social camouflaging in adults with autism spectrum conditions. *Journal of Autism and Developmental Disorders*, *47*(8), 2519-2534.

Hulme, C., & Snowling, M. J. (2013). Learning to read: What we know and what we need to understand better. *Child development perspectives*, *7*(1), 1-5

Humphrey, N., & Lewis, S. (2008). Make me normal' The views and experiences of pupils on the autistic spectrum in mainstream secondary schools. *Autism*, *12*(1), 23-46.

Hwang, Y. I., Arnold, S., Srasuebkul, P., & Trollor, J. (2020). Understanding anxiety in adults on the autism spectrum: An investigation of its relationship with intolerance of uncertainty, sensory sensitivities and repetitive behaviours. *Autism*, *24*(2), 411-422.

Imms, C., Adair, B., Keen, D., Ullenhag, A., Rosenbaum, P., & Granlund, M. (2016). 'Participation': a systematic review of language, definitions, and constructs used in intervention research with children with disabilities. *Developmental Medicine & Child Neurology*, *58*(1), 29-38.

Jasmin, E., Couture, M., McKinley, P., Reid, G., Fombonne, E., & Gisel, E. (2009). Sensori-motor and daily living skills of preschool children with autism spectrum disorders. *Journal of autism and developmental disorders*, *39*(2), 231-241.

Johnson, M. H., Jones, E. J., & Gliga, T. (2015). Brain adaptation and alternative developmental trajectories. *Development and psychopathology*, *27*(2), 425- 442.

Jones, C. R. G., Happé, F., Golden, H., Marsden, A. J. S., Tregay, J., Simonoff, E., Pickles, A., Baird, G., & Charman, T. (2009). Reading and arithmetic in adolescents with autism spectrum disorders: Peaks and dips in attainment. *Neuropsychology*, *23*(6), 718–728

Jones, E. K., Hanley, M., & Riby, D. M. (2020). Distraction, distress and diversity: Exploring the impact of sensory processing differences on learning and school life for pupils with autism spectrum disorders. *Research in autism spectrum disorders*, *72*, 101515.

Joosten, A. V., & Bundy, A. C. (2010). Sensory processing and stereotypical and repetitive behaviour in children with autism and intellectual disability. *Australian occupational therapy journal*, *57*(6), 366-372.

Kaiser, M. D., Yang, D. Y. J., Voos, A. C., Bennett, R. H., Gordon, I., Pretzsch, C., & Pelphrey, K. A. (2016). Brain mechanisms for processing affective (and nonaffective) touch are atypical in autism. *Cerebral Cortex*, *26*(6), 2705-2714.

Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous child*, *2*(3), 217-250.

Kapp, S. (2019). How social deficit models exacerbate the medical model: Autism as case in point. *Autism Policy & Practice*, *2*(1), 3-28.

Keen, D., Webster, A., & Ridley, G. (2016). How well are children with autism spectrum disorder doing academically at school? An overview of the literature. *Autism*, *20*(3), 276-294.

Keith, J. M., Jamieson, J. P., & Bennetto, L. (2019). The influence of noise on autonomic arousal and cognitive performance in adolescents with autism spectrum disorder. *Journal of autism and developmental disorders*, *49*(1), 113-126.

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.

Kern, J. K., Trivedi, M. H., Grannemann, B. D., Garver, C. R., Johnson, D. G., Andrews, A. A., & Schroeder, J. L. (2007). Sensory correlations in autism. *Autism*, *11*(2), 123-134.

Kern, J., Trivedi, M., Garver, C., Grannemann, B., Andrews, A., & Savla, J. et al. (2006). The pattern of sensory processing abnormalities in autism. *Autism*, *10*(5), 480-494.

Kientz, M. A., & Dunn, W. (1997). A comparison of the performance of children with and without autism on the Sensory Profile. *American Journal of Occupational Therapy*, *51*(7), 530-537.

Kim, S. H., Bal, V. H., & Lord, C. (2018). Longitudinal follow-up of academic achievement in children with autism from age 2 to 18. *Journal of Child Psychology and Psychiatry*, *59*(3), 258–267.

Kirby, A. V., Dickie, V. A., & Baranek, G. T. (2015). Sensory experiences of children with autism spectrum disorder: In their own words. *Autism*, *19*(3), 316-326.

Kuhaneck, H. M., & Britner, P. A. (2013). A preliminary investigation of the relationship between sensory processing and social play in autism spectrum disorder. *OTJR: Occupation, Participation and Health*, *33*(3), 159-167.

Lai, M. C., Lombardo, M. V., Pasco, G., Ruigrok, A. N., Wheelwright, S. J., Sadek, S. A., & MRC AIMS Consortium. (2011). A behavioral comparison of male and female adults with high functioning autism spectrum conditions. *PloS one*, *6*(6), e20835.

Lai, M. C., Lombardo, M. V., Ruigrok, A. N., Chakrabarti, B., Auyeung, B., Szatmari, P., .& MRC AIMS Consortium. (2017). Quantifying and exploring camouflaging in men and women with autism. *Autism*, *21*(6), 690-702.

Lai, M.-C., Lombardo, M. V., Auyeung, B., Chakrabarti, B., & Baron-Cohen, S. (2015). Sex/gender differences and autism: setting the scene for future research. Journal of the American Academy of Child and Adolescent Psychiatry, 54(1), 11–24

Lam, G. (2014). A theoretical framework of the relation between socioeconomic status and academic achievement of students. *Education*, *134*(3), 326-331.

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.

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. *Autism Research*, *7*(3), 322-333.

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.

Lavie, N. (2005). Distracted and confused? Selective attention under load. *Trends in Cognitive Sciences*, *9*(2), 75–82.

Lavie, N. (2010). Attention, distraction, and cognitive control under load. *Current Directions in Psychological Science, 19*(3), 143–148.

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control*. Journal of Experimental Psychology: Genera*l, 133(3), 339–354.

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.

Levy, S. E., Giarelli, E., Lee, L. C., Schieve, L. A., Kirby, R. S., Cunniff, C., & Rice, C. E. (2010). Autism spectrum disorder and co-occurring developmental, psychiatric, and medical conditions among children in multiple populations of the United States. *Journal of Developmental & Behavioral Pediatrics*, *31*(4), 267-275.

Liss, M., Saulnier, C., Fein, D., & Kinsbourne, M. (2006). Sensory and attention abnormalities in autistic spectrum disorders. *Autism*, *10*(2), 155-172.

Little, L. M., Dean, E., Tomchek, S. D., & Dunn, W. (2017). Classifying sensory profiles of children in the general population. *Child: care, health and development*, *43*(1), 81-88.

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.

Mandy, W., Chilvers, R., Chowdhury, U., Salter, G., Seigal, A., & Skuse, D. (2012). Sex differences in autism spectrum disorder: evidence from a large sample of children and adolescents. *Journal of autism and developmental disorders*, *42*(7), 1304-1313.

Mannion, A., & Leader, G. (2013). Comorbidity in autism spectrum disorder: A literature review. *Research in Autism Spectrum Disorders*, *7*(12), 1595-1616.

Marco, E. J., Hinkley, L. B., Hill, S. S., & Nagarajan, S. S. (2011). Sensory processing in autism: a review of neurophysiologic findings. *Paediatric Research*, *69*(5 Pt 2), 48R-54R.

Markram, K., & Markram, H. (2010). The intense world theory–a unifying theory of the neurobiology of autism. *Frontiers in human neuroscience*, *4*, 224.

Martin-Denham, S. (2020). The road to school exclusion: An interpretative phenomenological analysis of interviews with parents of children with autism in the UK. *Autism*.

May, T., Rinehart, N., Wilding, J., & Cornish, K. (2013). The role of attention in the academic attainment of children with autism spectrum disorder. *Journal of autism and developmental disorders*, *43*(9), 2147-2158.

Mayes, S. D., & Calhoun, S. L. (2003). Analysis of WISC-III, Stanford-Binet: IV, and academic achievement test scores in children with autism. *Journal of Autism and Developmental Disorders*, *33*(3), 329-341.

Mayes, S. D., & Calhoun, S. L. (2008). WISC-IV and WIAT-II profiles in children with high-functioning autism. *Journal of autism and developmental disorders*, *38*(3), 428-439.

Mayes, S. D., & Calhoun, S. L. (2011). Impact of IQ, age, SES, gender, and race on autistic symptoms. *Research in Autism Spectrum Disorders*, *5*(2), 749-757.

Mayes, S. D., Calhoun, S. L., Bixler, E. O., & Zimmerman, D. N. (2009). IQ and neuropsychological predictors of academic achievement. *Learning and Individual Differences*, *19*(2), 238-241

Mayes, S. D., Waschbusch, D. A., Calhoun, S. L., & Mattison, R. E. (2020). Correlates of academic overachievement, nondiscrepant achievement, and learning disability in ADHD, autism, and general population samples. *Exceptionality*, *28*(1), 60-75.

Mayes, S. D., Waschbusch, D. A., Calhoun, S. L., & Mattison, R. E. (2019). How Common are Academic Overachievement and Underachievement in Children with Autism or ADHD?. *Journal of Developmental and Physical Disabilities*, 1-9.

McCormick, C., Hepburn, S., Young, G. S., & Rogers, S. J. (2016). Sensory symptoms in children with autism spectrum disorder, other developmental disorders and typical development: a longitudinal study. *Autism*, *20*(5), 572- 579.

McDougal, E., Riby, D. M., & Hanley, M. (2020). Profiles of academic achievement and attention in children with and without Autism Spectrum Disorder. *Research in Developmental Disabilities*, *106*, 103749.

McDougal, E., Riby, D. M., & Hanley, M. (2020). Teacher insights into the barriers and facilitators of learning in autism. *Research in Autism Spectrum Disorders*, *79*, 101674.

McGurk, H., Macdonald, J., 1976. Hearing lips and seeing voices. Nature 264, 691– 811

McIntosh, D. N., Miller, L. J., Shyu, V., & Dunn, W. (1999). Development and validation of the short sensory profile. *Sensory profile manual*, 59-73.

McIntyre, N. S., Solari, E. J., Grimm, R. P., Lerro, L. E., Gonzales, J. E., & Mundy, P. C. (2017). A comprehensive examination of reading heterogeneity in students with high functioning autism: Distinct reading profiles and their relation to autism symptom severity. *Journal of Autism and Developmental Disorders*, *47*(4), 1086-1101.

Meilleur, A. A. S., Jelenic, P., & Mottron, L. (2015). Prevalence of clinically and empirically defined talents and strengths in autism. *Journal of autism and developmental disorders*, *45*(5), 1354-1367.

Merrell, C., & Tymms, P. B. (2001). Inattention, hyperactivity and impulsiveness: Their impact on academic achievement and progress. *British Journal of Educational Psychology*, *71*(1), 43-56.

Miles, J. H. (2011). Autism spectrum disorders—a genetics review. *Genetics in Medicine*, *13*(4), 278-294.

Milton, D. E. (2012). On the ontological status of autism: the ‘double empathy problem’. *Disability & Society*, *27*(6), 883-887.

Minshew, N. J., Goldstein, G., Taylor, H. G., & Siegel, D. J. (1994). Academic achievement in high functioning autistic individuals. *Journal of Clinical and Experimental Neuropsychology*, *16*(2), 261-270.

Mitchell, P., Sheppard, E., & Cassidy, S. (2021). Autism and the double empathy problem: Implications for development and mental health. *British Journal of Developmental Psychology*, *39*(1), 1-18.

Moffett, L., & Morrison, F. J. (2020). Off-task behavior in kindergarten: Relations to executive function and academic achievement. *Journal of Educational Psychology*, *112*(5), 938

Nally, A., Healy, O., Holloway, J., & Lydon, H. (2018). An analysis of reading abilities in children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *47*, 14-25.

Nation, K., Clarke, P., Wright, B., & Williams, C. (2006). Patterns of reading ability in children with autism spectrum disorder. *Journal of autism and developmental disorders*, *36*(7), 911

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.

O'Riordan, M., & Passetti, F. (2006). Discrimination in autism within different sensory modalities. *Journal of autism and developmental disorders*, *36*(5), 665-675.

Oakes, L. M., Kannass, K. M., & Shaddy, D. J. (2002). Developmental changes in endogenous control of attention: The role of target familiarity on infants' distraction latencies. Child Development, 73, 1644-1655.

Orton, A. (2004). *Learning mathematics: Issues, theory and classroom practice*. Bloomsbury Publishing.

Parham, L. D., & Ecker, C. (2007). *Sensory processing measure (SPM)*. Western Psychological Services.

Pellicano, E. (2013). Sensory symptoms in autism: a blooming, buzzing confusion?. *Child Development Perspectives*, *7*(3), 143-148.

Pellicano, E., Dinsmore, A., & Charman, T. (2014). What should autism research focus upon? Community views and priorities from the United Kingdom. *Autism*, *18*(7), 756-770.

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of child psychology and psychiatry*, *37*(1), 51-87.

Perez Repetto, L., Jasmin, E., Fombonne, E., Gisel, E., & Couture, M. (2017). Longitudinal study of sensory features in children with autism spectrum disorder. *Autism research and treatment*, *2017*.

Pham, A. V. (2016). Differentiating behavioral ratings of inattention, impulsivity, and hyperactivity in children: effects on reading achievement. *Journal of attention disorders*, *20*(8), 674-683.

Piller, A., & Pfeiffer, B. (2016). The sensory environment and participation of preschool children with autism spectrum disorder. *OTJR: occupation, participation and health*, *36*(3), 103-111.

Pozuelos, J. P., Paz-Alonso, P. M., Castillo, A., Fuentes, L. J., & Rueda, M. R. (2014). Development of attention networks and their interactions in childhood. Developmental Psychology, 50 (10), 2405-15

Rabiner, D., Coie, J. D., & Conduct Problems Prevention Research Group. (2000). Early attention problems and children's reading achievement: A longitudinal investigation. *Journal of the American Academy of Child & Adolescent Psychiatry*, *39*(7), 859-867.

Remington, A. M., Swettenham, J. G., & Lavie, N. (2012). Lightening the load: Perceptual load impairs visual detection in typical adults but not in autism. *Journal of Abnormal Psychology*, 121(2), 544–551

Remington, A. M., Swettenham, J. G., Campbell, R., & Coleman, M. (2009). Selective attention and perceptual load in autism spectrum disorder. *Psychological Science, 20*(11), 1388–1393

Remington, A., & Fairnie, J. (2017). A sound advantage: Increased auditory capacity in autism. *Cognition*, *166*, 459-465.

Remington, A., Hanley, M., O'Brien, S., Riby, D. M., & Swettenham, J. (2019). Implications of capacity in the classroom: Simplifying tasks for autistic children may not be the answer. *Research in Developmental Disabilities*, *85*, 197-204.

Reynolds, S., Lane, S. J., & Thacker, L. (2012). Sensory processing, physiological stress, and sleep behaviors in children with and without autism spectrum disorders. *OTJR: Occupation, Participation and Health*, *32*(1), 246-257.

Roberts, J., & Simpson, K. (2016). A review of research into stakeholder perspectives on inclusion of students with autism in mainstream schools. *International Journal of Inclusive Education*, *20*(10), 1084-1096.

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.

Robertson, A. E., & Simmons, D. R. (2015). The sensory experiences of adults with autism spectrum disorder: A qualitative analysis. *Perception*, *44*(5), 569-586.

Robertson, C. E., & Baron-Cohen, S. (2017). Sensory perception in autism. *Nature Reviews Neuroscience*, *18*(11), 671.

Robertson, S. M., & Ne'eman, A. D. (2008). Autistic acceptance, the college campus, and technology: Growth of neurodiversity in society and academia. *Disability Studies Quarterly*, *28*(4).

Rodriguez, A., Järvelin, M. R., Obel, C., Taanila, A., Miettunen, J., Moilanen, I., & Olsen, J. (2007). Do inattention and hyperactivity symptoms equal scholastic impairment? Evidence from three European cohorts. *BMC Public Health*, *7*(1), 1-9.

Rogers, S. J., & Ozonoff, S. (2005). Annotation: What do we know about sensory dysfunction in autism? A critical review of the empirical evidence. *Journal of Child Psychology and Psychiatry*, *46*(12), 1255-1268.

Rohde, T. E., & Thompson, L. A. (2007). Predicting academic achievement with cognitive ability. *Intelligence*, *35*(1), 83-92.

Ronconi, L., Molteni, M., & Casartelli, L. (2016). Building blocks of others' understanding: A perspective shift in investigating social-communicative deficit in autism. *Frontiers in Human Neuroscience*, *10*, 144.

Rosenberg, R. E., Law, J. K., Yenokyan, G., McGready, J., Kaufmann, W. E., & Law, P. A. (2009). Characteristics and concordance of autism spectrum disorders among 277 twin pairs. *Archives of pediatrics & adolescent medicine*, *163*(10), 907-914.

Ruff, H., & Rothbart, M.K. (2001). Attention in early development. New York: Oxford

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), 1-10.

Rutter, M., Le Couteur, A., & Lord, C. (2003). Autism diagnostic interview-revised. *Los Angeles, CA: Western Psychological Services*, *29*(2003), 30.

Saito, M., Hirota, T., Sakamoto, Y., Adachi, M., Takahashi, M., Osato-Kaneda, A., & Nakamura, K. (2020). Prevalence and cumulative incidence of autism spectrum disorders and the patterns of co-occurring neurodevelopmental disorders in a total population sample of 5-year-old children. *Molecular autism*, *11*(1), 1-9.

Samson, A. C., Phillips, J. M., Parker, K. J., Shah, S., Gross, J. J., & Hardan, A. Y. (2014). Emotion dysregulation and the core features of autism spectrum disorder. *Journal of Autism and developmental Disorders*, *44*(7), 1766-1772.

Savin-Baden, M., & Major, C. H. (2013). Qualititative research: the essential guide to theory and practice. *Qualitative Research: The Essential Guide to Theory and Practice. Routledge*.

Schaaf, R. C., & Lane, A. E. (2015). Toward a best-practice protocol for assessment of sensory features in ASD. *Journal of autism and developmental disorders*, *45*(5), 1380- 1395.

Schauder, K. B., & Bennetto, L. (2016). Toward an interdisciplinary understanding of sensory dysfunction in autism spectrum disorder: an integration of the neural and symptom literatures. *Frontiers in neuroscience*, *10*, 268.

Sedgewick, F., Hill, V., Yates, R., Pickering, L., & Pellicano, E. (2015). Gender differences in the social motivation and friendship experiences of autistic and non-autistic adolescents. Journal of Autism and Developmental Disorders

Sedgewick, F., Hill, V., Yates, R., Pickering, L., & Pellicano, E. (2016). Gender differences in the social motivation and friendship experiences of autistic and non-autistic adolescents. *Journal of Autism and Developmental Disorders*, *46*(4), 1297-1306.

Segal-Andrews, A. M. (1994). Understanding student behavior in one fifth-grade classroom as contextually defined. *The Elementary School Journal*, *95*(2), 183-197.

Shams, L., Kamitani, Y., Shimojo, S., 2000. Illusions. What you see is what you hear. Nature 408 (6814), 788

Silva, D., Colvin, L., Glauert, R., Stanley, F., Srinivas Jois, R., & Bower, C. (2020). Literacy and numeracy underachievement in boys and girls with ADHD. *Journal of attention disorders*, *24*(10), 1392-1402.

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.

Simpson, K., Adams, D., Alston-Knox, C., Heussler, H. S., & Keen, D. (2019). Exploring the sensory profiles of children on the autism spectrum using the short sensory profile-2 (SSP-2). *Journal of Autism and Developmental Disorders*, *49*(5), 2069-2079.

Simpson, K., Imms, C., & Keen, D. (2021). The experience of participation: eliciting the views of children on the autism spectrum. *Disability and Rehabilitation*, 1-9.

Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of educational research*, *75*(3), 417-453.

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.

Solari, E. J., Grimm, R., McIntyre, N. S., Swain-Lerro, L., Zajic, M., & Mundy, P. C. (2017). The relation between text reading fluency and reading comprehension for students with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *41*, 8-19.

South, M., & Rodgers, J. (2017). Sensory, emotional and cognitive contributions to anxiety in autism spectrum disorders. *Frontiers in Human Neuroscience*, *11*, 20.

Steele, A., Karmiloff-Smith, A., Cornish, K., & Scerif, G. (2012). The multiple subfunctions of attention: Differential developmental gateways to literacy and numeracy. *Child development*, *83*(6), 2028-2041.

Thye, M. D., Bednarz, H. M., Herringshaw, A. J., Sartin, E. B., & Kana, R. K. (2018). The impact of atypical sensory processing on social impairments in autism spectrum disorder. *Developmental cognitive neuroscience*, *29*, 151-167.

Timpson, E. (2019). Timpson Review of School Exclusion. CP92

Tomchek, S. D., Little, L. M., Myers, J., & Dunn, W. (2018). Sensory subtypes in preschool aged children with autism spectrum disorder. *Journal of autism and developmental disorders*, *48*(6), 2139-2147.

Tomlinson, C., Bond, C., & Hebron, J. (2020). The school experiences of autistic girls and adolescents: a systematic review. *European Journal of Special Needs Education*, *35*(2), 203-219.

Tøssebro, J. (2004). Introduction to the special issue: Understanding disability. *Scandinavian Journal of Disability Research*, *6*(1), 3-7.

Totsika, V., Hastings, R. P., Dutton, Y., Worsley, A., Melvin, G., Gray, K., & Heyne, D. (2020). Types and correlates of school non-attendance in students with autism spectrum disorders. *Autism*, *24*(7), 1639-1649.

Troyb, E., Orinstein, A., Tyson, K., Helt, M., Eigsti, I. M., Stevens, M., & Fein, D. (2014). Academic abilities in children and adolescents with a history of autism spectrum disorders who have achieved optimal outcomes. *Autism*, *18*(3), 233-243

Tunmer, W. E., & Hoover, W. A. (2019). The cognitive foundations of learning to read: A framework for preventing and remediating reading difficulties. *Australian Journal of Learning Difficulties*, *24*(1), 75-93.

Tymms, P., & Merrell, C. (2011). ADHD and academic attainment: Is there an advantage in impulsivity?. *Learning and individual differences*, *21*(6), 753-758.

Uljarević, M., Baranek, G., Vivanti, G., Hedley, D., Hudry, K., & Lane, A. (2017). Heterogeneity of sensory features in autism spectrum disorder: Challenges and perspectives for future research. *Autism Research*, *10*(5), 703-710.

Uljarević, M., Lane, A., Kelly, A., & Leekam, S. (2016). Sensory subtypes and anxiety in older children and adolescents with autism spectrum disorder. *Autism Research*, *9*(10), 1073-1078.

Unluer, S. (2012). Being an insider researcher while conducting case study research. *Qualitative Report*, *17*, 58.

Van Herwegen, J., Ashworth, M., & Palikara, O. (2018). Parental views on special educational needs provision: Cross-syndrome comparisons in Williams Syndrome, Down Syndrome, and Autism Spectrum Disorders. *Research in developmental disabilities*, *80*, 102-111.

Vivanti, G. (2020). Ask the editor: What is the most appropriate way to talk about individuals with a diagnosis of autism?. *Journal of Autism and Developmental Disorders*, *50*(2), 691-693.

Wallace, M.T., Stevenson, R.A., 2014. The construct of the multisensory temporal binding window and its dysregulation in developmental disabilities. Neuropsychologia 64, 105–123.

Waltz, M. (2008). Autism= death: The social and medical impact of a catastrophic medical model of autistic spectrum disorders. *Popular narrative media*, *1*(1), 13-24.

Watson, L. R., Patten, E., Baranek, G. T., Poe, M., Boyd, B. A., Freuler, A., & Lorenzi, J. (2011). Differential associations between sensory response patterns and language, social, and communication measures in children with autism or other developmental disabilities.

Wechsler, D. (2005). Wechsler individual achievement test–Second UK edition. *The Psychological Corporation*.

Wechsler, D. (2011). Wechsler Abbreviated Scale of Intelligence–Second Edition. *San Antonio, TX: NCS Pearson*.

Wei, X., Christiano, E. R., Yu, J. W., Wagner, M., & Spiker, D. (2015). Reading and math achievement profiles and longitudinal growth trajectories of children with an autism spectrum disorder. *Autism*, *19*(2), 200–210

Wendelborg, C., & Tøssebro, J. (2010). Marginalisation processes in inclusive education in Norway: a longitudinal study of classroom participation. *Disability & Society*, *25*(6), 701-714.

Wiggins, L. D., Robins, D. L., Bakeman, R., & Adamson, L. B. (2009). Breif report: sensory abnormalities as distinguishing symptoms of autism spectrum disorders in young children. *Journal of autism and developmental disorders*, *39*(7), 1087-1091.

Wilkinson, K. and Twist, L. (2010). Autism and Educational Assessment: UK Policy and Practice. Slough: NFER.

Williams, M. S., & Shellenberger, S. (1996). *How does your engine run?: A leader's guide to the alert program for self-regulation*. TherapyWorks, Inc.

Wood-Downie, H., Wong, B., Kovshoff, H., Mandy, W., Hull, L., & Hadwin, J. A. (2021). Sex/gender differences in camouflaging in children and adolescents with autism. *Journal of Autism and Developmental Disorders*, *51*(4), 1353-1364.

Woodcock RW, McGrew KS and Mather N (2001) Woodcock-Johnson III tests of cognitive ability. Itasca, IL: Riverside

Yeung, L. H. J., & Thomacos, N. (2020). Assessments of sensory processing in infants and children with autism spectrum disorder between 0–12 years old: A scoping review. *Research in Autism Spectrum Disorders*, *72*, 101517.