University of Reading

Exploring the relationship between sensory reactivity differences, the indoor environment and classroom behaviour of autistic children.

Doctor of Philosophy in Psychology

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Declaration

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged. Paper contribution statements approved by Teresa Tavassoli.

Hannah Marcham

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Contents

Abstract

Autistic children are known to be at risk for underperforming academically and there is a need for research investigating how we can better support their learning. Sensory reactivity differences are now part of the core diagnostic criteria for autism and can impact behaviour and response to environments. Sensory reactivity differences fall into three domains: hyperreactivity differences (a heightened response to stimuli), hyporeactivity (an under response to stimuli), and sensory seeking (a fascination or craving for a stimuli). There has so far been limited empirical research examining how sensory reactivity differences might be impacting classroom learning. Additionally, while we know that the environments we spend our time in can greatly impact us, there has been little research examining how the sensory environment might be impacting autistic students in the classroom. Thus, this thesis aimed to investigate the relationship between sensory reactivity differences, the classroom environment, and classroom behaviour of autistic children, particularly those with high support needs.

The first study examined the relationship between directly observed sensory reactivity differences and classroom behaviour of 58 autistic students. The second study qualitatively investigated the views of school staff on classroom design for autistic students. The third study investigated how the sensory environment of classrooms is linked to classroom behaviour of 19 autistic students.

The findings from this thesis showed a relationship between sensory reactivity differences and classroom behaviour. In particular, providing evidence that hyporeactivity differences may be the most influential and further research into the role of hyporeactivity differences is needed. The findings also suggest that classroom design is linked to sensory differences and behaviour. School staff discussed specific needs around classroom design, including aspects such as Building Layout, Indoor Environmental Quality and Interior Fnishings. Empirical research then suggested a potential relationship between increased temperature and a reduction in classroom behaviours that may facilitate learning, and increased sound level and greater engagement in behaviours that may impede learning.

This thesis contributes to the lack of empirical literature regarding relationship between sensory reactivity differences, the classroom sensory environment and learning. While the findings may be preliminary, they may have implications for tailoring support in the classroom, informing design considerations and guiding the direction of future research.

Chapter 1. Introduction

1.1 Autism

Autism spectrum condition (hereafter referred to as autism) is a neurodevelopmental condition centred around the diagnostic criteria of A) differences in social interaction and communication, B) restrictive and repetitive patterns of behaviours, interests or activities, including sensory reactivity differences. This thesis will use identity, rather than person, first language throughout i.e. autistic person rather than person with autism. This is in accordance with the general preferences of autistic people within the U.K (Kenny et al., 2016). However, it is worth noting that there is no universally agreed upon language style when describing autism, and peoples' individual preferences should always be established when working with autistic people. An autism diagnosis can be with or without intellectual disability or communication impairments (DSM-5; APA, 2013). Common comorbidities include epilepsy, gastrointestinal disorders, Attention Deficit Hyperactivity Disorder (ADHD) and mental health conditions such as anxiety (Cassonova et al., 2020; Mpaka et al., 2016). Due to positive improvements in public awareness, approximately 1/100 children are diagnosed autistic worldwide (Zeidan et al., 2022). Historically autism was believed to be more common in men, and current research still estimates the ratio of males to females diagnosed with autism at 3:1 (Loomes et al., 2017). However, there is ever increasing awareness that the current diagnostic criteria are biased towards male presentations of autism and that women may engage in higher levels of camouflaging. This leads to autistic women going undiagnosed or being diagnosed later in life, meaning they go longer without access to support and services, which is detrimental to life outcomes (Lockwood et al., 2021).

Autism is a spectrum condition, meaning it can manifest very differently between individuals. The DSM-5 diagnosis criteria suggest diagnosis should come with a severity rating of 1 (requires support), 2 (requiring substantial support) or 3 (requiring very substantial support). However, the sub labelling of different autistic populations is a heavily debated area. Many autistic students will attend mainstream schools (72% in the 2020/2021 academic year), be able to live independently and engage in full time employment, and have positive social functioning outcomes (DfE, 2022; Lord et al., 2022;

Steinhausen et al., 2016). Others may require higher levels of care and reside in a residential setting (Hewitt et al., 2017). Intellectual disability is common, but not universally found in autistic children with few to no spoken words, and rates of prevalence depend on IQ test used (Bal et al., 2016; Chenausky et al., 2019; Chenausky et al., 2023). There is also no clear definition around what constitutes “minimally verbal” (Jack & Pelphrey., 2017).

Some researchers feel there is a need to label these subgroups in order to reflect the heterogeneity; for example, the recent commission by the Lancet (Lord et al., 2022) on the future of autism research calls for the use of the label profound autism. This is generally viewed as people with IQ less than 50, who use few to no spoken words and require high levels of care (Lord et al., 2022). However, terms such as high or low functioning, profound or complex autism are also seen as reductionist and stigmatising. Kapp (2023) clearly outlines how sub labels lack clear definition and validity and can lead to the segregation of those autistic people with the highest support needs. Kapp also details how our current ability to measure differing capacities is limited and autistic people’s ability/development is not static. Rather than sub-labelling, Kapp and other researchers call for a unified autism diagnosis, where each individual receives individualised recognition of their unique needs and strengths. Due the detrimental impact sub labels can have, this thesis will use the phrase “with high support needs” to reflect autistic students who require continuous care in specialised settings, with few to no spoken words.

1.2 Underrepresentation in autism literature

In general, there has been a significant increase (24-fold) in the amount of research focused on autism in the last two decades (Chakrabarti, 2017). However, autistic people with few to no spoken words (often referred to as minimally verbal in the literature) and low IQs are significantly underrepresented in autism literature (Chakrabarti, 2017; Jack & Pelphrey, 2017). This is a substantial problem given that estimates suggest up to a third of autistic people may have few to no words (Rose et al., 2016; Norrelgen., 2015). In Kasari et al’s (2013) article, the authors highlighted how the existing assessment measures for a wide range of skills such as language, play, communication, imitation and non-verbal cognition have serious limitations in their use with autistic children with few to no words, which is impeding research and clinical practice. Given the issues just outlined, it will be a key aim of this thesis to ensure the research conducted is with autistic individuals with few to no spoken words and high support needs.

It is also important to note that historically autism research has tended to focus on the deficits of autistic people, highlighting negative ways in which they may differ to neurotypical people. However, there is now, rightly, a call for a shift to research that focuses on the strengths and wellbeing of autistic people (Burnham et al., 2017). There is also under representation of other groups within the autism community such as autistic people of colour and those from lower socioeconomic status in autism research (Maye et al., 2021). Whilst this thesis begins to address the underrepresentation of autistic individuals with few to no spoken words and high support needs, we did not collect any demographic information on ethnicity or socioeconomic status of participants. Future research should aim to collect such demographic information to increase transparency and try to increase representation from all underrepresented groups.

1.3 Autism and learning

Autistic children are known to be at increased risk for academic difficulty and are often under-achieving academically, relative to their level of ability (Griswold et al., 2002; Mallory & Keehn, 2021). Academic performance is a complex picture for autistic students, Jones et al. (2009) showed 72.4% of a sample of autistic 14-16 year olds demonstrated significant ability-achievement discrepancy (either positive or negative) for a key area of academic achievement.). Education level is closely linked to employment rates (Åberg, 2003), and the academic underachievement of autistic individuals is reflected in low adult employment rates. In the UK, a recent government review found only 3 in 10 autistic adults are in employment, compared to 5 in 10 for all disabled people and 8 in 10 for non-disabled people (Department for Work and Pensions, 2024) Previous work has suggested that the difficulties autistic children experience in education could be a result of the fact that the classroom is a difficult place for them to be able to maintain their attention and regulate their emotions and behaviours

(Ashburner et al., 2010). Qualitative work with autistic adolescents echoes this, with studies demonstrating that sensory reactivity differences can make the classroom an uncomfortable environment for them, for example background noise and brightly coloured classrooms cause distraction and the overall overwhelming sensory environment leads to symptoms such as anxiety and stomach aches (Howe & Stagg, 2016). As autistic children are also more likely to struggle to be able to communicate their feelings, the classroom can then become a frightening and disorientating place for them (Branigan-Pipe, 2017).

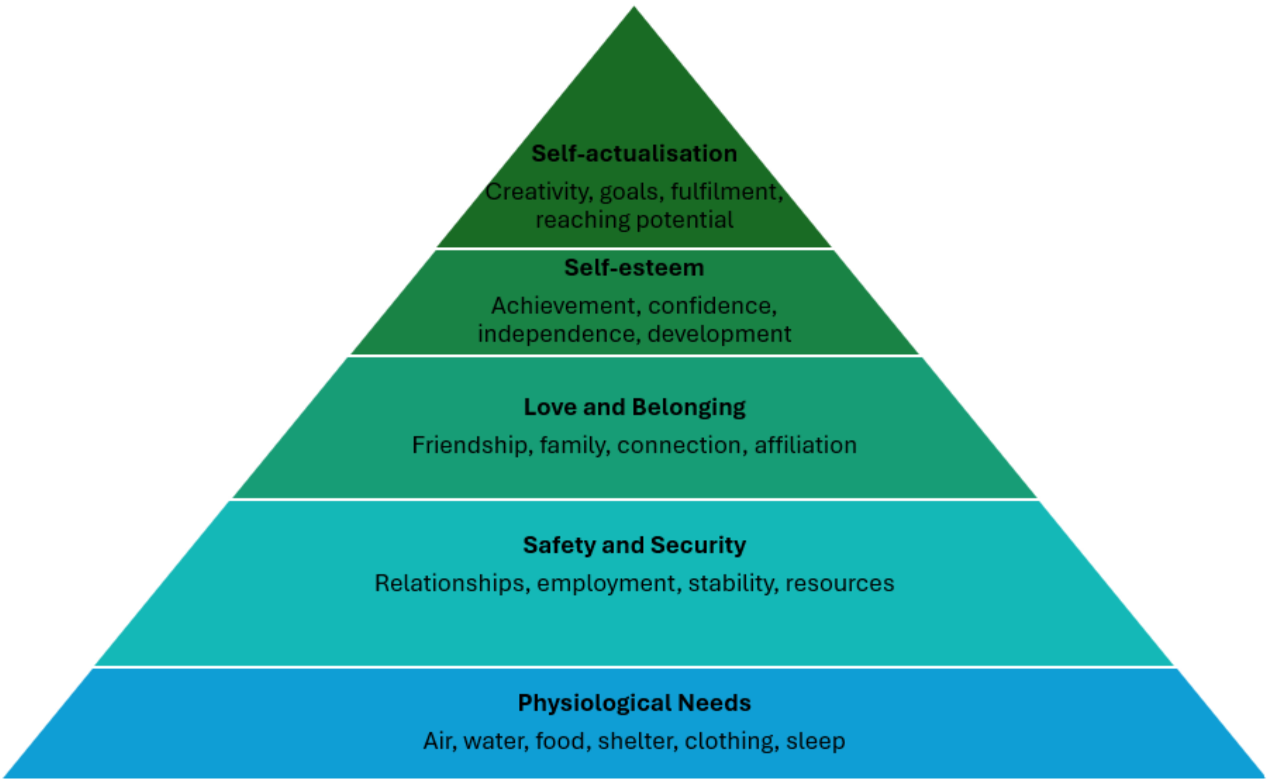
Within SEN classrooms for autistic students, the focus of teaching will differ from that in mainstream schools. In order to better prepare students for life after school there will be less focus on academic work and increased focus on teaching life and independence skills such as cutlery use, completing hygiene activities independently or being able to access and engage in the community such as going to the shop or a restaurant (Howell et al., 2022). How well a student is able to complete these skills may determine the kind of adult placement they later live in. This demonstrates the importance of ensuring we are providing autistic students with high support needs the best possible educational experience.

1.4 Biopsychosocial model of disability

Historically, autism has been viewed through the medical model of disability, which attributes the challenges faced by autistic individuals to their own deficits (Graby, 2016). This focus on deficit has caused autism research to focus on “intervening” and “treating” the individual themselves. However, there is now growing understanding that autism should be viewed using the biopsychosocial model of disability instead (Pellicano & den Houting, 2022) where a more nuanced view is taken and disability is viewed as being created by a combination of biological and psychological and social (environmental) factors. In the context of autism and sensory differences, biological factors include how autistic peoples sensory processing systems differ to neurotypical peoples, for example how sensory input is filtered or interpreted by internal biological systems (further explanation of these systems is provided in section 1.6). Psychological factors include attributes of each individual person that might mitigate or worsen their experience, these include mental health, cognitive function and emotion regulation (L3ai & Baron-Cohen, 205; Mazefsky et al. 2013) . This thesis aligns itself with the biopsychosocial model of disability, with a particular focus on the social (environmental) aspects. This means when investigating the role of sensory reactivity differences in the classroom, the impact of the classroom environment itself needs to be considered as the difficulties autistic students face in the classroom are a result of mismatch between their needs and the setting There are two further models which support the need for investigating the impact of the environment Maslow's theory of human motivation (1943) and Bronfenbrenner's (1989) ecological systems model. Maslow's 1943 theory of motivations depicts a hierarchy of human needs, containing multiple levels which need to be achieved in an ascending order (See Figure 1).

Figure 1.

Image depicting Maslow's (1943) hierarchy of needs.



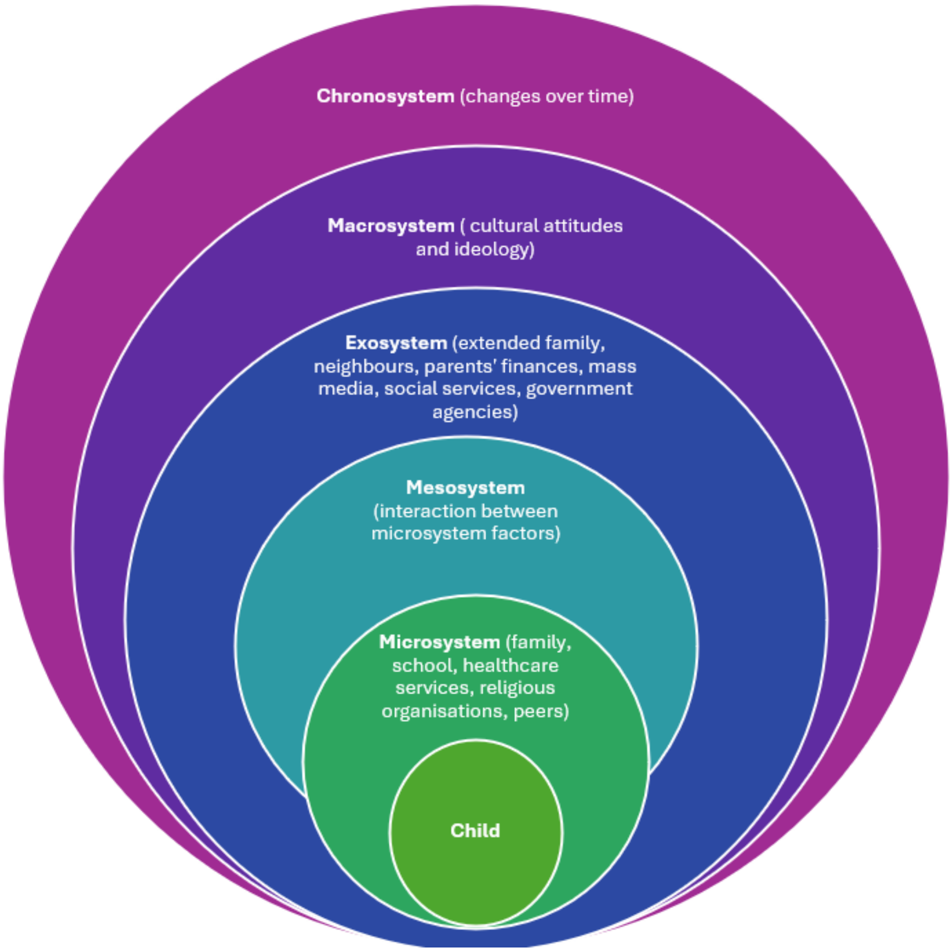
The lowest, and most fundamental, level is physiological needs (the basics for human survival, water, food, clothing etc). This is followed by safety needs; humans need to feel safe and protected in terms of environments and relationships. Without safety being achieved people are unable to progress onto achieving higher level needs such as belonging and self-esteem.

This model can be applied to autistic students in the classroom. Fulfilment of the lower levels of the model are crucial to a student's ability, and motivation, to engage in anything else in the classroom (Burleson et al., 2012). For example, if a student is hungry or hot their physiological needs are not met. Additionally, if the sensory environment of the classroom is overwhelming or distressing due to autistic students' differences in sensory reactivity, then they are not having their safety and security needs met. It is crucial that students feel safe in classroom environments to enable them to engage in learning activities (Maslow, 2014). Adams et al. (2016) suggests that the majority of autistic students never progress past the safety and security level.

Another model which demonstrates the importance of examining the environment around a student is the Bronfenbrenner Ecological systems mode (Bronfenbrenner, 1989). This model depicts how people's development is impacted by the relationships between the environmental systems we encounter throughout life. Bronfenbrenner suggests that relationships between systems are the key to positive emotional development. See Figure 2. One of the immediate systems a child encounters (one of their microsystems) is school. If a child is unable to develop a positive relationship with school and the people inside, then this will harm their development and progress. Applying this model to autistic children in school, if students feel unsafe and distressed in the school environment, because the environment is not meeting their sensory needs perhaps then this will lead to negative child/school relationship.

Figure 2.

Simplified depiction of Bronfenbrenner's ecological systems model (1989)



1.5 Sensory reactivity differences

One reason that an autistic student may feel unsafe in their classroom environment is that the environment does not match their sensory needs. Sensory reactivity differences are not exclusive to autism and are seen across other neurodevelopmental conditions such as ADHD and cerebral palsy, or genetic conditions such as Phelan McDermid syndrome (Bijlenga et al., 2017; Schaaf et al. 2010; Baranek et al. 2014; Pavão & Rocha, 2017; Mieses et al., 2016). However, sensory reactivity differences are experienced by the vast majority of autistic people (Ben-Sasson et al, 2019; Tomcheck & Dunn, 2007; Cascio et al., 2016), so much so that they are now one of the core diagnostic criteria for autism (falling under category B of the DSM-5 diagnostic criteria). Sensory reactivity differences can impact all sensory modalities; touch, taste, vision, smell and auditory (Kern et al., 2006). The differences fall into three subtypes: hyperreactivity, hyporeactivity and sensory seeking.

Sensory Hyperreactivity is a heightened sensitivity to sensory stimuli. Hyperreactivity can cause feelings of being overwhelmed, discomfort and pain, as well as contribute to meltdowns. Examples include finding a loud noise painful, a smell making someone feel sick, lights causing headaches. This intense experience of sensory stimuli can lead to autistic individuals avoiding places such as supermarkets, cafeterias, public transport and lecture halls or classrooms (MacLennan et al., 2021; Jones et al., 2003; Robertson & Simmons, 2015).

Sensory hyporeactivity is an under responsiveness or delayed response to sensory stimuli. Individuals may miss, not notice, or show a dampened reaction to sensory input. Examples include not noticing/responding to pain, not hearing the phone ring or your name being called. Not responding, or taking longer to respond when someone touches you, not reacting to touching something hot, or not being as aware of body sensations (interoception) such as being hungry, needing the bathroom, or being slow to notice getting too hot or cold (Elwin et al., 2013; Siper et al, 2017). Qualitative work with autistic adults suggests sensory hyporeactivity may also make visual search difficult, e.g. finding it hard to find items you are looking for, as well as being slower to notice changes or danger in the environment (MacLennan et al., 2022). This suggestion differs to the literature which has consistently found superior visual search in autistic people such as Remington et al., 2009; Joseph et al., 2009). It is possible this discrepancy is a result of differing methods, literature that finds superior visual search abilities is primarily based on studies which use highly controlled, computerised tasks which may not reflect the experiences of autistic people in real world settings doing day to day tasks where there are many other confounding variables such as sensory overload or social factors.

Sensory seeking is a fascination or need for a certain input. This is sometimes called unusual sensory interests or sensory craving. An individual may really enjoy and crave a certain sensory input and engage with this for longer periods of time than others might. Examples include intently enjoying music and bringing sounds close to the ear, peering closely at objects, repeatedly feeling a certain texture or material or intentionally bumping into things. In some instances, sensory seeking may be a self-soothing behaviour, to help cope with anxiety (MacLennan et al., 2022; Siper et al., 2017; Pellicano, 2013).

Autistic individuals might oscillate between sensory reactivity types across the sensory modalities, therefore hyperreactivity, hyporeactivity and sensory seeking may all be found within the same individual depending on the stimuli (Baranek et al., 2006). For example, an individual may be hypersensitive to physical touch but hyposensitive to temperature. Sensory reactivity differences have been linked to negative outcomes for autistic people including sleep disturbances (Mazurek & Petroski, 2015), anxiety (MacLennan et al., 2020), depression (Rossow et al., 2021), reduced participation in daily living skills (Jasmin et al., 2009), family life (Schaaf et al., 2011) and academic underachievement (Ashburner et al., 2008).

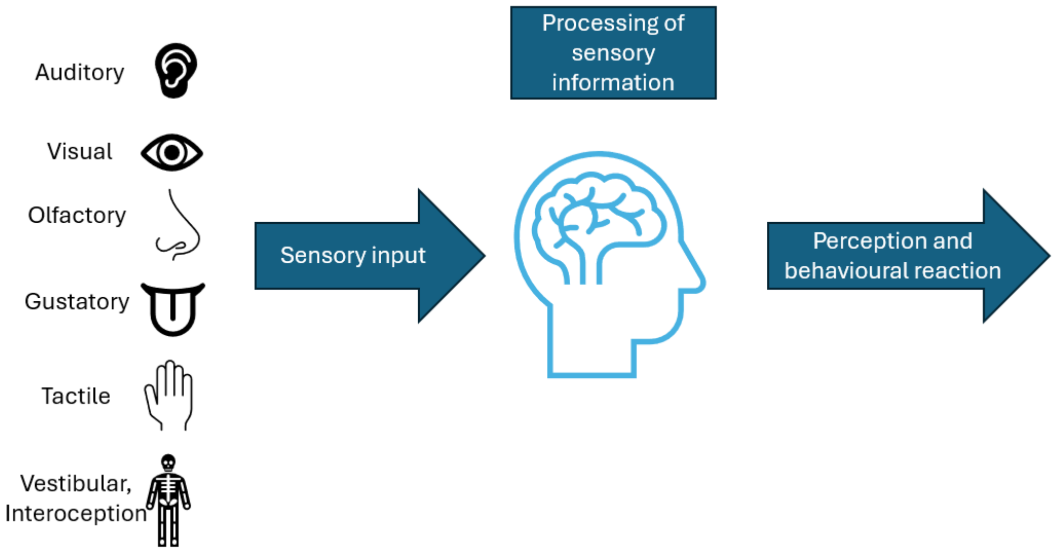
It is also important to recognise that while sensory reactivity differences can cause distress and difficulties, autistic people report they can bring comfort when distressed by other things or be used to distract themselves from less pleasurable stimuli (Kirby et al., 2015; MacLennan et al., 2022).

1.6 Models of sensory reactivity differences

One of the first explanations of sensory reactivity differences came from Ayres (1972), who described sensory integration as the process between how someone perceives and interprets sensory information (sensory processing) and their corresponding functional behaviour. See Figure 3.

Figure 3.

Simplified depiction of Ayres (1972) sensory integration process.

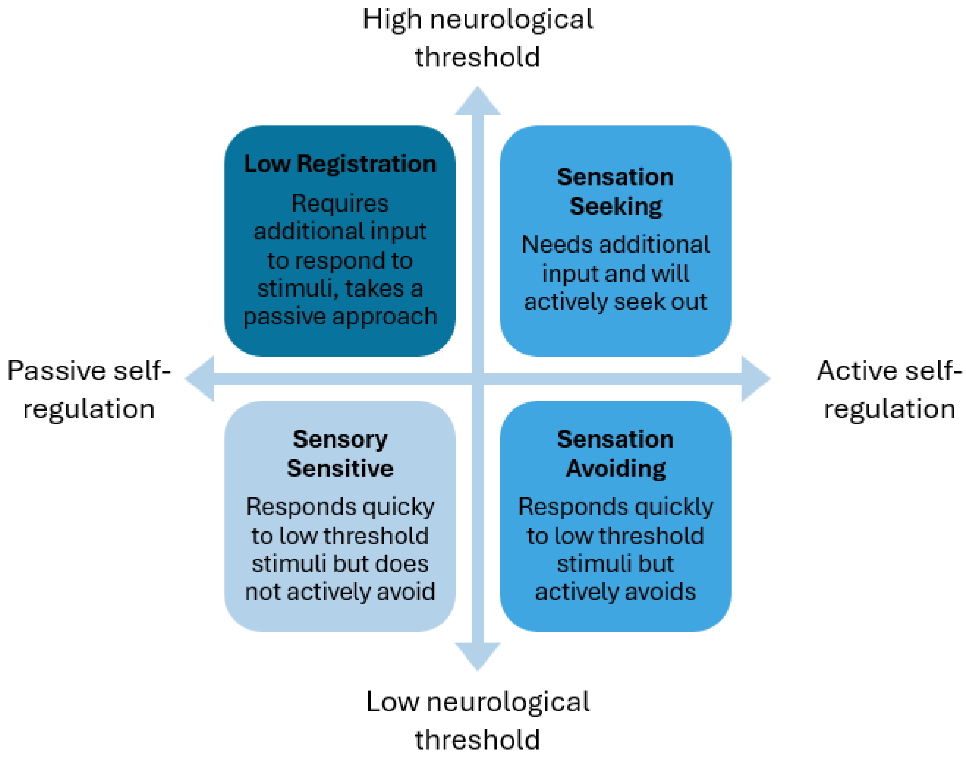


When this process works effectively, we can appropriately respond to situations and environments based on sensory information, e.g. feeling water temperature is uncomfortably hot or cold and not getting in the bath. Having altered sensory processing (sensory reactivity differences) means individuals may react differently to sensory information.

Two models have since been proposed to explain how sensory reactivity differences arise. Winnie Dunn created a quadrant model (Dunn, 1997) where neurological thresholds (how much sensory input is needed for it be registered by the central nervous system) interacts with behavioural response of the person (how someone responds to the stimuli). See Figure 4.

Figure 4.

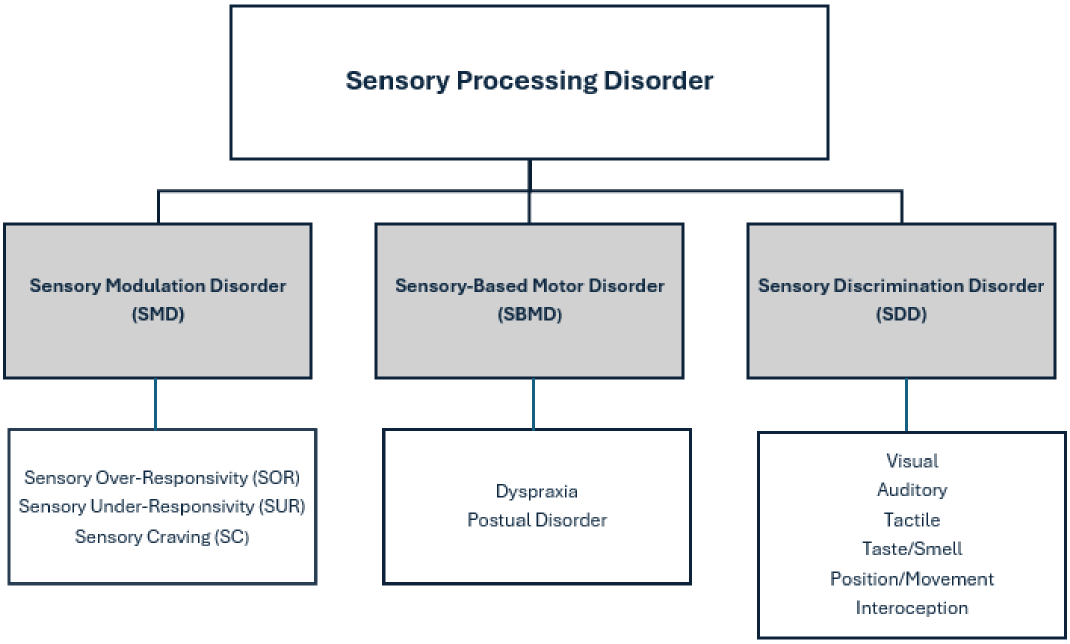
Depiction of Dunn (1997) sensory processing model.



Lucy Miller proposed a model that depicted a new diagnostic condition called sensory processing disorder (SPD; Miller et al., 2007). This condition is made up of three subgroups: sensory modulation disorder (SMD), sensory discrimination disorder (SDD) and sensory based motor disorder. SMD is defined by Miller as when the central nervous system does not regulate sensory input appropriately, creating atypical physiological and behavioural responses to an environment or situation There are three subtypes within SMD: over-responsivity (or hyperreactivity), under-responsivity (hyposensitivity) and sensory seeking. (Miller et al., 2007; Miller et al., 2009). See Figure 5.

Figure 5.

Depiction of Miller (2007) sensory processing disorder.

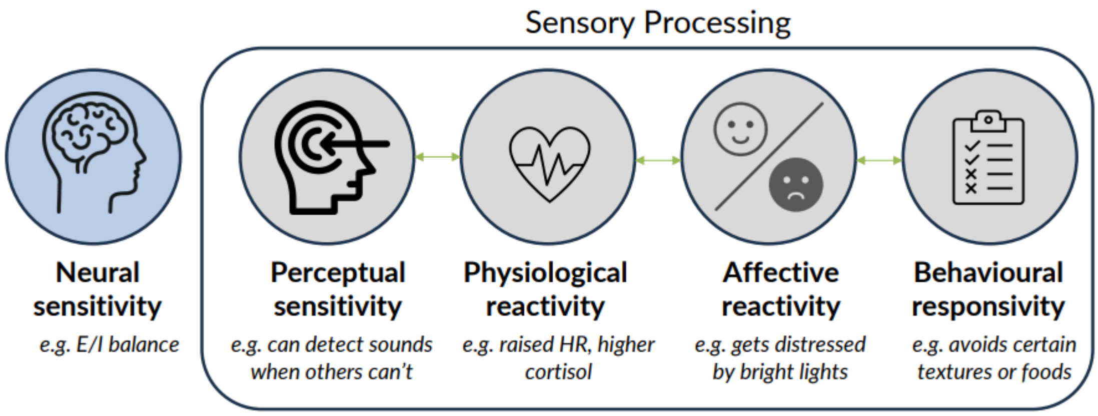


It is important to note that these models were created to explain sensory reactivity differences in neurotypical people, not specifically autistic people (Bundy & Lane, 2020).

As outlined in the recent He et al. (2023) article, within the increase in literature investigating sensory reactivity, there is a large inconsistency with terminology use (for example it may be called sensory sensitivity, or responsivity) instead of sensory reactivity. This inconsistency has a detrimental impact on the progression of the field. To address this, He et al. (2023) created a hierarchal taxonomy for sensory reactivity, where each level of the hierarchy represents a level of analysis, with clearly defined terminology attached. See Figure 6. The levels start at sensory related neural excitability which refers to activation of central and peripheral neural structures following sensory input. Methods often utilised in measuring this level of sensory reactivity include neuroimaging such as magnetic resonance imaging (MRI) and electroencephalography (EEG). Perceptual sensitivity is the next level, and this refers to how well someone can detect changes in in sensory information, this is often measured through psychophysics methods such as signal detection (e.g. assessing at what noise level someone can first hear a sound). The third level is physiological reactivity; this refers to changes in either the autonomic nervous system (e.g. heart rate and blood pressure) or limbic-hypothalamic-pituitaryadrenal axis (e.g. cortisol changes). The following level, affective reactivity, is someone's subjective experience/judgement of sensory information as either pleasant or unpleasant. Methods used to assess this level include questionnaires or interviews which ask people to judge or rate stimuli. This level of measurement should ideally be people reporting on their own feelings rather than a third parts making inferences based on behaviour. The highest measurement level is then behavioural responsivity, which refers to observable, or lack of expected, reactions to sensory input. For example, someone placing their hands over their ears or not reacting to physical touch. Measures to assess behaviours responsivity include questionnaires asking about behaviour or clinician administered assessments such as the Sensory Assessment for Neurodevelopmental Differences (SAND; Siper et al., 2017).

Figure 6.

Simplified depiction of He et al (2023) sensory taxonomy.



When discussing levels of measurement related to sensory reactivity differences this thesis will use the terminology as laid out in He et al. (2023). The methods used throughout this thesis will focus on affective reactivity and behavioural responsivity levels of measurement. The methods used will measure participants' observable reactions to sensory stimuli.

1.7 Sensory differences and behaviour

Given the academic disparity and difficulties faced in the classroom by autistic students there is a need for research that helps us understand how we can improve their school experience. Despite sensory differences being an established characteristic of autism, there has been limited research examining the role of sensory reactivity differences specifically within the classroom.

Dellapiazza et al. (2018) concluded that there is a range of evidence that demonstrates sensory reactivity differences impact upon adaptive behaviour and attention skills, particularly the impact of increased auditory sensory reactivity differences in reduced attention to tasks in autistic children. The review highlights findings such as increased sensory dysregulation (measured via a questionnaire, the Short Sensory Profile/ SSP) being associated with increased behaviour problems on the teacher version of the Strength and Difficulties Questionnaire in Green et al (2016). However, Dellapiazza's review was inclusive of behaviour in any setting, and was not classroom specific.

Some of the first research looking at the relationship between sensory differences and learning was Ashburner et al. (2008). They measured sensory reactivity through parent/caregiver report of the Short Sensory Profile (SSP) and measured educational outcomes such as classroom behaviour and emotions through The Conner's Teacher Rating Scale (Connors, 1997) and the Achenbach System of Empirically Based Assessment: Teacher Report Form (Achenbach & Rescorla, 2001). The key findings from the study were that autistic children, aged 6-10 years old, who scored highly in the hyporeactivity/sensory seeking and auditory filtering domains of the SSP were more likely to score highly for academic underachievement and inattention to cognitive tasks. More recently Butera et al. (2020), demonstrated that increased sensory sensitivity, with fewer avoidance behaviours (determined by SSP-2) was a strong predictor of school performance. In particular, they found school performance to be lowest for those autistic students with increased hyperreactivity and fewer avoidance behaviours.

Work by Liss et al (2006), utilising parent report found a relationship between hyperreactivity and over focus of attention, as well as a link between increased hyporeactivity and lower adaptive functioning and communication skills. However, this link was not specifically based on classroom behaviour but general adaptive functioning. Schulz & Stevenson (2019) found evidence that increased hyperreactivity was predictive of increased repetitive behaviours, again this was via parent report and not specifically enquiring about behaviour within a classroom.

There is still a need for this relationship to be further investigated and researched so that we can understand how to better support autistic children in the classroom.

1.8 Autism friendly spaces

Given how much sensory reactivity differences are impacting autistic students it is vital that researchers take a social model of disability approach and consider the impact of the classroom environment. This approach aligns with design principles such as Universal Design (Story et al., 1998). Universal Design is a design approach that states spaces should be created as inclusive for everyone at the initial concept, rather than being modified later (Milton et al., 2016). Research is unpicking more and more how we can create environments that are less challenging for autistic people. Autism friendly spaces aim to increase the "person-environment" fit by making adaptions that suit the needs of autistic people. Adaptions might include things such as reducing sensory elements such as lighting or noise or creating stability and predictability within environments (Lai et al., 2020; Tola et al., 2021; Turnock et al., 2022). Recent research has begun to identify specific qualities of enabling environments. An example of this is MacLennan et al. (2023) who qualitatively investigated the autistic adults experience of public spaces. They suggest six factors that need to be considered when designing spaces for autistic people: the sensory scape, space, predictability, understanding, adjustments and recovery. Implementing these factors will reduce the burden places on autistic individuals and allow them to more comfortably access spaces such as supermarkets or hospitals and increase quality of life MacLennan et al. (2023).

1.9 Current Design guidance

In 2009 the Building Bulleting 102 (BB102, Department for Education & Employment, DfEE) was published, this offers non-statutory guidance on school design for disabled children and children with special educational needs (SEN). Whilst this was specific guidance for school design it was not specific to the needs of autistic children and is now fifteen years old.

One of the biggest contributions to the field of design for autistic people is by Magda Mostafa who created the Autism ASPECTSS™ design index (Mostafa, 2014). This guidance can be applied to any environment, including school environments. There are seven main principles within the guidance: acoustics, spatial sequencing, escape space, compartmentalisation, transition zones, sensory zoning and safety. The Acoustics principle recommends the environment is designed to minimise noise, echo, and reverberation. The Spatial Sequencing principle suggests areas should be organised in their order of use, so people can move easily from one to the next. The Escape Space principle recommends incorporating in an internal space that allows autistic individuals to have a break from overstimulation. The fourth principle, Compartmentalisation, this refers to organising spaces into compartments where each compartment has a clearly defined function. The Transitions principle recommends transition zones between areas to help signal a change or allow time to adjust to an environmental change. The final principle is Sensory Zoning which recommends spaces should be organised by their sensory quality rather than their function.

Most recently the has been the publication of the British Standards Institution's design standard on Neurodiversity and the Built Environment (BSI, 2022). This guidance covers a wide range of design considerations from layout to materials and furniture recommendations. Whilst this guidance is extremely detailed it is not school specific, instead intended to be able to be applied to a range of spaces (e.g. health care or leisure environments).

Some key aspects of the indoor environment include, lighting, air quality (Co2 and Pm2.5 concentration), sound levels and thermal comfort (including indoor temperature and relative humidity, RH) (Brink et al., 2021). There ise some existing guidance for these aspects within a classroom. Noise levels within a classroom should not exceed 35dB for optimal teaching and learning, 60 dB – 85 dB is considered loud (Building Bulletin 93, Department for Education, 2015). Recommended lighting levels for classrooms range from 300-500 Lux (Lighting Guide 5, CIBSE, 2011). For thermal comfort it is recommended that the RH of classrooms ranges from 40-75% and the recommended range for classroom temperature in special needs schools 20°c – 25°c (Building Bulletin 101, Department for Education, 2018). Regarding air quality $PM_{2.5}$ should not exceed 10ug/m3 and Classroom Co2 levels should not exceed 1000ppm (BB101, 2018). There has been very limited empirical research examining the impact of these IEQ elements on autistic students, and even less on the impact of those autistic students with high support needs.

1.10 Thesis objectives

The aim of this thesis is to investigate the relationship between sensory reactivity differences, the classroom environment, and classroom behaviour of autistic children. In particular (in order to help address their underrepresentation in autism literature) to include autistic students with high support needs. The academic underachievement and discomfort in classrooms experienced by autistic students demonstrates the need for more research in this area. Increasing our understanding of the roles sensory reactivity differences and the classroom environment play in education may allow us to provide practical recommendations for improving classroom design and autistic students' learning experience.

Therefore, this thesis will attempt to answer the overall research question: Is there a relationship between sensory reactivity differences, the indoor environment, and classroom behaviour of autistic children with high support needs?

To help answer this large question the thesis will address the following two specific research questions:

A) Is there a relationship between sensory reactivity differences and classroom behaviour?
   This research question will be addressed in Chapters 1 and 3.
B) Is there a relationship between the indoor environment of classrooms and classroom behaviour?
   This research question will be addressed in Chapters 2 and 3.

1.11 Context

There are some contextual aspects that are worthy of note in regard to this thesis and the work contained within it.

Firstly, the work for this thesis began in September 2020, a few months into the COVID-19 pandemic. Due to lockdowns and encouragement of limited social contact and mixing over the following months/years recruiting participants and schools to take part in research was challenging. For Chapter 4, recruiting schools to allow multiple researchers to spend extended time in classrooms was particularly challenging, this inherently impacted our final recruitment numbers.

Secondly, due to the profile of schools we were trying to recruit, our pool of potential schools was limited. As explained above, we were specifically looking to recruit special needs schools where students require high levels of support. Additionally, given the staff shortages the SEN area is facing (Tylerport, 2024) these schools have limited resources to accommodate research projects. This is relevant to both the qualitative and quantitative research in this thesis.

These limitations in recruitment meant one school was used to recruit participants in both Chapter 2 and Chapter 4. In Chapter 4, 6 out of the 19 participants also took part in the study in Chapter 2.

Chapter 2: The relationship between directly observed sensory reactivity differences and classroom behaviours of autistic children.

2.1 Paper contribution

Authors: Hannah Marcham, Teresa Tavassoli

Author contributions: Data collection for 29 participants was completed by Brett Davies, Charlotte Daniels and Frankie Englezou (acknowledged in paper). Data collection for 24 of the participants, all data analysis and interpretation and drafting of the paper was done by Hannah Marcham. Teresa Tavassoli aided with study design, oversaw data collection and analysis as well as provided critical revisions for the paper.

Published: American Journal of Occupational Therapy (brief report).

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2.2 Abstract

Importance: Differences in sensory reactivity are a core feature of autism; however, more remains to be learned about their role in classroom learning.

Objective: To use direct observational measures to investigate whether there is a link between sensory reactivity differences and classroom behaviours of autistic children.

Design: Correlational study.

Setting: Two special educational needs schools.

Participants: Children with a clinical diagnosis of autism, ages 5 to 18 yr (N 5 53).

Outcomes and Measures: Sensory reactivity differences were assessed with the Sensory Assessment for Neurodevelopmental Differences. Classroom behaviours were measured using the Behaviour Assessment for Children–Second Edition Student Observation System.

Results: Total sensory reactivity differences were correlated positively with behaviours that impede learning (r 5.31, $p < .05$) and negatively with behaviours that facilitate learning (r 5 _.38, $p < .05$). Hyporeactivity differences were correlated positively with behaviours that impede learning (r 5.28, $p < .05$) and negatively with behaviours that facilitate learning (r 5 _.31, $p < .05$). Hyperreactivity and sensory-seeking differences were not significantly correlated with behaviour.

Conclusions and Relevance: Results suggest a link between sensory reactivity differences and classroom behaviours, highlighting a need for further research using observational measures in special education settings.

Plain-Language Summary: Differences in hyporeactivity for children with autism may play a bigger role in classroom behaviour and learning than previous literature has suggested. This has implications in occupational therapy practice for how to tailor support for children with hyporeactivity differences.

2.3 Introduction

Sensory reactivity differences are a core diagnostic criterion for autism spectrum conditions (American Psychiatric Association, 2013). These differences are found across all sensory domains, including the tactile, visual, and auditory domains (Dunn, 1997). Differences fall into three subtypes: (1) hyperreactivity (a strong response to stimuli, such as finding noise painful); (2) hyporeactivity (an underresponsiveness, such as not noticing the cold); and (3) sensory seeking (fascination with or need for a certain input; Ben-Sasson et al., 2009). All subtypes may be found within the same individual (MacLennan et al., 2022). Although autistic individuals describe finding enjoyment or comfort in some of their sensory reactivity differences (MacLennan et al., 2020), these differences may be challenging in a range of areas (Dellapiazza et al., 2018).

Autistic students are at higher risk for underachieving academically (Mallory & Keehn, 2021), and research looking into the role of sensory reactivity differences in this underachievement is increasing. A correlation between sensory reactivity differences and poorer academic performance has been demonstrated among autistic students in mainstream classrooms (Ashburner et al., 2008). Dunn (1997) theoretically demonstrated why sensory differences affect behaviour and learning, and Jones et al. (2020) described how teachers and parents see sensory differences causing distress and distraction and reducing classroom participation. Sensory differences have also been shown to reduce attention (Mallory & Keehn, 2021).

Investigating the role each sensory subtype plays in learning is vital because different support methods are needed to aid with each. Using parent reports, Liss et al. (2006) found a relationship between hyperreactivity and overfocus of attention and between hyporeactivity and lower adaptive functioning and communication skills. However, this link was with general adaptive functioning skills rather than classroom behaviour specifically. Ashburner et al. (2008) found that autistic students with increased hyporeactivity and sensory-seeking differences (measured with the Short Sensory Profile [SSP]) were at increased risk of inattention to tasks in the classroom, a behaviour that impedes learning. Using parent and teacher reports, Green et al. (2016) found sensory reactivity differences were linked to increased emotional, but not behavioural, challenges.

The limited previous literature in the field relies on parent and teacher reports. Although these are important sources of information, they are vulnerable to recollection bias and parent–teacher discrepancies (Jordan et al., 2019). More research using direct observational methods is needed. Furthermore, previous work has focused on students in mainstream schools and has not incorporated autistic students in special education settings.

This study investigated whether there is a link between sensory reactivity differences and classroom behaviours of autistic children in special education settings, using objective direct observational measures.

2.4 Method

2.4.1 Participants and Procedures

Fifty-three students (9 female, 44 male) ages 5–18 yr (M 5 10.53, SD 5 3.98) with a clinical diagnosis of autism participated. Participants were recruited from two special education schools in which all students have an Education Health and Care Plan and require a high level of support, reflected in high staff:student ratios ranging from 1:1 to 1:3. Informed consent was gained from parents via electronic forms. Participants were unable to provide written or verbal consent, so they were continuously monitored for signs of distress. If they appeared distressed or if school staff stated that they were displaying anxiety, the assessment stopped. Research was conducted in participants' usual classroom, with behaviour observations completed during a routine seated table work activity. There was no set order in which the BASC-SOS or SAND were completed, this was to ensure the research was flexible to the needs of the students and their usual timetables to cause minimal disruption as is possible.

2.4.2 Measures

Sensory Assessment for Neurodevelopmental Differences

The Sensory Assessment for Neurodevelopmental Differences (SAND) consists of direct observation of an individual's response to sensory stimuli and an accompanying parent interview (Siper et al., 2017). In line with study aims to use a direct observation method, only the observational aspect of the SAND was used. During the observation, individuals' observable reactions to stimuli are scored; a verbal response is not required, which makes the tool suitable for individuals with minimal spoken language. Structured observation using standardized manipulatives is completed and lasts approximately 15 min. The SAND was designed specifically to capture sensory reactivity differences among autistic people; sensory hyperreactivity (adverse reaction to noisy toys or flashing lights), hyporeactivity (not noticing being touched by a cold pack or sudden unexpected noise), and seeking behaviour (looking very closely at a spinning wheel or bringing a toy close to their ear) are examined across visual, tactile, and auditory domains. If a difference is observed, a score of 1 is given. If no difference is observed, a score of 0 is given. A severity rating is given for the hyperreactivity, hyporeactivity, and seeking categories in each domain (1= mild differences; 2 = moderate–severe differences, such as when a reaction is shown multiple times). The number of differences observed and severity ratings are combined to give an overall score (out of 15) for each domain, with total scores ranging from 0 to 45. Higher scores represent higher presence of sensory reactivity differences. The SAND has high internal consistency (Cronbach's a 5 0.90) and strong interrater and test–retest reliability (>0.8 and 0.8, respectively; p < .001; Siper et al., 2017). Researchers were trained on the SAND by one of the codevelopers of the tool.

Behaviour Assessment for Children–Second Edition Student Observation System

The Behaviour Assessment for Children–Second Edition Student Observation System (BASC–SOS; Reynolds & Kamphaus, 2004) assesses 13 adaptive behaviours that facilitate learning (e.g., following instructions, completing an activity, interacting with staff) and 58 problem behaviours that impede learning (e.g., aggression, self-injury, inattention). For this study, the BASC–SOS language was changed to be less stigmatising; behaviours were referred to as behaviours that impede or facilitate learning. It is important to recognize that autistic students may learn in different ways than neurotypical students; however, in the context of a routine table-based learning activity (during which the BASC–SOS was completed), the behaviours assessed would either impede or facilitate task engagement. The BASC–SOS procedure entails watching the participant for 3 s and then recording the behaviours witnessed for 27 s, repeated over a 15-min period. The total number of each behaviour type observed was used as the participant's score. The BASC–SOS shows high internal consistency (0.8 with children, 0.9 with adolescents) test–retest reliability (Reynolds & Kamphaus, 2004). Furthermore, it was designed specifically for use with children who are experiencing difficulties significant enough to impede academic progress and has previously been used in research with autistic students (Hodges et al., 2022).Previous literature using the BASC-SOS in children in special education and Eastern countries has found moderate to good interrater reliability, and evidence of its predictive and convergent validity (Schmidt et al. 2021; Al-Hendawi, et al., 2024) Multiple researchers collected data across schools, and all BASC and SAND procedures were followed. We were unable to collected information for interrater reliability in this study.

2.5 Results

The data was analysed with IBM SPSS Statistics (Version 24). Alpha was set at .05. The Kolmogorov– Smirnov test (Berger & Zhou, 2014) was used to test normality. The behaviours that facilitate learning variable were normally distributed, D(53) 5 .09, p 5 .20. The behaviours that impede learning variable, D(53) 5 .13, p < .05, and the total number of sensory reactivity differences, D(53) 5 .13, p < .05; hyperreactivity differences, D(53) 5 .23, p < .001; hyporeactivity differences, D(53) 5 .268, p < .001; and sensory seeking differences, D(53) 5 .15, p < .05, were not normally distributed; therefore, nonparametric tests were used. Pearson correlations (Freedman et al., 2007) showed that age was correlated with behaviours that facilitate learning, r(51) 5 .47, p < .001. Nonparametric Spearman's rank correlation coefficient (Zar, 2005) showed that age was also correlated with sensory-seeking differences, r(51) 5 .37, p < .05, but not with behaviours that impede learning, r(51) 5 .15, p 5 .28, or total number of sensory reactivity differences, r(51) 5 1.17, p 5 .247; hyperreactivity differences, r(51) 5 0.17, p 5 .247; or hyporeactivity differences, r(51) 5 .03, p 5 .844. Therefore, age was controlled for in analyses involving the behaviours that facilitate learning and the sensory seeking differences variables. Descriptive statistics are provided in Table 1, correlation results are given in Table 2, and scatterplot matrices of significant results are provided in the Supplemental Materials (page 34).

Table 1.

Descriptive statistics for SAND domains and BASC-SOS classroom behaviours

	Behaviours that facilitate learning	Behaviours that impede learning
Total sensory differences	-.38*	.31*
Hyperreactivity	-.03	.10
Hyporeactivity	-.31*	.28*
Seeking	-.23	.20

Note: * correlation significant at .05 level (two-tailed)

Table 2.

Correlation matrix

	Minimum	Maximum	Mean (SD)
Classroom Behaviours			
Behaviours that facilitate learning	1.0	36.0	15.77 (8.39)
Behaviours that impede learning	3.0	33.0	15.06 (8.21)
Sensory Reactivity Differences			
Total number of sensory reactivity differences	2.0	17.0	10.70 (3.75)
Hyperreactivity differences	0.0	10.0	1.98 (2.37)
Hyporeactivity differences	0.0	8.0	2.20 (2.61)
Sensory seeking differences	0.0	14.0	6.51 (3.41)

A nonparametric Spearman's rank correlation coefficient showed the behaviours that impede learning and behaviours that facilitate learning variables were strongly correlated, r (51) -.77 p = <.001. Indicating they are both measuring the same concept, classroom engagement.

2.6 Discussion

Sensory reactivity differences and autistic students' classroom behaviour were related. The more sensory reactivity differences students displayed, the more behaviours that impede learning and fewer behaviours that facilitate learning were observed. Our findings are consistent with those of previous research demonstrating that sensory differences have a negative effect on adaptive behaviour and attention and participation (Dellapiazza et al., 2018; Jones et al., 2020; Mallory & Keehn, 2021). This finding adds to the field because we addressed a limitation of previous literature by using direct observational methods rather than teacher and parent reports. We also included autistic students with high support needs in special education settings, who are underrepresented in research. Hyporeactivity was the only sensory subtype independently linked to classroom behaviour. This is consistent with Liss et al.'s (2006) work based on parent report, which found that increased hyporeactivity was linked to general lower adaptive functioning. The relationship we found between hyporeactivity and reduced behaviours that facilitate learning is supported by previous research demonstrating that hyporeactivity has a negative impact on key learning skills, such as joint attention (Baranek et al., 2013), motor skills (Jasmin et al., 2009), and communication (Watson et al., 2011). Ashburner et al. (2008) found that increased hyporeactivity and seeks sensation scores on the SSP were related to inattention and reduced academic achievement. Our use of the SAND allowed us to separately assess hyporeactivity and sensory-seeking differences. Our results suggest that hyporeactivity differences could have been driving this link and that sensory seeking might not have been significantly linked in Ashburner et al.'s (2008) work if it had been a separate variable. Hyporeactivity may be less noticeable; thus, the role of hyporeactivity differences may have been underreported in the previous literature given its reliance on parent and teacher reports. Hyperreactivity and sensory-seeking differences can be disabling for autistic students (Howe & Stagg, 2016); therefore, it is intriguing that we found no significant link to classroom behaviours. Nevertheless, we found moderate effect sizes for sensory-seeking differences and classroom behaviour, which is supportive of the previous literature (Jones et al., 2020). Our finding may reflect the fact that teachers in special education settings make various adaptions to classrooms to accommodate sensory needs, mainly for hyperreactivity and sensory seeking (Pillar & Pfeiffer, 2016), including lowering lighting or providing rocking chairs. Without direct assessment, hyporeactivity differences may be harder for teachers to notice, so they may be unaware of a need for accommodations. Increased hyperreactive and sensory-seeking differences might be better supported because these differences are more overtly noticeable.). Some of the ways in which hyporeactive students need to be supported will differ to the strategies used for hyperreactivity or sensory seeking, therefore it is important that school staff are aware of which students may need hyporeactive strategies. One way hyporeactivity needs to be supported is by enhancing task stimuli so the task can reach the higher sensory registration levels of hyporeactive students (Dunn, 1997). This means learning/task cues need to be presented in a way that is clear and overtly obvious to the student such as using concise and simple language about what the student needs to be doing, avoiding long sentences or giving too many instructions at once or providing visual supports. The work area needs to be set up in an organised and structured way so it is clear to student what they should be doing, learning approaches like TEACCH® incorporate this into their guidance (Soetikno & Mar'at, 2021) and may be particularly relevant for hyporeactive students). Hyporeactive students may take longer to respond to learning stimuli so need to be given extra time to process information/instructions before they display a response. Hyporeactive students also benefit from time to engage in movement (such as jumping or spinning) or other sensory experiences such as sensory trays or fiddle toys to increase their alertness. Some of these strategies might be similar to what can be offered to sensory seeking students, but it is important for school staff to be aware these supports should be available for hyporeactive students too, and these students may not know/seek these experiences as overtly as sensory seekers.

If hyporeactivity is playing a larger role in classroom engagement, this has implications for teaching and classroom design. Current design guidance already considers sensory reactivity differences, with a focus on how to address sensory hyperreactivity (Tola et al., 2021) These findings also have implications for the design of classrooms that need to be highlighted in design guidance such as allowing for increased saliency of learning cues and stimuli.

2.6.1 Limitations and Future Research

This data was collected at a single time point and therefore may not be representative of participants' overall classroom behaviour, which may have affected our findings. We were unable to collect more information about participant characteristics, which is significant given that there is literature linking sensory differences to communication ability (Dellapiazza et al., 2018) and lower cognitive ability (Zachor & Ben-Itzchak, 2014). The SAND is a novel tool for sensory assessment but is not yet widely used in research. The BASC–SOS categorizes behaviours on the basis of neurotypical students' learning styles; therefore, it is possible that behaviours may be inappropriately categorized for autistic students' learning. Future research should measure variables multiple times and collect detailed participant demographic information.

2.6.2 Implications for Occupational Therapy Practice

This study has the following implications for occupational therapy practice:

- Autistic students showing increased behaviours that impede their learning or reduced behaviours that facilitate their learning might benefit from a sensory assessment.
- More research into the role of hyporeactivity differences in classroom behaviours is warranted. Students who are particularly hyporeactive may be at increased risk for not engaging and need targeted support.

2.6.3 Conclusion

This study found a link between increased sensory reactivity differences and more behaviours that impede learning and fewer behaviours that facilitate learning when assessed using direct observations in a special education setting. Hyporeactivity was correlated with both fewer behaviours that facilitate learning and increased behaviours that impede learning. This has implications for how support is tailored to students with increased sensory differences, especially those with hyporeactivity.

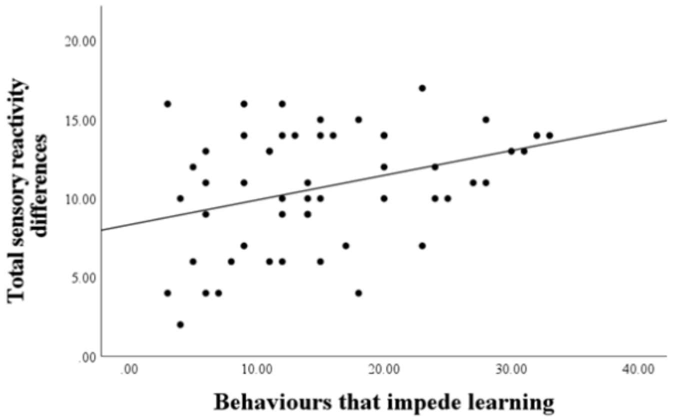
2.6.4 Acknowledgements

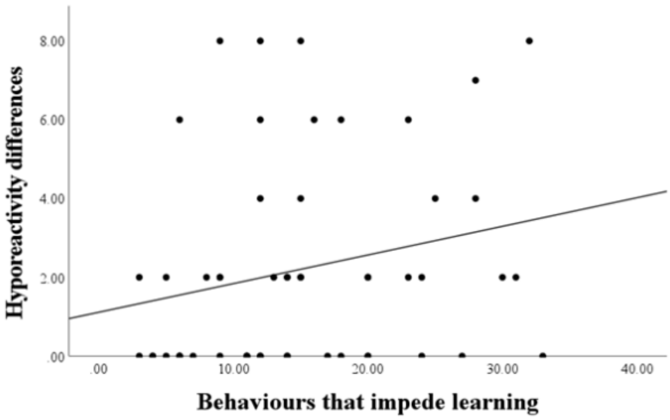
We thank the autistic students and their schools for participating. We also thank past students who supported this study, specifically Brett Davies, Charlotte Daniels, and Frankie Englezou. Last, we thank the Economic and Social Research Council's South East Network for Social Sciences doctoral program for funding this research.

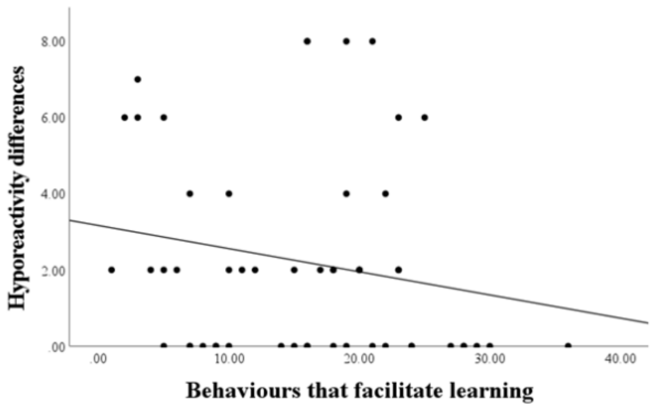
2.7 Supplementary Materials

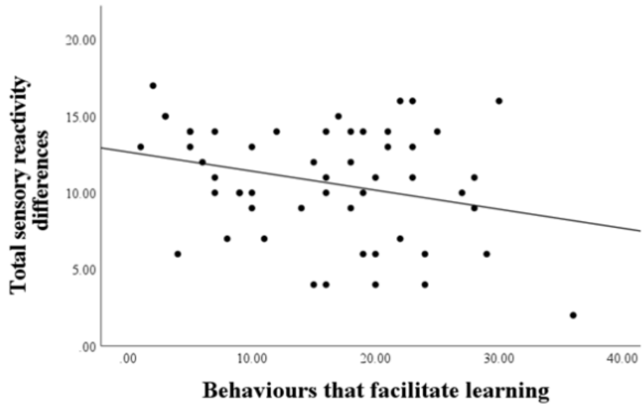
Supplementary A

Scatterplots of significant results









Chapter 3: School staff perspectives in improving the built environment of classrooms for autistic students

3.1 Paper contribution

Authors: Hannah Marcham, Rahaf Alqutub, Zhiwen Luo, Teresa Tavassoli

Author contributions: Focus groups were designed, conducted, transcribed and coded by Hannah Marcham. Hannah Marcham also drafted the paper. Rahaf Alqutub and Zhiwen Luo provided consultation for final themes and critiques of the paper. Teresa Tavassoli oversaw design of focus groups, supported with data analysis through discussion of themes and provided critiques of paper.

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3.2 Abstract

Purpose: Sensory reactivity differences are a core feature of autism and have been linked to distress and anxiety. The environments we spend our time in greatly impact us, and classrooms can be a challenging place for autistic students to be in. There has been little research into what design features might make classrooms more suitable for autistic students. Method: This research utilised qualitative methods to investigate school staff's views about the built environment of classrooms for autistic students. We conducted four online focus groups, with a total of 11 participants. The data was analysed using thematic analysis.

Results: Three themes were created from the data. Building Layout (comprised of location, access to outside space, designated functional areas and occupant density sub themes). Indoor Environmental Quality (comprised of colour, lighting, temperature. Windows and Ventilation) and Interior Finishings (consisting of storage, partitions and displays sub themes).

Conclusions: Findings highlight key design aspects that school staff feel are important to consider when designing classrooms for autistic students. Themes align with previous literature in the area, demonstrating a clear direction for design.

3.3 Introduction

The environments we spend our time in can influence many aspects of wellbeing including mental and physical health (Evans, 2003; Song et al., 2020) and productivity (Clements-Croome, 2006). There is increasing recognition that we need to be designing and creating environments that are more accessible for those who are neurodivergent, including autistic people, to reduce the barriers they face (Schneidert et al., 2003). This is reflected in design approaches such as universal design (Steinfeld & Maisel, 2012) and design for all (Kercher & EIDD, F. P. 2008). Furthermore, educational outcomes vary widely for autistic children and there is increasing emphasis on research that helps understand what aspects might be impacting this variation (Keen et al., 2016).

The classroom environment can be a difficult place for autistic children to be., Less than half of the autistic children asked in the All Party Parliamentary Group on Autism (2017) said they were happy in school. Autistic children have been found to be at increased risk for not engaging in classroom activities, less awareness of learning, and increased risk of avoidance behaviours (Gentil-Gutiérrez et al., 2021; Ashburner et al., 2008). Autistic students at university report how environmental aspects, such as volume levels and amount of people can mean they are unable to attend social events, increasing feeling of loneliness (Madriaga, 2010). Caregivers of autistic children highlight how environmental stimuli such as lighting or loud noises directly impact upon their children's sensory reactivity differences (SRD) and in turn their ability to participate in activities (Pfeiffer et al., 2017). SRD are now recognised by the Diagnosis and Statistics Manual (DSM-5, American Psychiatric Association 2013) as a core feature of an Autism diagnosis. SRD are experienced by the majority of autistic people, with studies showing differences are present in over 90% of the autistic population (Green et al., 2016; Tomchek & Dunn, 2007). As in the DSM-5, SRD are typically categorised into hyperreactivity (an oversensitivity to stimuli) hyporeactivity (under sensitivity) and sensory seeking (need for increased input from a stimuli; Baranek et al., 2006). SRD can occur across multiple domains such as auditory, visual, and tactile (Robertson & Baron-Cohen, 2017). The profile of SRD a person experiences may change over time and environments (Brown & Dunn, 2010) but they are present throughout life (Ben-Sasson et al., 2009). It is important to note autistic people have expressed that their sensory differences can bring them comfort and reassurance, however they can also cause distress and anxiety and have been linked to mental health difficulties (MacLennan et al., 2022; Rossow et al., 2022; Green et al., 2012).

The Building Bulletin 102 (BB 102, Department for Education & Employment, DfEE, 2009) offers non-statutory guidance on designing schools for disabled children and children with special educational needs. However, as well as being over a decade old, this guidance if not specific to classrooms for autistic children, instead merging their needs with a range of other needs such as physical disabilities. The British Standards Institution recently published the Design Standard on Neurodiversity and the Built Environment (BSI, 2022).Whilst this is an important document for helping to facilitate more inclusive spaces for neurodivergent people, it is guidance covering a wide range of spaces (transport, health care settings, leisure spaces) so is not specifically focused on classrooms for autistic students.

The Autism ASPECTSS™ Design Index (Mostafa, 2014) was created as a guide for designing environments for autistic people. The index was originally based on surveys of 100 families and their views of the most impacting sensory environment issues and can be applied to school environments. It consists of seven principles: acoustics, spatial sequencing, escape space, compartmentalization, transition zones, sensory zoning and safety.

Despite the creation of these design guidance there are limited research studies to underpin their suggestions and a call for more empirical research to build the evidence base to verify their guidance and further our understanding of how to create more inclusive spaces for autistic people (Manning et al., 2023).

A recent scoping review by Tola et al. (2021) found only 21 studies examining the relationship between environments and autistic people that resulted in design recommendations. The recommendations were summarised into three distinct factors that designers should consider in relation to autistic people and spatial environments: “sensory quality” (how to reduce the impact of sensory stimuli), “intelligibility” (space being easily understood and clear) and “predictability” (creating an environment that is easy to navigate with visual supports such as signs). They then propose three further categories that relate to recommendations more generally, “identification of a quiet and accessible location”, “safety and security” and “flexibility and customisation”. While most studies included in this review were focused on learning environments, it combines studies looking at different types of learning settings, as well as including data from studies looking at non learning environments or environments for adults.

Piller & Pfeiffer (2016) interviewed pre-school teachers and occupational therapists to assess the impact of the sensory environment on young autistic children’s participation in class. They identified that the sensory environment of classrooms, including aspects such as high noise levels, unexpected sounds like fire alarms and being touched by others can lead to meltdowns, avoidance of activities and self-injurious behaviour. They also highlight how teachers adapt the pre-school environment to make it more sensory friendly. Modifications include playing calming music to block out noise, using sound-absorbing items, reducing brightness of lights, reducing visual stimuli on walls and sectioning off the classroom into smaller areas.

The academic environment was highlighted by McDougal et al. (2020), as one of their key themes (alongside “pupil behaviour and abilities” and “teacher skills and training”) in the investigation into barriers and facilitators to learning for autistic children (created after interviewing teachers). The academic environment theme included “access to resources”, “structure, planning and transitions” and “class size/ratio”. Furthermore, within their “pupil behaviour and abilities” theme, the relationship between sensory differences and their negative impact on concentration and attention was referenced by teachers. They also spoke of adapting the classroom environment to try and meet the sensory needs of pupils and how challenging this can be when pupils have differing sensory needs.

Despite growing recognition of the impact that environmental design has on the well-being and learning outcomes of autistic students and development of guidance such as Autism ASPECTSS Design Index (Mostafa, 2014) and BSI (2022), there remains a limited evidence base for creating educational spaces. There is a lack of empirical evidence from those working directly with autistic students. Specifically, very few studies have explored the insights of special education school staff, who have first-hand experience of supporting autistic students in real classroom settings. This is critical gap in the literature as school staff have extensive knowledge of how autistic students respond to classroom environments, as well as experience in adapting classrooms to better meet students' needs. The following study addresses this gap by capturing the views of school staff who work directly with autistic children in special educational classrooms.

Aim

This work aimed to further our understanding of what design aspects make classrooms more enabling environments for autistic students. Specifically to use qualitative methods to capture the insights of special education school staff.

3.4 Method

3.4.1 Design

This research utilized a qualitative approach. Focus groups were chosen as this method allows for collection of shared and individual experiences, (Krueger & Casey, 2014) and the discussion would prompt more detailed explanations (Barbour, 2008).

Focus groups were conducted online due to COVID-19, but also due to the benefit this format has of reducing time and participation burden on participants, while still allowing for participants to bond cohesively (Tates et al., 2009; Watson et al., 2006).

3.4.2 Participants

Recruited via contacting special educational needs (SEN) schools that researchers already had connections with as well advertising on social media with Twitter and Facebook posts. All participants provided consent before taking part in a focus group. The research was granted approval by the University of ANNONYMISED School Ethics Committee.

A total of eleven participants took part. Participants consisted of 5 teachers, 1 trainee teacher, 1 occupational therapist, 1 head of care, 1 education advisor, 1 learning support assistant, 1 family support practitioner. 2 participants were aged 18–25, 5 were aged 26-35, 2 were aged 36-45 and 2 aged 46-55. Combined, participants had over eighty years' experience of working with autistic children in schools. Range of education levels 4 participants educated to master's level, 3 educated to PGCE level, 2 to undergraduate level, 1 to A-Levels and 1 to PhD level. Specific data on socioeconomic status and race were not collected. Recruitment was carried out via targeted recruitment and snowball sampling method. The researchers contacted schools they had contacts with and asked contacts to invite colleagues to take part. This study was also advertised on social media. The concept of data saturation (and how to determine it) in qualitative research is an area of large debate. Braun and Clarke (2021) themselves highlight the subjective nature of this decision. In this study the researchers decided to stop recruitment at four focus groups as it was felt there were no more codes being created on initial analysis.

Focus groups can raise some ethical challenges, such as unintended topics being brought up or a participant being unable to divert the conversation away from a distressing topic (Sim & Waterfield, 2019). To ensure all members felt comfortable, rules of engagement were outlined at the start of each group. These included informing participants that they were free to leave or take a break from the group at any time and were able to message the researchers in a private chat should they need to. Explaining that differing opinions should be treated respectfully, and any experiences shared should not be discussed outside of the group.

3.4.3 Measures

Four open-ended questions were created as a topic guide for the group discussions. Researchers felt it was important to have a topic guide to send to participants before the focus group took place in order to reduce uncertainty about focus groups for any neurodivergent participants. These questions were: What aspects of the built environment have an impact on your autistic students in the classroom? What aspects of the built environment help your students in the classroom? How do you know the environment is having an impact on your students? What would you change about the built environment of your classrooms to make them more suitable for your students?

These questions were created in order to encourage participants to think specially about design aspects of their classrooms without labelling any aspects in particular and biasing responses. Due to the profile of the students these school staff will have been supporting (students who are likely unable to verbalise preferences) we felt it was important to have a question asking staff what they were seeing that made them think design aspects were impacting students. Additionally, in order to be able to create practical findings, researchers felt it was important to ask what needed to change.

3.4.4 Procedure

After ethical approval was gained, advertisements for the study were emailed to SEN schools and placed on social media. Individuals who expressed an interest in participating were then provided with detailed information sheets and consent forms. Groups were then arranged around availability of participants. Groups were scheduled as hour long meetings, with meeting time ultimately ranging from thirty-five to sixty-five minutes. Groups started with brief introductions and rules of engagement, and the aims of research outlined. Topic guide questions were posed one at a time with participants then being asked to share their view and experience. Due to drop outs and scheduling, groups had 2-4 participants. Small focus groups have been shown to be effective and have the benefit of allowing everyone a turn to speak (Toner, 2009). Focus groups were digitally recorded and then transcribed verbatim with identifying information removed.

3.4.5 Community Involvement Statement

This research was conducted to help answer one of the top ten questions for autism research as outlined in the 2016 Autistica and James Lind Alliance priority setting partnership. Specifically, they asked "Which environments/supports are most appropriate in terms of achieving the best education/life/social skills outcomes in autistic people?". Other than school staff working alongside autistic students, no other community members were involved at any other stage of the research. We attempted to recruit autistic teenagers to capture their experiences of classrooms, but recruitment was unsuccessful.

3.5.6 Analysis

The data was analysed using thematic analysis approach where themes are created from patterns in the data (Braun & Clarke, 2006). An inductive approach was used so the resulting codes and themes were data driven, rather than trying to fit the data into any pre-defined categories (Boyatzis, 1998).

Analysis was conducted primarily by the lead researcher, a doctoral student who does not identify as autistic. After transcription the data was analysed using Nvivo

(Castleberry, 2012). Transcripts were analysed following Braun and Clarke's (2006, 2013) six stages: familiarisation, coding, generating themes, reviewing themes, defining and naming themes, and writing up. Themes were then reviewed and agreed in discussions with the co-author. Inductive thematic analysis is a reflective approach, and it is important to note that themes do not emerge from the data but are created by those analysing it and their interpretations (Braun & Clarke, 2012).

3.5 Results

Table 3 shows the three themes, and their sub themes, created from the focus groups.

Table 3.

Themes and sub themes created from focus groups

Building layout	Indoor environment quality	Interior finishings
Location	Colour	Storage
Direct outside access	Temperature	Partitions
Designated functional areas	Light	Displays
Occupant density	Outside view	
	Ventilation	

3.5.1 Theme 1. Building layout

Sub theme 1: Location.

Participants discussed how the physical location of their classroom within the whole school layout was very important. Areas that a student has to pass through to get to their classroom, such as a big reception area or crowded hallway, can delay their arrival or cause distress before even entering the classroom.

"For them to get off the bus and walk into that big huge open space with everyone else going around and going to their classrooms and that's it takes some of them over half an hour to get into the classroom because it's like it's like coming up to a big big lake and not being able to swim and you thinking it's just a big trauma to get from the front door to the classroom door" P1

It was also noted that being near to other frequently used locations such as the lunch hall or toilets was important for decreasing anxiety around transitions particularly for those with higher support needs. However, there needs to be consideration of the noise arising in busy locations like halls,and ensuring this cannot be heard from the classroom.

"Not connected to any spaces that are particularly noisy like the school hall, but also they are connected to areas that they need with as little transition as possible so that the students with the highest needs or most difficulty in transition are located close to things like lunch or to toilets" P3

Sub theme 2: Access to outside space

School staff feel immediate access to outside space is important for both learning opportunities as well as for regulation space/resource when a student is distressed. Participants discussed how they wanted to incorporate more outdoor learning into teaching as they notice students "come out of their shell" when given opportunity to explore outside and the benefit of sensory exploration.

"I think for our learners again sort of thinking about their sensations and their sensory needs sort of having a space to explore that outdoors you know, linking into outdoor learning as well that would be amazing for lots of our learners" P2

Staff who were working in classrooms without access to outside learning space felt their students are *"Missing an important bit of sensory exploration that other children do get" P5*

Staff described how having to go through multiple doors to get outside was limiting students' independence and regulation opportunities, and feel classrooms should have immediate access to the outside.

"We're supposed to be promoting independence with trying to teach them to regulate themselves and they can't just sort of make that decision to nip outside… it's a big long process before they can even get into a safe outside space for them to calm or regulate" P4

"Outside space without having to go past too many classrooms or other rooms is so important 'cause transitions are hard anyway, and if the children are dysregulated and they, they'll run into other classrooms before getting through to the outside and so I think that's really important to keep in mind when you're planning you know future schools."

P6

Not only that, but without easy access to an outside area staff may have to physically intervene to support a student to get outside, this physical intervention can then cause further distress for students.

"It makes it worse in a way because you're having to guide them out there if you think if you made the decision that that's what the best thing to do to calm them or give them a bit of time, you're having to guide them and then you having to go hands-on and even just that touch sometimes can trigger and make things worse and make the crisis more than it should be" P4

Sub theme 3: Designated functional areas

Multiple participants discussed the benefit of having clear areas with facilities for different activities, such as an art, kitchen, sensory, computer or group time areas. This helps students to know what they might be doing in that area, provides facilities to practice life skills and offer sensory input for regulation without having to leave the classroom. Sensory areas were also viewed as vital for giving students who need increased sensory input a space for what they need to be able to engage.

"Like kitchen counter you had like all the cupboards and things and a sink and a fridge, so at break times they could make their own drinks and things like that and that's why, that's such a valuable skill" P6

"Sort of sensory corner or a sensory room that might be attached to them and that's obviously highly beneficial... so they can take a break from their activities so they can bounce on a trampoline so they can do some organized activities like rolling over a bouncy ball... a special sensory area and that's you know critical for the classroom environment" P7

Sub theme 4: Occupant density

Participants agreed there was clear link between lack of space in their classroom and students' mood and behaviour.

"No doubt there is a correlation between the amount of the amount of space that you have available, which has obviously means more noise and more people around and more busier environment and general mood and as a result the number of incidents of challenging behaviour, so this is really really important" P8

Participants repeatedly mentioned their classrooms were too small for the number of students plus their support staff, especially when a student experiences distress.

Participants who taught older students felt the size of their classrooms had no account for the age and size of their students. They are expected to be comfortable and be able to learn in a classroom the same size the youngest students use.

"We go from 3 to 25 year olds and when I go down to the secondary department and you've got nine big blokes, you know these aren't little tiny ones, in the same size classrooms as the reception class, you know? so it's space and being able to move about definitely" P9

3.5.2 Theme 2. Indoor environment quality

This theme encompasses design aspects relating to sensory elements of the indoor environment and the requirements needed to create a suitable environment.

Sub theme 1: Colour.

Participants discussed the importance of using "*low arousal colours*" for walls and furniture. Some colours that were mentioned as working well were light colours.

"It's all light, very light, blue, grey or white" P3

These were described as calming for students and helping to keep sensory stimulation low

"but the fact the walls are plain I think that has a positive impact um to reduce visuals and um like avoid over overstimulating" P2

"so I think the low arousal colours that we use at [SCHOOL NAME] they help to keep the kids calm" P10

Sub theme 2: Temperature.

Staff discussed various problems they have encountered with the temperature of classrooms; they were often too hot or too cold and the teachers had no individual control over the temperature settings of their classrooms. This in combination with students who can struggle to regulate their body temperature, or children who may have illnesses, has a direct impact on students' behaviour and engagement, with heat causing students to feel lethargic

"you can't control the temperature and that can affect the kids who are really sensitive to too much heat or too little heat...and that effects their behaviour as well" P10

"it can be very warm and that temperature difference uh is very distracting for the children. It can make them quite lethargic at times or it can make them you know they just get hot and sweaty and bothered" P1

"they aren't then able to regulate their temperatures properly because of introception, you know, senses aren't working properly. Umm definitely I've seen quite challenging behaviour because of heat for sure" P9

Staff make adaptions for students, such as around uniform, but this is not enough to minimise impact of warm temperatures inside classrooms.

"*one of my students can't regulate his own body temperature, he gets really red and we've got a special uniform pass for him where he doesn't have to wear long sleeves, or the tie done all the way up and blazer, but it's just not enough"* P3

Sub theme 3: Lighting.

Harsh and bright lighting was reported as being a "trigger" for students, with children described as "hiding" from the bright overhead classroom lights and staff having to create darker spaces for students to go Bright lights are noted as creating an environment in which students do not feel "*happy or safe"* P3

"Um one of the big things for us, so I'm in the early years, one of the big things I found with my pupils is light. So very harsh lighting can be a huge trigger and you

regularly see children hiding from the light a little bit. In the last two years I've relied very heavily on having a big, quite big dark den in the classroom" P9

Staff discussed the need for softer lighting, as well as dimmer switches. Meaning that staff could adjust lighting to comfortable brightness for different students as well as adjusting for the various activities that are run in the same classroom.

"actually dimmer switches that would be fantastic because some of the kids get over-stimulated or they can't tolerate too much of this, I think we have strip lighting… it would be really good if we had a dimmer switch that they could kind of yeah, use to kind of calm the kids and the kids have more control about the lighting in the room …I think if we had different switches that would be great to adapt to different children" P10

Staff who do have the ability to dim classrooms lights highlighted the benefit of this.

"in my classroom the light switch is not like you can on on and off it, but you can like dim it um, and that's amazing so I never really have it on full full brightness I'll always keep it a little bit sort of dimmed if we do need the lights on. And then it does help for sessions that need to you know, so like therapy sessions where I want it to be a bit darker, but one of the students isn't quite comfortable with it being fully dark in there so we can sort of find a nice middle ground that sort of suits all of the students in some way" P4

Sub theme 3: Outside view.

Both the transparency and ability to open or close windows was discussed as being an important thing staff feel they would benefit from more control over. Some staff reported the distraction that transparent windows provide, whilst others reported the benefit of outside views. Transparent windows can lead to distraction from busy outside environments, so teachers reported frosted windows can benefit learning and engagement in tasks.

"*Um the frosted windows we have um I think stop the students being so distracted by outside stimuli like trees and you know vehicles and birds [laughs] you know all kinds of like visual stimuli" P6*

However, staff also felt it was important this is balanced with the benefit of the calming impact of being able to see outside, or for students to be able to observe things that interest them like planes or cars.

"I've had pupils who've found just being able to look out the window at trees and just what's going on outside is really amazing for their emotional regulation" P5

Importantly having completely opaque or frosted windows was viewed negatively and as *"institutionalising"* and staff did not want to *"cut off the world"*.

Sub theme 4: Ventilation

Windows were also talked about in terms of their ability to provide fresh air, and that this is limited within classrooms: *"so we only have one window in our classroom which we can open, but I find the children clamouring to be near the window seeking the fresh air"* P5

Windows were not always openable, sometimes for safety reasons, and windows on the ground floor were described as being pushed closed from the outside and causing distraction to pupils.

"we've got windows that on the ground floor that you can open them, anybody outside can just shut them so that becomes a game of then people opening and shutting windows" P9

There is a need for windows that open practically and safely.

3.5.3 Theme 3: Interior finishings

The third theme created from the data is interior finishings. These encompass decorative elements and equipment needed to create optimum classroom for students.

Sub theme 1: Displays.

Typical displays that you might find in mainstream schools were reported as being too overwhelming for students, often called "visual clutter". Staff find displays useful only if they are minimal and may contain key information.

"There's only displays of like you know information about the children and what they like or what might trigger them and like pen portraits I think they're called? [other participants nod heads yes] but otherwise there's no kind of, you know, the displays you get in mainstream classes where they display the children's work and things like that. That's too stimulating and to visually distracting I think for the kids so we don't put those up [laughs] it's not that we don't like the kids work but it would be to visually distracting for the kids, and that's helpful, I think" P3

School staff felt that displays with key information and reminders work best

"so there's lots of helpful things instead of it just being all about the lesson that you're in they might have reminders about like school conduct, which is brilliant, and what to do if you're stuck on a question. It's like the three before me rules, just some general reminders, and I think they were work really well" P1

Consistency of displays was highlighted as well, keeping displays the same throughout the year so that they are predictable and familiar to students. Implementing new displays can be *"distressing*" for students, and some will take down any new ones that are put up as a result.

"*One of the students in my class if I put something up if I was to go in tomorrow and put something new up on the wall, it would be coming straight down 'cause it's not been there since he's been in the class"* P2

Sub theme 2: Storage.

Storage space was discussed as being significantly lacking in classrooms, it was highlighted that autistic students in SEN classrooms have a lot of individualised and personal items that they need access to/space to keep.

"Personally, there's not enough, when you've got five students that have so much stuff and sensory bits and PECS symbols. Just so much that comes with five students with challenging behaviour and autism…there's not enough space in the cupboards to put everything away but having things out in the classroom is a complete distraction and to the point where it becomes overstimulating" P4

Items being out in the room can lead to distress for some students and contribute to increased anxiety levels.

"*So one of the students in my class, you can't really leave anything out but there isn't enough space to put it all away...Um But he's always, always walking around, always seeing what there is, even just bits of paper at my desk um It's not even that he's just being nosy it just overstimulates him to the point where it can, if we don't, if we're not on top of it, it can get to a crisis, and then when he's in crisis, we're having to try and find things, places for things to go and it shouldn't really get to that point and the, even when he's in crisis, we're still trying to like put things away to stop him getting so over stimulated"* P4

Participants see storage as key to creating a low arousal environment and helping students to focus on an activity or task, as well as helping students to know where they can find things,

"also having storage cupboards. So like once then that kind of like learning through play time had ended we kind of had our routine of putting everything back in the box and can pop it away and then we can focus on the next thing, so I think that's a really positive thing, having storage" P6

Practical storage space that is easily accessible can also benefit the successful running of lessons, ensuring activities are immediately available when a student is ready to engage to maximise learning opportunites

"making sure my resources were super organised 'cause you've got such a tiny window for the children's attention spans. So building into things like your computer area, places where you can have your resources really easily accessible and organised" P5

Sub theme 3: Partitions

Multiple participants referenced needing to divide up the space in their classrooms to create smaller work areas.

"The layout is just too open. It's a big space which is lovely sometimes, not big enough but big, but maybe I will try to find ways of compartmentalising the space so you can get more structure" P11

Compared to mainstream classrooms there is often less whole class group work, activities need to be more differentiated and individualised for students. The panels allow for students to have their own area to work, or complete activities in smaller groups. This helps to direct students' focus to the activity in front of them and reduce distraction from other things that might be going on in a classroom.

"I do prefer to break down into smaller groups, especially if the work is being quite well differentiated. So then it can be very helpful to have quite large blue screens so we can section off different areas within the classroom. Um that then has the dual purpose of obviously being low arousal, but also helping the pupils in the two different activities to really focus on what they have got in front of them because they're not being distracted by what else they can see" P2

"the use of the blue screens to divide and partition the area to create um low arousal and uh like, like low arousal spaces for doing their work, so then it does reduce distraction" P9

3.6 Discussion

This study utilised qualitative methods to highlight the views of special educational school staff to further our understanding of important design considerations for classrooms for autistic students. Including the views of professionals who work directly with autistic students in classrooms in design guidance is of critical importance so that guidance is as practical and meaningful as possible. The perspectives captured in this study not only align with many of the sensory and spatial recommendations described in existing guidance, but also provide more detail around practical and implementable recommendations.

We created three themes based on the views of school staff: Building Layout, Indoor Environmental Quality and Interior Finishings. Participants discussed a wide range of aspects, ranging from big architectural considerations like location and size of classroom to smaller, but still key, considerations such as storage and lighting options. Participants highlighted design aspects which they feel contribute to anxiety for their autistic students, such as harsh lighting, changes to displays or needing to transition through busy spaces. We felt it was important this research produced themes that were practical and useful for those involved in the design of classrooms. Those who are involved in the early stages of designing a new classroom environment could utilise all the themes found in this research. While those adapting an existing environment may find the Control and Adaptability and Low Arousal Environment themes provide more feasible design recommendations.

Within the Building Layout theme, the sub theme of access to outside space detailed teachers desires to be able to engage students in outdoor learning, staff's description of the enjoyment their students get from exploring outside areas is in line with autistic adults' reports that outdoor spaces are enabling sensory environments (MacLennan et al, 2022). The DfEE BB 102 (2009) states outside spaces should be easily accessible in SEN schools. Our findings agree with this statement, but add the detail that school staff feel each classroom should have direct access to outside. The sub theme of Location reflects staff awareness that the location of their classroom within a site is of high importance. School staff feel students need to be close to regularly used locations, as transitions can be anxiety provoking. Autistic people tell us they can have challenges with wayfinding and spatial navigation, which is also demonstrated in empirical studies (Smith, 2015). Designers can help to ease these difficulties by keeping distances between SEN classrooms and key locations small. BB 102 has design suggestions reflecting this view, such as having small clusters of toilet areas to minimise travel distances for students. BB 102 also has recommendations for creating accessible reception areas in SEN schools. However, our findings suggest that if this guidance is being followed in schools for autistic students then they are still not creating a comfortable area, as school staff described how getting through these areas and into the classroom is still difficult for their students. Our findings suggest multiple arrival points or entrances may be beneficial. Designated Functional Areas sub theme is a theme that reflects existing literature in the area, for example the Compartmentalization principle from the Autism ASPECTSS design index (2015), and the Intelligibility theme from Tola et al (2021). These frameworks all detail the importance of having spaces clearly set up for a single function, allowing autistic students to understand clearly what they will be doing in the area. Our staff detailed particular functional areas they feel are useful such as kitchen areas, sensory areas and art areas. Kitchen space was also listed as a design recommendation from McAllsiter & Maguire's (2012) work with teachers of key stage 1 autistic children. The Building Bulleting 102 recommends two types of practical areas for special schools - one for art/science and one for food technology, suggesting these can either be within the classroom or in separate areas depending on space. Our findings show that school staff feel it is important these areas and facilities are present within the classroom for autistic students. Specific sensory areas are not listed in the bulletin as a recommendation, however we found school staff felt this was a vital need for classrooms for autistic students, so may need to be specified in future guidance. The final sub theme within Building Layout was occupant density. School staff explained how they felt their classrooms were too small for the number of people in them, and this lack of space has a direct negative impact on behaviour. Having increased space is listed as a key design feature in much of the existing literature and guidance. For example, autistic adults reported that having to be in close proximity to others and not having enough personal space is one of the key features of a disabling public space (McLennan et al, 2022). Piller & Pfeiffer's (2016) interviews found being touched by others was a trigger for distress in young autistic children. School staff explained how there was no difference in the size of classrooms between the older and younger students. The DfEE provided updated guidance on area guidelines for SEND and alternative provision classrooms (Building Bulletin 104), with separate guidance for primary and secondary classes. Our findings suggest that existing guidance on classroom size for autistic students, if being used, may need to be reevaluated to make sure it is recommending big enough space, especially for older autistic students.

The Low Arousal Environment theme includes many aspects relating to the needs to reduce stimuli in classrooms, such as limited colour use lighting and windows. These practices fit with the literature on visual processing in autism. Differences in visual processing can mean aspects of the visual environment such as colour and patterns can be distressing and disorientating for autistic people (Grandin, 1995; Simmons & Robertson, 2012). Because the type of stimuli (the particular colour or pattern for example) that causes distress can vary between autistic people, reducing a range of visual aspects within the classroom helps to ensure it is an enabling space for a wider range of people. This reduction in stimuli is counter balanced with the need for a sensory area as listed in the designated functional areas sub theme of Building Layout. Having an adaptable sensory space enables those autistic students who benefit from and enjoy increased visual stimuli (and other stimuli such as tactile or auditory) to have an area in which their needs are met. Creating a low arousal environment was a key aspect of Tola et al (2021) Sensory Quality theme, highlighting that this approach is common in spaces for autistic people. The Building Bulletin 102 briefly mentions the need for consideration of sensory awareness and suggests reducing stimuli where possible to create a calm environment. This research provides more detail on how this is being done by school staff in classrooms for autistic students demonstrated in our sub themes of Displays and Colour. As well as more understanding of the resources they need to do this as described in the sub themes of Partitions and Storage in Interior Finishings. Partitions are used to separate students' workstations and to break down the class into smaller groups to aid concentrations. Increased storage is necessary to reduce distracting items and facilitate progress of a lesson. Need for storage is highlighted throughout the BB 102 as a requirement for classrooms catering to SEN, both because students with SEN often have an increased amount of items they need throughout the day, and to reduce presence of stimuli. This was a need very much echoed by the school staff in this research.

Key to the Indoor Environmental quality theme is the ability to alter aspects of the indoor environment (light, temperature, windows etc). This aligns with the conclusions drawn from Tola (2001) who identifies flexibility and customisation as an important general criteria of environments for autistic people. Both this work and Tola's recognise the importance of being able to adapt indoor environmental aspects to be able to facilitate the range of sensory profiles that present across autistic people (Crane, Goddard & Pring, 2009). BB 102 also outlines the importance of flexibility and adaptability in SEN settings in order to cater for a range of needs across time and function of the environment. A "one shoe fits all" design approach is not suitable in environments for autistic people, and this should be a key factor designers take into consideration. Our staff discussed how, in particular, control over the lighting, temperature and windows within classrooms was important for them to be able to make the classroom environment the most enabling space for their students. Our sub theme of lighting showed staff need softer lighting in their classrooms, with dimmer options. Rather than just overhead strip lighting. The lighting requirements highlighted here are consistent with lighting recommendations in the existing guidance such as BB 102 and the BSI (2022) guide. Both of these sets of guidance, in line with our findings, highlight that lighting should be able to be controlled and adjusted at a local level. The sub theme of temperature describes school staff's desire to have classroom specific control over temperature of their classrooms, many of whom did not have this. BB 102 outlines that SEN provisions should have local temperature control in order to facilitate a range of health needs. This study shows this is an important feature of classrooms for autistic student as well.

Whilst there is a large variability in autism presentation and needs, the consistency between the themes found in this work, based on the views of school staff, and previous literature in the area is evidence there are some clear design features of classrooms that can be implemented to make them more suitable for autistic students. It is important that stakeholders involved in designing and building of classrooms are aware of these aspects, such as those highlighted in this study, so that they become common practice. Additionally, this research demonstrates that school staff are raising design issues that are already addressed in the existing guidance, perhaps suggesting that inadequate classroom design is not a result of the right guidance not being available but more an implementation issue. Future research might benefit from establishing the extent to which design recommendations are being implemented in the creation of schools for autistic students, given that it is non-statutory. Future research may also benefit from assessing the suitability of classrooms built before guidance was available.

Limitations and future research

This research helps to build the limited literature base around suitable design of environments for autistic students, it is important that designing for environments is done in collaboration with the people who will be using it, in this case school staff, but also importantly autistic pupils. Autistic individuals should be involved at all stages of design as they will have unique insights and lived experience (Kinnaer et al., 2016). The researchers attempted to conduct focus groups with autistic students, but recruitment was difficult, perhaps due to the timing of the research during COVID-19. Whilst staff had worked at multiple schools throughout their careers, the majority of participants were based at the same school during time of focus groups. Future research would benefit from continuing to capture the views of professionals who work directly with autistic students so that future design guidance reflects the diverse needs of autistic learners. Specifically future research should look to recruit teachers from an increased number of locations, particularly those in other countries, as well as other types of schools, to ascertain the similarities and differences in desirable design features.

As Tola et al (2021) concluded, the majority of the still limited literature on creating more suitable environments for autistic people focuses on autistic children and educational environments. Future research would benefit from continuing to investigate the needs of autistic students in other environments, such as those in mainstream classrooms or higher education, as well as the needs of older autistic people and environments they spend time in. A need highlighted in a recent editorial on inclusive sensory environments by Manning et al (2023).

Conclusion

By capturing the views of school staff who work directly with autistic students in special educational settings this study has contributed to the development of the evidence base for design guidance of special educational classrooms. We created three themes; Building Layout, Indoor Environmental Quality and Interior Finishings. Many of the themes and sub themes are consistent with the, (limited) previous literature and guidance in the area. This raises questions over whether current guidance is being implemented if teachers are still voicing a need for the same design aspects. The themes created in this study should be used alongside findings from other literature to ensure a wide range of environmental aspects are being considered in the design process of special educational classrooms.

Chapter 4: Relationship between indoor environment and classroom behaviour of autistic students

4.1 Paper contribution

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Author contributions: The study design was created as a collaboration between all authors. Data collection was primarily carried out by Hannah Marcham, with support from Rahaf Alqutub. Data analysis was carried out by Hannah Marcham with oversight from Vincent Luo and Teresa Tavassoli. Hannah Marcham drafted the paper with critiques provided by other authors.

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4.2 Abstract

Indoor environmental quality (IEQ) can impact upon the concentration, mood and performance of students in the classroom. Much less is known about how IEQ might be impacting autistic students in the classroom, particularly those with high support needs. This study utilised a repeated measures correlational design to examine the relationship between air temperature, CO2, relative humidity, PM2.5 concentration, light and sound levels on behaviours that impede or facilitate learning in classrooms for autistic students. Nineteen autistic students aged 8-15 years participated. At time point 1 there was a significant correlation between increased sound level and increased behaviours that impede learning. Across time points there was a significant correlation between increased temperature and reduced behaviours that facilitate learning. Significant correlation between sensory overload (combination of all IEQ factors) and reduced behaviours that facilitate learning, only at time point 1. This study demonstrates the impact of IEQ on classroom behaviour for autistic students, particularly that classroom temperature may be the most impacting factor, therefore there is a need for better temperature control in special needs schools. Study also highlights the importance of repeating measures to ensure replicability of findings.

4.3 Introduction

4.3.1 IEQ

The indoor environmental quality (IEQ) of the spaces we spend our time in can impact multiple aspects of our wellbeing such as comfort, stress and cognitive performance (Thach, 2020; Hygge & Knez, 2001) as well as physical health including asthma and allergies (Fisk, 2002).

Key aspects of IEQ include lighting, air quality, sound and thermal comfort (Brink et al, 2021). Experts have suggested that poor IEQ could reduce productivity for adults by 5% in lab situations, 10% in the field and potentially by over 20% for students in schools (Wyon & Wargocki, 2013). Given that comfort levels can depend on personal characteristics such as age and gender (Kraus & Novakova, 2019; Haselsteiner, 2021) it is important research continues to investigate the impact of IEQ on different groups.

4.3.2 IEQ and Schools

The academic achievement of students can be impacted by multiple factors (Kuh et al, 2011) and given children spend thousands of hours inside school throughout their education (OECD, 2016) it is not surprising the IEQ of classrooms is a contributing factor. Children are also particularly susceptible to the impact of IEQ due to their higher respiratory rates, and underdeveloped organs and systems (Sly & Flack, 2008).

IEQ has been linked to students' attendance rates, performance on tasks and key learning skills such as attention (Fisk, 2017; Brink et al, 2021). IEQ factors can also impact neurotypical students physically such as by inadequate lighting causing fatigue and eye strain (McCreery & Hill, 2005; Sleegers et al, 2013).

4.3.3 Autism

One group of students who are particularly susceptible to the impacts of IEQ are neurodivergent children. For example, autism is a neurodevelopmental condition characterised by differences in social communication/interactions and restricted and repetitive behaviour, interests or activities (Diagnostic and statistical manual 5th edition, DSM-5, APA, 2013). Within the diagnostic criteria is the presence of sensory reactivity differences, impacting over 90% of autistic individuals (Ben-Sasson et al, 2019). These sensory differences may impact autistic students' perception and experience of IEQ elements such as increased sensitivity to light or sound. Sensory reactivity differences can be categorised into hyperreactivity (an over response to stimuli, such as finding noises or lights overwhelming, hyporeactivity (an under or delayed response to stimuli, such as not noticing when someone is speaking) or sensory seeking (seeking out enjoyable stimuli such as spinning or closely inspecting objects; Ben-Sasson et al, 2009). These differences are suggested to be caused by differences with perception, filtering and processing sensory information, meaning autistic people are particularly sensitive to their environments (Brinkert & Remington, 2020; Belmonte et al, 2004). Sensory reactivity differences have been linked to negative outcomes such as mental health difficulties (MacLennan et al, 2021; Rossow et al, 2023), reduced participation in classroom activities (Jones et al, 2020) and daily life routines as well as sleep difficulties (Case-Smith et al, 2015). Whilst sensory reactivity differences can cause challenges, it is also important to note that autistic people report they can provide comfort and joy (MacLennan et al, 2022).

4.3.4 IEQ and Autism

Autistic children are also at higher risk of underachieving academically compared to neurotypical students (Mayes et al, 2020), and are twice as likely to be excluded from school (National Autistic society, 2023). Qualitative reports show that classrooms are difficult place for autistic students to be, and sensory factors, such as overhead lights, are often highlighted as a leading reason for this (Howe & Stagg, 2016). Interactions between IEQ and students' sensory differences may be contributing to the academic difficulties and autistic students' experience. For example, students with hyperreactivity differences may be forced into using avoidance strategies to cope with overwhelming classroom environment stimuli and students with hyporeactivity differences may not be provided with salient enough information and therefore missing learning cues (Lamp & Thoonsen, 2022).

Given how sensitive autistic students are to their environments, there has been limited empirical research on how IEQ might be impacting them within the classroom. This need is highlighted in a recent review paper by Al Qutub et al. 2024. There is a need for much greater consideration of the impact of the classroom environment on autistic students and consequences for their learning.

4.3.5 Sound

High sound levels in classrooms are detrimental to concentration for autistic students (NAS, 2023) and can make it hard to follow verbal instructions (Ashburner et al, 2008). Research has shown that teachers of autistic students report high sound levels as a cause of behaviour change in their students and believe that using sound proofing materials is important in classrooms (Kanakri et al. 2017). Autistic students tell us that classroom noise leads to a reduction in their concentration and attention (Howe & Stagg, 2016). Teachers and parents report that auditory sensory differences impact learning more than other sensory differences (such as tactile, taste, visual or olfactory; Jones et al., 2020).

In an observational study, Kanakri et al. (2017b) found that autistic students in noisy classrooms (higher sound level) demonstrated significantly more instances of repetitive motor movements, covering ears, producing loud sounds, and hitting others than those in quiet classrooms. Mostafa (2008) found that autistic children displayed longer attention spans and quicker response times when in a classroom that had been acoustically modified compared to when they were in an unmodified classroom. Kinnealey et al (2012) experimentally demonstrated that adding sound-absorbing walls and ceilings reduced the number of non-attending behaviours autistic students displayed as well as self-reported increases of comfort in the classroom. Studies which have aimed to reduce the sound to noise ratio in classrooms cautiously suggest that this can result in improvements in listening, communication, on task behaviours and speech recognition (Schafer et al. 2013, 2016; Rance et al 2014). However, the evidence base for this is limited, and is based on studies with small sample sizes, often not including autistic students with higher support needs and relying on a methodology where students are able to wear frequency modulation devices (van der Kruk et al. 2017).

4.3.6 Light

There is limited empirical research on the impact of lighting on autistic students in the classroom, with no conclusive consensus on best lighting conditions (Martin & Wilkins, 2022). Teachers of autistic students report that the source of light (daylight or fluorescent) is a leading trigger for hypersensitivity and having dimmable lighting is beneficial to student's classroom behaviour. Those without dimmer switches report needing cover lights to reduce their impact on students (Gaines et al., 2014). Fluorescent lights are recognised as a source of stress for autistic people -the flickering in the bulbs can lead to agitation, and cause headaches and eye strain for students. Diffused daylight is often reported as the most preferable source of light in environments for autistic people (Mostafa, 2020). Autistic adults report that fluorescent lighting can be distracting because they are able to see the flickers in the bulbs (Grandin, 2011). Kinnealey et al., (2012) modified classrooms, including replacing fluorescent lights with halogen lights and found this improved students' comfort in the classroom as well as engagement.

4.3.7 Thermal Comfort

Air temperature and relative humidity are important environmental variables for indoor thermal comfort. For neurotypical children, it is evidenced that increased temperature has negative consequences on multiple measures of learning, and that the impact of temperature is greater than seen for adults and office work (Wargocki, Porras-Salazar & Contreras-Espinoza,2019). There has been very little experimental research investigating the impacts of either temperature or humidity on autistic students. This is a significant gap in the literature given it is recognised that many personal characteristics impact people's perception of thermal comfort as well and how temperature impacts a person's behaviour (Hoof & Hensen, 2006). A survey asking autistic adults about their experiences of different environments found temperature was rated highly as a cause of discomfort and avoidance of environments (Noble, 2018).

Indifference to temperature (and pain) is often used as an example of hyporeactivity in autistic people, i.e. that they are less/under sensitive to these. However, the evidence for these claims comes from studies based on caregiver interview/reports or clinical reports (Williams et al, 2019) so it is important the research continues to investigate autistic people's experiences of these to ensure our understanding is accurate.

4.3.8 Air quality

CO_2 and $PM_{2.5}$ are recognised as indicators air pollutants commonly found in classrooms and are often used to represent air quality (Brink et al., 2021; Yuhe et al., 2021).

Studies involving neurotypical students suggest that air quality can impact neurotypical students' cognitive abilities, such as attention, memory and problem solving (Brink et al, 2021). However, there is very limited literature investigating the impact of air quality of autistic students learning or performance. In a survey (primarily filled out by caregivers and parents of autistic people) air quality was not rated as an indoor environmental factor that autistic people are sensitive to (Wohofsky et al, 2023).

4.3.9 Aim and rationale

Existing studies often offer environmental recommendations without any empirical evidence to demonstrate their benefit on classroom engagement for autistic children (Maritn, 2016; Dargue et al, 2022.

There has been limited research on the role of the IEQ of classrooms and learning of autistic children. Additionally, the research has tended to focus on autistic children in mainstream schools, with a distinct lack of research involving autistic students with high support needs in special educational settings. A need for research including a wider range of autistic presentations was highlighted in the recent review of indoor environment perception of autistic people (Zaniboni & Toftum, 2023)

The aim of this study is to investigate the relationship between IEQ factors (specifically lighting, sound, temperature, humidity, CO_2 and $PM_{2.5}$ concentration) and their impact on autistic children in special educational settings.

4.4 Methodology

4.4.1 Participants and locations

Nineteen students aged 8-15 years (*M* = 12.47, 3 females and 16 males) with a clinical diagnosis of autism participated. Participants were recruited from two special education schools, where all pupils have an Education Health and Care Plan with high support needs, reflected in high staff to student ratios of 1:1. Students follow an adaptive curriculum appropriate to their level of learning. Informed consent was gained from parents/caregivers via electronic forms. Due to their cognitive profiles, participants were unable to provide their own written or verbal consent. Students were continuously monitored for signs of distress or anxiety relating to participation in this research. If a student appeared distressed by any research activities or a member of school staff informed the researchers a student was distressed, research stopped. This study was granted ethical approval by University of Reading research ethics committee.

Eighteen students participated in the Wechsler Non-Verbal Scale of Ability (Wechsler & Naglieri, 2006) two-subtest version. Participants sum of t-scores ranged from 20-77 (*M* = 25.83) Full scale scores and percentile ranks cannot be calculated if a participant scores 0 on either subtest, which was true for fifteen participants. See Supplementary Materials A for participant raw scores.

4.4.2 Measures

Sound

The sound level of the classroom was measured in decibel (dB) using the Reed R8080 data logger and sound meter. The R8080 has an accuracy of ±1.4dB with a measuring range of 30-130dB. Sampling rate was set at once every minute. Data was processed using accompanying R8080 software. Guidelines recommend that sound levels within a classroom should not exceed 35dB for optimal teaching and learning, 60 dB – 85 dB is considered loud (Building Bulletin 93, Department for Education, 2015).

Light

Light level in the classroom was measured in lux using the Lux Meter with datalogger PCE-174. The PCE-174 has an accuracy of ±5% of reading ±10 digits (when <10,000 lux). Measurement range of up to 4000 lux. Manual readings were recorded at 3 time points throughout every research day (9am, 12pm, 3pm). Recommended lighting levels for classrooms range from 300-500 lux (Lighting Guide 5, CIBSE, 2011).

Temperature and relative humidity

Temperature (°C) and relative humidity (RH, %) were both measured using the Tinytag Ultra 2 temperature and relative humidity logger, TGU-4500. The Tinytag has a measurement range of -25°c - +85 °c with an accuracy of ±0.6 °C for temperature. Measurement rang of 0 – 95% RH with an accuracy of ±3.0% RH. Sampling rate was set at once every minute. Data was processed using accompanying software, Tinytag Explorer. The recommended range for classroom temperature in special needs schools 20°C – 25°C (Building Bulletin 101, Department for Education, 2018). It is recommended that the RH of classrooms ranges from 40-75% (BB 101, 2018).

PM2.5

$PM_{2.5}$ concentration (fine particles of 2.5 microns or less in size) was measured using the Dylos DC1700-PM. Dylos sensors have been shown to have an accuracy in the range of -325% - 78%, performing better at higher concentrations. The decision was made to use the Dylos DC1700-PM despite the large range in accuracy as alternative devices created a low-pitched humming noise that could have been distracting or distressing for students when used in the classroom. The Dylos has internal storage, sampling rate was set at once every minute. Data was processed using accompanying DylosLogger 3.0 software. $PM_{2.5}$ should not exceed 10μg/m3 (BB101, 2018, WHO).

Co2

The Rotronic CP11 carbon dioxide detector was used to measure CO_2 levels in the classroom. The CP11 has an accuracy of ± 30 parts per millions (ppm) and a detection range of 0-5000ppm. The Rotronic is portable device with internal storage and sample rate was set at once every minute. Data was processed using accompanying Rotronic SW21 software. Classroom CO_2 levels should not exceed 1000ppm (BB101, 2018).

Behaviour Assessment for Children – second edition Student Observation System (BASC-SOS)

The BASC-SOS (Reynolds and Kamphaus, 2004) was used to measure classroom behaviour. This is a systematic direct observation which assesses 13 "adaptive" behaviours that facilitate learning (e.g. engaging in activity, following an instruction, talking to the teacher) and 58 "problem" behaviours that impede learning (leaving classroom, inattention, self-injury). The BASC-SOS was designed for use with students who are experiencing difficulties significant enough to impede learning and has been used in previous research with autistic students' (Hodges et al, 2022). The language used by the BASC-SOS has been altered in this study to be less stigmatising, "adaptive" behaviours are referred to as behaviours that facilitate learning, and "problem" behaviours are referred to as behaviours that impede learning. The BASC-SOS has good interobserver agreement (Pearson correlation coefficients 0.69-1.0), high internal consistency (0.8 with children, 0.9 with adolescents and test-retest reliability (Lett & Kamphaus, 1997; Margiano et al., 2009; Reynolds & Kamphaus, 2004). The time sampling element of the observation entails watching student for 3 seconds, followed by 27 seconds to record observed behaviours. This is repeated over a 15-minute period.

Participants also completed a sensory assessment, the Sensory Assessment for Neurodevelopmental Differences (SAND) and attempted a reaction time task, details of these as well as results between SAND and classroom behaviour can be seen in supplementary materials B, C and D.

4.4.3 Procedure

This study utilised a repeated measure, correlational design. Participants completed the BASC-SOS classroom behaviour observations four times, two in winter and two in summer to capture different extremes of seasons. This measure was repeated to capture a representative picture of student behaviour as well as to capture wide range of variations in the IEQ factors. The BASC-SOS was completed when the student was engaging in a staff led lesson, where there was a structured activity in place (such as maths, science, group time). Participants completed the SAND once, during first testing period in their usual classroom. SAND caregiver interview was completed by the students' teacher. Temperature/RH sensors were installed on to the wall of the classroom in a high location out of direct sunlight and remained in place across each testing period. The Reed8080, Dylos and Rotronic C11 were set up at the start of each testing day at a table height location and recorded continuously throughout the day. Table height location was used so that readings were reflective of the IEQ as experienced by students. Each BASC-SOS was matched for the average measurement of each IEQ parameter across the time it took place. Light was the only IEQ parameter measured slightly differently. The Lux Meter was used to measure light in the classroom at 3 time points throughout the day in different locations. Each BASC-SOS was then time matched to the closest light reading. Measuring light at more time points resulted in disruption to the classroom routine.

4.5 Results

4.5.1 Descriptive statistics

Data was analysed using SPSS IBM 24.

Nineteen participants completed the BASC-SOS four times (two observations during winter and two in summer), resulting in 76 classroom behaviour observations. Eighteen participants completed the sensory reactivity differences assessment (SAND). Descriptive statistics for IEQ measurements across all time points and BASC-SOS can be seen in Table 4. Results from analysis between SAND and BASC-SOS variables can be in supplementary materials. The Kolmogorov-Smirnov test was used to test normality. Parametric as well as nonparametric correlations were conducted depending on the normality of the variables.

Table 4

Descriptive statistics and BASC-SOS variables

	Minimum	Maximum	Mean (SD)
Classroom Behaviours			
Behaviours that facilitate learning	1	30	17.11 (5.91)
Behaviours that impede learning	0	35	15.89 (7.36)
IEQ			
Sound (dB)	39.5	74.13	57.62 (8.62)
Light (Lux)	78.55	3420.0	817.15 (593.61)
Temperature (°c)	17.05	28.9	22.83 (3.70)
Humidity (%)	112.8	2135	951.78 (361.39)
CO_2 (ppm)	31.4	61.15	43.44 (7.70)
$PM_{2.5}$ (µg/m^3)	0.64	11.89	4.33 (2.26)

4.5.2 IEQ parameters and classroom behaviour

Results from simple correlations between IEQ parameters and classroom behaviours at each time point can be seen in Table 5.

Table 5

Correlations between IEQ parameters and classroom behaviours at each time point

Time Point	Behaviour Type	Temp (r)	(p)	Light (r)	(p)	CO_2 (r)	(p)	Humidity (r)	(p)	Noise (r)	(p)	PM2.5 (r)	(p)
T1	**Facilitating**	–.41	.08	.08	.73	-.48*	.04	.11	.66	–.32	.19	–.26	.29
	Impeding	.29	.24	–.21	.40	.35	.14	-1.10	.68	.51*	.03	.10	.69
T2	**Facilitating**	–.06	.81	.30	.22	.10	.68	.01	.97	–.22	.37	–.14	.58
	Impeding	.13	.59	–.26		.02	.93	–.21	.38	.31	.09	–.14	.57
T3	**Facilitating**	.08	.74	.04	.86	.09	.71	.31	.19	–.08	.75	.21	.38
	Impeding	–.23	.35	–.10	.69	-.35	.15	.05	.85	.19	.43	–.36	.13
T4	**Facilitating**	.21	.39	–.20	.41	-.04	.87	–.13	.59	.05	.84	.20	.42
	Impeding	–.19	.45	–.10	.68	-.03	.92	.11	.67	–.08	.75	–.34	.16

*Note: * is significant at .05 level but not .001 level, df = 17 for all correlations*

4.5.3 Repeated Measures Correlations

IEQ and classroom behaviour data from all four time points was then analysed using rmcorrShiny app. This is a graphical interphase which uses rmcorr r package to compute and plot repeated measure correlations (Marusich & Bakdash, 2021; Bakdash & Marusich, 2017).

Repeated measures correlations were used to assess the within-participant association between classroom behaviour and each IEQ parameter. Correlation results can be seen in Table 6.

Table 6.

Repeated measures correlation results.

	Behaviours that facilitate learning			Behaviours that impede learning		
	r	*p*	95% BCa CI	*r*	*p*	95% BCa CI
Light	0.14	.029	-.012,0.39	-0.17	0.21	-.04,0.09
Sound	0.01	0.93	-0.25,0.27	0.09	0.51	-0.17,0.34
Temperature	-0.27*	0.04	-0.49,-0.01	0.18	0.19	-0.09,0.42
CO_2	-0.08	0.53	-0.33,0.18	-0.10	0.46	-0.35,0.16
Humidity	-0.06	0.63	-0.32,0.20	0.00	0.99	-0.26,0.26
PM2.5	0.19	0.15	-0.07,0.43	-0.29*	0.02	-0.51, 0.03

Note: *correlation significant at .05 level (two-tailed), df = 56

Scatterplots of significant correlations can be seen below in Figure 7 and Figure 8.

Figure 7

Scatterplot depicting correlation between temperature (°c) and classroom behaviours that facilitate learning.

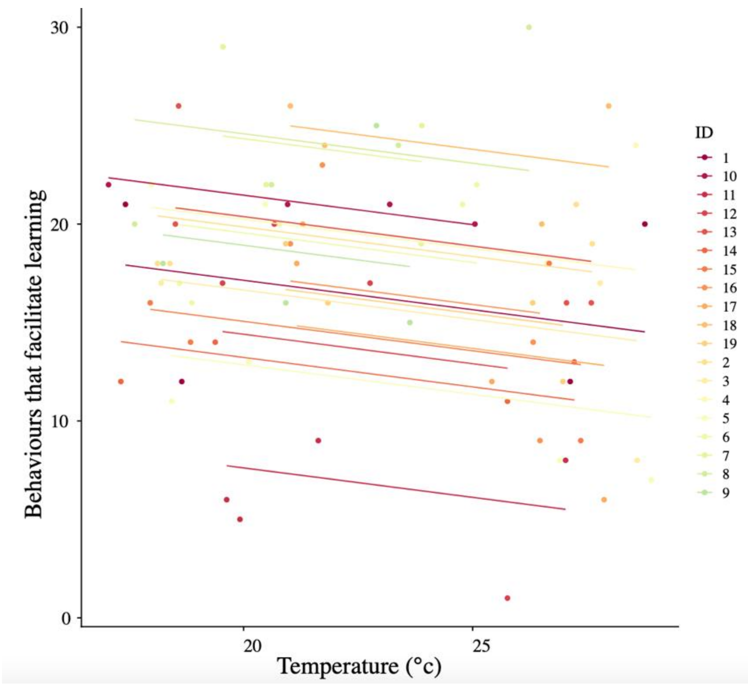
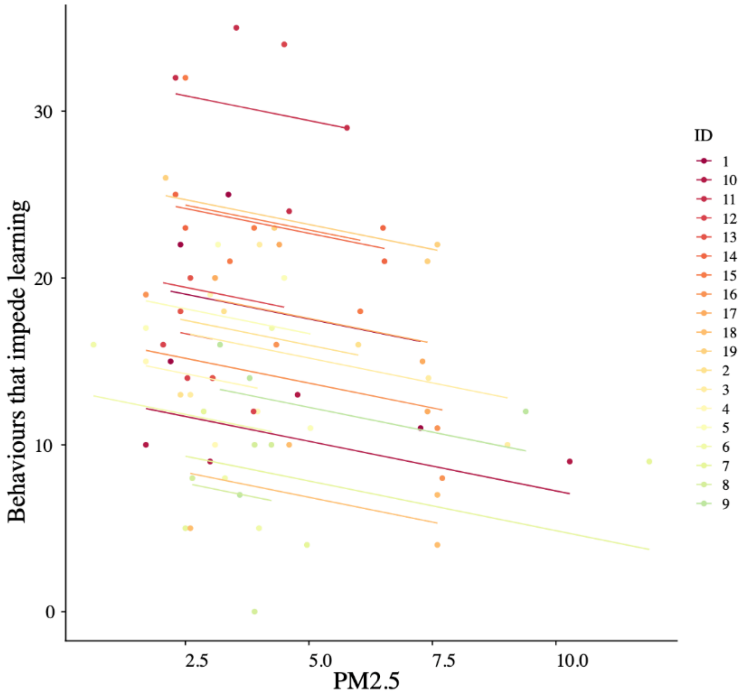


Figure 8.

Scatterplot depicting correlation between $PM_{2.5}$ and classroom behaviours that impede learning.



4.5.4 Exploratory analysis

Given all the IEQ parameters are experienced by students at the same time, it is important to look at the combined impact of them on classroom behaviour. To do this we created a Sensory Overload score for each observation. This was done by turning each IEQ parameter into a percentage by dividing the recorded IEQ parameter measurement for the observation by the highest recorded measurement for that IEQ parameter across all observations (the max) and multiplying by 100. Then combining each IEQ percentage together to get overall Sensory Overload score. E.g. the highest recorded sound measurement during any observation was 74.13 dB, during one observation the mean sound level was 64.02 dB, so $64.02 \div 74.13 \times 100 = 83.35\%$. All IEQ percentage scores then added together for Sensory Overload score for the observation.

Simple Pearson's correlations between Classroom Behaviour and Sensory Overload scores at each time point can be seen in Table 7.

Table 7.

Correlations between Classroom Behaviour and Sensory Overload score at each time point

Time Point	Behaviour Type	Sensory Overload
T1	Facilitating	-.48*
	Impeding	.34
T2	Facilitating	.08
	Impeding	-.02
T3	Facilitating	.19
	Impeding	-.31
T4	Facilitating	.00
	Impeding	-.19

Note: *correlation significant at .05 level (two-tailed).

We then used the rmcorrShiny app and it rmcorr r package to conduct repeated measures correlations and analyse impact of Sensory Overload score on classroom behaviour across all four time points combined. Results of this analysis can be seen in Table 8.

Table 8.

Repeated Measures correlation between Sensory Overload and Classroom behaviour

Behaviour Type	Sensory Overload
Facilitating	0.01
Impeding	-0.18

Note: *correlation significant at .05 level (two-tailed)

4.6 Discussion

This study investigated the relationship between six IEQ factors (sound level, light, temperature, humidity, CO_2 and $PM_{2.5}$ concentration) and their correlations with classroom behaviour of autistic students with high support needs. Simple correlations between each IEQ parameter and classroom behaviour type at each time point demonstrated only a trend towards significance between sound level and increased behaviours that impede learning at time point 1, and a trend towards significance between CO_2 and reduced behaviours that facilitate learning at time point 1. Additionally, across time points, the direction of the correlations was variable for each IEQ aspect, when all four time points were combined in a repeated measures correlation, we found a significant correlation between increased temperature and reduced behaviours that facilitate learning. We also found a significant correlation between increased $PM_{2.5}$ and reduced behaviours that impede learning. There were no significant correlations between sound levels, light levels, CO_2 levels or humidity on either classroom behaviour type. When examining the impact of the combination of all IEQ parameters (sensory overload) on behaviour there was a significant correlation between sensory overload and reduced behaviours that facilitate learning only at time point 1. Repeated measures correlation revealed no significant correlation between sensory overload and classroom behaviour across all four time points.

This study found a trend towards a correlation between sound level and classroom behaviour at one out of four timepoints, no stable correlation between sound levels and classroom behaviour were present. This is surprising given there are many examples of previous literature which suggest that autistic students are continuously impacted by classroom noise. This includes qualitative research (Howe & Stagg, 2016) detailing accounts from autistic students regarding how classroom noise impacts their ability to concentrate, as well as parent and teacher reports that auditory sensory differences impact learning more than the other sensory domain (Jones et al., 2020). Given we found one correlation between increased sound level and classroom behaviour, our results are partly consistent with previous experimental work by Kinnealey et al (2012) who found that reducing noise levels with sound absorbing materials not only reduced non-attending behaviours, but increased comfort levels as reported by autistic students themselves. However, their study's findings and the generalisability are severely limited given only 3 autistic students participated. Our results are partly consistent with studies such as Stiegler & Davis (2010) who found that noise was recognised as causing many behavioural responses in autistic children, including covering ears, crying, vocalisations, trembling and self-injury. These are all examples of behaviours that impede learning (as well as being signs of distress), this is consistent with our finding of a trend towards a correlation between increased sound level and increased behaviours that impede learning, at T1. Additionally, the findings are partly consistent with Kanakri et al. (2017b), who observed that autistic students in noisy classrooms (sound level above 70dB) displayed more behaviours like covering ears, hitting others, and making loud sounds compared to those in quieter environments. A possible explanation for the lack of consistent correlation between noise and classroom behaviour across time points is that we only measured sound level (dB level), and no other information such as the source of the sound, it's relevance to an activity, or if it was an expected or non-expected sound. As Al Qutub et al. 2024 details that there needs be a range of metrics used to represent a detailed picture of the acoustic environment of a classroom. This is potentially important as research suggests aspects other than sound level contribute to their impact on autistic students. For example, in Jones et al, 2020 teachers describe that sudden and unexpected noises (such as a sound from another student or a hand dryer) cause distress. Alternatively, loud sound sources might be enjoyable such as music, or noises being created by students themselves. These might raise the sound level reading but not result in any behaviour change for students.

We found no correlations between the lighting level (lux) in the classroom and students' behaviour. Our light findings also do not align with autistic adults' descriptions of how bright lighting negatively impact upon them, causing both distraction and distress (Grandin, 2011).

There is limited empirical evidence in investigating this area in which our findings can be embedded. Our findings are inconsistent with teacher reports that having the option to dim lights is beneficial to students' behaviour (Gaines et al., 2014). Our results suggest that the light intensity level (Lux) may not be the most important factor regarding the impact of light on classrooms. Type of lighting may be more important such as in

Kinnealey et al., (2012) who replaced florescent lights with halogen lights and found an increase in student engagement and comfort. However, while halogen lights are typically softer and more akin to natural daylight the authors do not report the light intensity (Lux) levels during the study.

An explanation for our lack of correlation between light and its impact on classroom behaviour may be due to sampling method used for light in this study. We also did not investigate the impact of colour of lighting, this has been demonstrated to have an effect in neurotypical classrooms (Brink et al., 2021). Light level was the only one of our IEQ variables to not be measured continuously. This was due to fact that taking light reading meant moving around the classroom and placing the Lux Meter at table height location. Whilst we initially aimed to do this for every behaviour observation it became clear this movement was distracting for students within the class and was not a tenable sampling method. Instead, behaviour observations were matched to one of three classroom light level readings taken throughout the day, whilst this was the most feasible sampling method it may not have produced the most accurate data. Additionally, the students in our study were unable to self-report the impact of lighting, it is possible that lighting might cause distress and future research should aim to explore this further in autistic students with few to no spoken words. The measuring of other aspects of light, such as glare or flicker should be considered in future research to explore their impact.

This was one of the first studies to experimentally investigate the impact of air quality on the classroom behaviour of autistic students. Our findings suggest that air quality, as measured both by CO_2 and $PM_{2.5}$ levels are not influencing classroom behaviours that facilitate learning. There was a trend towards a correlation between CO_2 and reduced behaviours that facilitate learning, however this was only seen at time point one and was not a stable correlation across the study. There is a lack of literature regarding impact of air quality on autistic students to which we can compare our findings, however they differ from findings in neurotypical students which generally suggest that poor air quality (increased CO_2 and $PM_{2.5}$) worsens students' cognitive performance (Brink et al, 2021). Many of these studies used standardised experimental tasks as outcomes, rather than the more ecologically valid measure of engagement used in this study. These standardised experimental tasks are unsuitable for the students who participated in this study. Air quality has been linked to the physical health of students, however physical health was not measured in the current study. This is something that future research might benefit from further investigating. Our results did show a significant correlation between increased $PM_{2.5}$ levels and fewer behaviours that impede learning. This finding is surprising and not consistent with previous research. $PM_{2.5}$ has been linked to increased fatigue in previous air quality studies (Shao et al., 2023). However, in this study $PM_{2.5}$ levels were within the acceptable range so there was little variation in the measurement. It is possible that higher levels of $PM_{2.5}$ were causing students to feel more tired and therefore engage in less behaviours such as leaving their seat or playing with other objects. It is also possible this finding is linked to the use of the Dylos DC1700-PM measurement device for $PM_{2.5}$. As discussed in the methodology, this device does not provide the most accurate measurements, therefore the finding in this study should be treated cautiously and future research should aim to replicate the correlation.

There was a significant correlation between increased temperature and reduced facilitating learning behaviours (but not with behaviours that impede learning) when all four time points were combined in a repeated measures correlation. Engaging in less facilitating learning behaviours will impacts student's ability to learn in the classroom. Our finding suggests that temperature is playing the biggest role in autistic students learning in the classroom. This is significant given that temperature is often used as an example of something that autistic people are hyporeactive to. For example, the diagnostic criteria for autism in the DSM-5 describes that autistic people display "indifference to pain/temperature". This was also the previous theory in experimental work. Previous literature on detection thresholds (perceptual sensitivity) and often suggested that autistic people are hyposensitive to temperature changes and have higher detection thresholds than neurotypical people (Duerden et al. 2015; Chien et al., 2017). However, these studies were experimental lab-based research strongly lacking ecological validity (conducted with verbal autistic people with normal range IQ's). In line with our findings more recent work has started to question this assumption and suggests that autistic people's temperature sensitivity is no different to neurotypical people (Williams et al, 2019) and that the experience of temperature for autistic people appears to be different depending on the level of sensitivity (He et al. 2023). Cascio et al. (2008) found no differences between the thermal detection thresholds of autistic people and neurotypical people, suggesting autistic people are not hyposensitive to temperature. Additionally, they found autistic people (with typical IQ) showed *greater* pain sensitivity in relation to temperature e.g. cold pain was indicated at a higher temperature and heat pain at lower temperatures. More recent work (Failla et al, 2020) has also found that autistic people report greater pain sensitivity to temperature, particularly for heat. They also pose that previous findings in differences in temperature detection thresholds may be a result of differing processing and response speeds between groups. Our results align with this recent research and add to the literature as they are based on the measurement of behavioural responsivity. Our findings are also consistent with previously reported case studies where sensitivity to warmer temperatures is associated with self-injurious behaviours like scratching and pinching skin (Ghanizadeh, 2009). They also align with Noble (2018) whose survey data showed autistic people rated temperature highly as a source of discomfort and reason they might avoid environments. The correlation between temperature and behaviours that facilitate learning was significant only when data from all four time points were analysed together. At individual time points, no significant correlation was found. This highlights the importance of conducting measures at multiple points to gather comprehensive data that reflects students' experiences across different times of the year and under varying conditions.

Our results suggest that, in a UK context, classroom temperature is of high importance to autistic students' experience and behaviour. In particular that higher temperature leads to a decrease in students' ability to engage with learning. Our findings provide evidence that the impact of room temperature on autistic people warrants further investigation, with particular differentiation between the impact on the different levels of sensory reactivity, and across different contexts and groups of participants. These preliminary findings suggest that investing in air conditioning or temperature control in schools for autistic students with high support needs could significantly improve the classroom environment, enhancing their learning experience. This is an important consideration, and our study provides empirical evidence for recent design guidance such as the recent British Standards Institute guide for designing spaces for neurodiverse people (BSI, 2022) which highlights the importance of having adaptable temperature control.

We examined the combined impact of IEQ parameters on behaviour, considering that students experience sensory input from these parameters simultaneously rather than in isolation. Therefore, we created the sensory overload score as described in the results section. Surprisingly, the only significant correlation between the sensory overload score and behaviour was at time point 1. There was no correlation at the other time points or when time points were combined. Given the previous literature on the impact of sensory stimuli on autistic students this was an unexpected finding. Our lack of consistent correlations suggest that other factors not measured in this study may be more influential for autistic students' experience of the classroom environment. Recent qualitative work with autistic adults has detailed how the sensory environment (e.g. light and noise) is only one of 6 factors that contribute to how enabling or disabling and environment is (MacLennan et al., 2023). Other key factors include the predictability of the environment, understanding from others, space and adjustments. The setting of our research may partly explain why we found no consistent correlations. This research was conducted in SEN schools where staff have a high level of understanding of their students' needs and sensory differences. SEN classrooms contain fewer students than in mainstream so provide their students with more space. Schools also provide many adjustments for students to help them cope with their environments such as ear defenders, sensory toys and equipment, regular breaks form the classroom if needed. It is possible that given the support in these key areas is higher than might be found in other environments, the impact of IEQ on behaviour has been reduced.

As with the presentation of our temperature and behaviour finding, the findings between sensory overload and behaviour highlight the importance of collecting data at multiple time points to see the larger picture of experiences. If data had only been collected at a single time point, we would not have seen that there is a significant correlation between increased temperature and reduced behaviours that facilitate learning across the year or that across time sensory overload is not consistently linked to classroom behaviour.

Additionally, only measuring at one time point may have made the relationship between increased sound level and increased behaviours that impede learning seem clearer cut, however this correlation does not hold across time points either. This research demonstrates the importance of being able to replicate replicating findings and to show robust correlations between variables, measures at multiple timepoints allowed us to gain a more in depth understanding of the link between classroom behaviours and IEQ elements. We would encourage other researchers to aim to repeat measures for this reason. For practical considerations though, we highlight that we did find that IEQ elements of temperature, sound level and sensory overload can all have an impact on classroom behaviours of autistic students in SEN schools and the management of these elements should be taken into consideration when designing or working in classrooms for autistic students.

4.6.1 Limitations and future research

Our study was novel in its approach to investigating the impact of IEQ on classroom behaviour of autistic children using observational measures. However, there are limitations to our method. Firstly, the use of the BASC-SOS as a measure of classroom behaviour may not correctly classify behaviours for autistic students, or be appropriate for their learning styles. For example, behaviours such as leaving their seat would be classed as a 'maladaptive behaviour', a behaviour that impedes learning. For an autistic student this might be necessary for regulation. There is a need for the development of a more appropriate tools to evaluate classroom behaviour for autistic students. Additionally, there no published normative data for the BASC-SOS, this makes it difficult to ascertain whether BASC-SOS scores show students engaging well in the classroom or a group struggling to engage. The BASC-SOS is intended as a descriptive tool to capture patterns in behaviour and did allow us to capture changes in behaviour over time in the classroom setting. Recruitment to our study was limited (potentially impacted by the presence of COVID-19 during our initial recruitment period) therefore future research should aim to replicate this study and findings in a larger sample of participants to ensure generalisability of findings. Future research, with a larger sample size, should also explore the possibility of non-linear relationships in the data. The study was conducted in the UK, which has a mild climate with cold winters and only a few hot summer days. Therefore, the findings from this study may not be directly applicable to other climates such as the ones with hot summers, where indoor temperatures are well controlled.

4.6.2 Conclusion

We conducted a repeated measures investigation to understand the impact of IEQ on classroom behaviour for autistic children with high support needs. Our findings indicate a trend towards a correlation between increased sound levels and behaviours that hinder learning at the first time point, aligning with existing literature. However, this correlation was not consistently observed across all time points.

We found no correlation between light intensity level and classroom behaviour, which suggests other aspects of light (flicker, glare) may be more important when considering the impact of light on autistic students, and future research would benefit from investigating this. There was significant correlation between increased $PM_{2.5}$ concentration and reduced behaviours that impede learning, however this finding needs to be treated with caution. There was no correlation between CO_2 levels and classroom behaviour. Our results indicate that across the year the temperature of classrooms plays a significant role on autistic students' ability to engage in learning, however this finding was only found due to our repeated measures design. Similarly, sensory overload was only seen to be impacting behaviour at time point 1. These results provide empirical evidence for the need for temperature control in special education schools as well as demonstrating the importance of collecting data at multiple time points.

4.7 Supplementary Materials

Supplementary A

Participant Non-verbal IQ scores

ID	Matrices raw score	Spatial Span raw score	Matrices T-Score	Spatial Span T-Score	Sum of T-Scores	Full Scale score	Percentile rank	95% CI
1	0	2	10	19	29	34	< 0.1	32-48
2	0	0	10	10	20			
3	5	0	10	10	20			
4	0	0	10	10	20			
5	0	0	10	10	20			
6	0	0	10	10	20			
7	0	0	10	10	20			
8	2	5	10	23	33	38	< 0.1	36-52
9	6	1	11	13	24	30	< 0.1	28-44
10	22	7	49	28	77	78	7	72-88
11	0	0	10	10	20			
12	1	0	10	10	20			
13	0	3	10	20	30			
14	0	0	10	10	20			
15	0	0	10	10	20			
17	0	0	10	10	20			
18	0	0	10	10	20			
19	10	0	22	10	32			

Supplementary B

Description of SAND assessment

The SAND (Siper et al, 2017) was used to measure sensory reactivity differences. The SAND comprises of a direct observation of an individual's response to sensory stimuli and an accompanying caregiver interview. Both parts were used in this study. During the observation part the student is presented with a range of sensory stimuli and their reactions scored. Observation does not require a verbal response from students so is suitable for use with participants with minimal spoken language. The observation lasts around 15 minutes. The SAND was designed to capture autistic sensory reactivity differences in line with DSM criteria so examines sensory hyperreactivity, hyporeactivity and seeking differences across visual, tactile and auditory domains. If a difference is observed it scores a one, if not then it scores zero. A severity rating is given for hyper, hypo and seeking sections within each domain. A severity rating of one for a mild difference and two for moderate/severe differences. Number of differences plus severity score are combined to give an overall score (out of 15) for each sensory domain, with a total observed score ranging from 0-45. The caregiver interview assesses the exact same differences with the same scoring. Observation and interview scores were combined to give a total score which ranges from 0-90. One student did not wish to take part in the SAND.

Supplementary C

Descriptive statistics for SAND and BASC-SOS variables

	Minimum	Maximum	Mean (SD)
Classroom Behaviours			
Behaviours that facilitate learning	1	30	17.11 (5.91)
Behaviours that impede learning	0	35	15.89 (7.36)
Sensory reactivity differences			
Total number of sensory reactivity differences	22.0	41.00	30.39 (6.73)
Hyperreactivity differences	2.0	19.00	9.00 (4.49)
Hyporeactivity differences	0.00	10.00	5.50 (3.15)
Sensory seeking differences	6.00	26.00	15.94 (5.73)

Supplementary D

Sensory reactivity differences and classroom behaviour analysis

Kolmogrov-Smirnov test (Berger & Zhou, 2014) was used to test assumption of normality. Total SAND score variable was not normally distributed, $D(18) = .21$, $p = <.05$. All other variables were normally distributed. Hyporeactivity differences, $D(18) = .18$, $p = .11$. Hyperreactivity differences, $D(18) = .11$, $p = .20$. Sensory seeking differences, $D(18) = .14$, $p = .20$. Students mean behaviours that facilitate learning score, $D(18) = .14$, $p = .20$ and students mean behaviours that impede learning score $D(18) = .13$, $p = .20$.

Non parametric Spearman's rank test (Zar, 2005) showed no significant correlation between students total SAND score and their mean behaviours that facilitate learning score, $r(18) = -.04$, $p = .88$. Nor was there a significant correlation between total SAND score and mean behaviours that impede learning score, $r(18) = .19$, $p = .45$.

Pearson correlation (Freedman et al, 2007) showed no significant correlation between hyporeactivity differences and mean behaviours that facilitate learning ($r[18] = -.35$, $p = .16$) or mean behaviours that impede learning ($r[18] = .43$, $p = .08$). No significant correlation between hyperreactivity differences and mean behaviour that facilitate learning ($r[18] = -.08$ $p = .74$) or behaviours that impede learning ($r[18] = .17$, $p = .51$). No significant correlation between sensory seeking differences and mean behaviours that facilitate learning ($r[18] = .15$, $p = .55$) or behaviours that impede learning ($r[18] = -.13$, $p = .60$).

Chapter 5: General Discussion

This dissertation aimed to answer the research question of if there is a relationship between sensory reactivity differences, the indoor environment and classroom behaviour of autistic children with high support needs. Within this research question the aim was to specifically investigate:

A) Is there a relationship between sensory reactivity differences and classroom behaviour? Addressed in Chapter 2 and 4.

B) Is there a relationship between the indoor environment of classrooms and classroom behaviour? Addressed in Chapter 3 and 4.

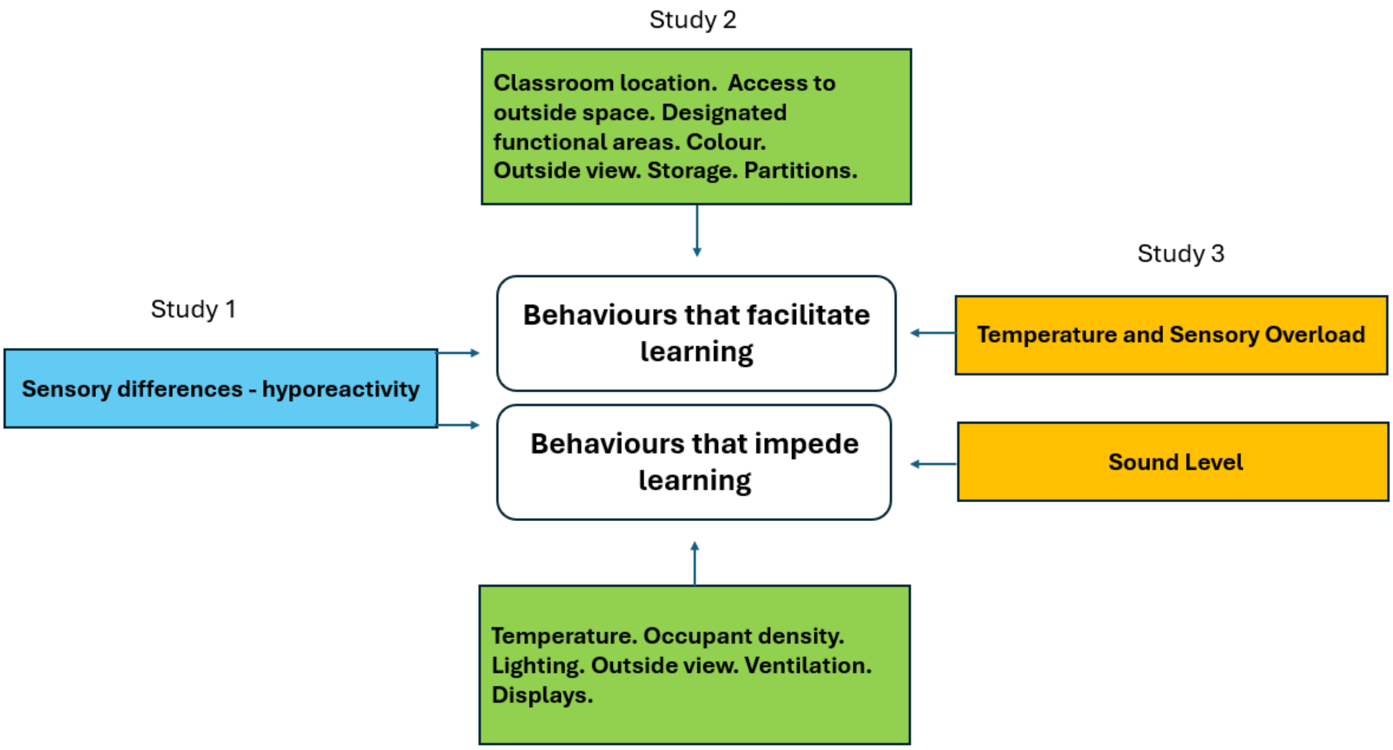
A key aim of this thesis was also to include autistic children who are often underrepresented in research, those with high supports needs in SEN schools. In our first study with 58 autistic students, where sensory reactivity differences and classroom behaviours were measured at a single timepoint using the SAND and BASC-SOS, we found significant correlations between increased sensory differences and increased behaviours that impede learning as well as reduced behaviours that facilitate learning (Chapter 2). Hyporeactivity differences were the only sensory domain to be independently linked to both classroom behaviour types. Thus, this study provided support that sensory reactivity and classroom behaviours are associated.

Further on, a qualitative second study in which 11 members of SEN school staff participated in online focus groups asking about the built environment of their classrooms. Through reflexive thematic analysis we identified three overarching themes (Chapter 3). Building layout (comprised of location, access to outside space, designated functional areas and occupant density sub themes), Indoor Environmental Quality (comprised of colour, lighting, temperature. Windows and Ventilation) and Interior Finishings (consisting of storage, partitions and displays sub themes). This study contributes to the evidence base for design guidance for SEN classrooms, highlights the views of school staff, and further provided support for an association between sensory reactivity differences, as well as environmental factors and classroom behaviours.

Lastly, study 3 investigated the impact of IEQ elements (temperature, light, humidity, noise, Co2 and Pm2.5) on classroom behaviour (Chapter 4). Measures were conducted over 4 time points across the year to capture a large range in variance of IEQ elements. Across time points there was a significant correlation between increased temperature and reduced behaviours that facilitate learning. There was also a significant correlation between sensory overload (combination of all IEQ factors) and reduced behaviours that facilitate learning, only at time point 1. This last chapter again provided evidence to suggest that sensory reactivity and classroom behaviours are linked and provided further detail on the role that environmental factors, specifically temperature, and sound level play. Taken together, all three studies answered the original question set and showed that sensory reactivity as well as environmental aspects are associated with classroom behaviours. This has implications for classroom design recommendations, planning support structures for autistic individuals based on their sensory differences and the direction of future research. See Figure 7 for an image synthesising all the study findings from this thesis.

Figure 7.

Depiction of thesis findings.



5.1 Sensory differences and classroom behaviour

Specifically, across the studies in Chapters 2 and 4, correlations and trends towards correlations between sensory differences and classroom behaviour, in terms of behaviours that impede or facilitate learning were found. In Chapter 2 with 53 autistic children aged 5-18 years and in Chapter 4 with 19 autistic students aged 8-15 years. Chapter 2, with its larger sample set, demonstrated a significant correlation between increased sensory differences and increased engagement in behaviours that impede learning and reduced engagement in behaviours that facilitate learning when utilising direct observational measures. This finding is consistent with previous research detailing the impact of sensory differences in the classroom (Dellapiazza et al., 2018; Jones et al., 2020; Mallory & Keehn, 2021).

When the sensory domains were analysed separately in Chapter 2, it was increased sensory hyporeactivity that was independently correlated to both increased behaviours that impede learning and reduced behaviours that facilitate learning. When sensory domains were analysed in relation to classroom behaviour in Chapter 4, there was a trend towards significance between increased hyporeactivity differences and increased behaviours that impede learning (this was not present with sensory hyperreactivity or seeking differences). This similarity across the study findings strengthens the argument detailed in the discussion of Chapter 1 that the role of hyporeactivity differences and their role in behaviour, particularly that in the classroom, may have been overlooked in previous literature. There are two key studies that have also demonstrated a link between hyporeactivity and behaviour. Firstly Liss et al. (2006) who found a relationship between hyporeactivity (under reactivity on the Sensory Profile) and lower adaptive behaviour and daily living skills (measured via Vineland) in autistic children. Then Lane et al. (2010) who found hyporeactivity (measured on SSP) was correlated with maladaptive behaviour (measured via Vineland adaptive behaviour scales). There are also studies which demonstrate hyporeactivity is linked to skills such as joint attention (Baranek et al., 2013), motor skills (Jasmin et al., 2009) and communication (Watson et al., 2011) which are key to engaging in learning and adaptive behaviour. This research adds to the existing literature as while the Liss et al. (2006) and Lane et al. (2010) studies relied on parent report (via questionnaires) measures, the research in this thesis utilised objective, researcher administered measures (SAND and BASC-SOS). This fills a gap in the literature which was highlighted by Baranek et al. (2013) who described the need to investigate differences in hyporeactivity across multiple stimuli, contexts and methodologies. While it is hard to compare participants needs, due to their placement in special education schools, the participants of studies in this thesis likely had higher support needs. In Lane et al. (2010) the participants were rated as having low developmental levels, which suggests the participants profile is closer to those used in this thesis. Therefore, this research compliments Lane et al. and adds to the literature demonstrating the relationship between hyporeactivity and behaviour is present in autistic children with high support needs. However, this research not only compliments Lane et al (2010) but builds on it. This work adds to the literature that this relationship is present in older children within this population. The mean age of participants in Lane et al. (2010) was 6.5 years old (8.5 years in Liss et al., 2006), compared to 10.53 years in Chapter 2 of this thesis and 12.47 in Chapter 4.

It is possible the use of the SAND assessment across the studies is allowing hyporeactivity differences to be better assessed. The SAND is a researcher-administered, standardised assessment of a student's sensory differences. Previous literature has often relied on parent/teacher reports or self-report (Ashburner et al., 2008, Liss et al., 2006). Whilst these can provide valuable data, they may be biased and discrepancies between reports exist (Jordan et al., 2019). These sources of information may be leading to under-recognition of the role of hyporeactivity differences as these differences may be less noticeable to parents and teachers than hyperreactivity or sensory seeking behaviours. Future research should aim to continue using the SAND or other direct assessments of sensory reactivity differences, as well as parent/teacher reports to ensure sensory differences are being accurately captured.

5.2 Indoor environment of classrooms

The studies in chapters 3 and 4 both examined the role of the classroom environment, with chapter 2 utilising qualitative methods and chapter 4 quantitative methods. Across these two chapters there are some similarities between school staff reported needs of classroom design and empirically demonstrated needs for classroom design. The first similarity between the results is temperature. In chapter 3 temperature was a subtheme of the indoor environment theme. School staff described how they need classroom specific temperature control in order to create a better learning environment for their students. School staff directly related this to sensory reactivity differences, this is demonstrated in a quote from P10:

"you can't control the temperature and that can affect the kids who are really sensitive to too much heat or too little heat...and that effects their behaviour as well" P10

In chapter 4, when all four time points were combined, temperature was the only indoor environment factor that was correlated to classroom behaviour. With increased temperatures reducing facilitating learning behaviours. The results from these two studies demonstrate the importance of improving temperature control in classrooms for autistic students with high support needs in the UK. This finding aligns with previous research in UK mainstream primary schools (Barrett et al., 2015) who showed that classroom temperature was correlated with learning progress and that students performed better academically when they were in classrooms where temperature was easy to control. The similarity between these findings suggest that temperature control in UK schools is important to students learning.

The second similarity between results from chapters 3 and 4 is the impact of noise. In chapter 3, when discussing the importance of classroom location, school staff highlighted how classrooms need to be away from other loud environments as this impacts students' sensory reactivity differences and engagement:

"not connected to any spaces that are particularly noisy" P3

"*the one that was closest to the hall then it's really, really difficult and the children then do tend to get over stimulated and and failed to engage or to focus because it's just to distracting and the noise... that's not great" P2*

This is similar to the results of chapter 4 that showed, at time point 1, a trend towards a significant correlation between increased sound level and increased impeding learning behaviours. Both studies provide further evidence for the impact of classroom sound levels on autistic students' engagement in the classroom. This finding support previous literature such as Howe & Stagg (2016) where autistic students rated auditory sensory differences as the most distracting for learning. There is a significant lack of empirical studies investigating the sensory environment of classrooms and its impact on learning for autistic students. In a systematic review, Dargue et al. (2022) found only 10 studies summarising research into classroom modification and engagement. In a recent preprint, Jones et al. (2024) highlight the need for research exploring the impact of classroom noise in real classrooms rather than lab settings. So, whilst this is not a novel finding, the results provide empirical and qualitative evidence for the need for better sound control in classrooms for autistic students. Sound control/sound absorbing materials are often recommend in design guidance such as the BSI Design for the mind (2022) or Mostafa (2008). If sound is so often still being reported as disrupting for autistic students, perhaps future research needs to establish if these recommendations are actually being implemented in schools, and if they are, are they enough?

5.3 Importance of repeating measures

A key takeaway from this thesis is that the studies detailed within demonstrate the importance of repeating measures in order to ensure findings are robust and replicable.

The issue of replicability in Psychology, and other fields, is not a new or small issue. The 'replicability crisis' as it has been called discusses how there appears to be an overabundance of false positives in published studies, or studies failing to replicate significant results from previous work (Wiggins & Christopherson, 2019). In order to improve the quality of psychological research, researchers have called for increased replication of studies and disclosure of non-significant results (Shrout & Rodgers, 2018). This thesis has demonstrated a commitment to research quality by both attempting to replicate and improve upon conducted studies.

Chapter 2 had some limitations that limit the generalisability of its findings, relatively small sample size and measures completed at a single time point. In order to try and strengthen the findings of chapter 2 the same measures (the BASC-SOS and SAND) were incorporated into chapter 4, so that comparisons could be drawn.

This thesis demonstrates two examples in which, despite using the same measures, results were not replicated. The first example is across studies; in both chapter 2 and 4 we utilised the SAND as a measure of sensory differences and the BASC-SOS as a measure of classroom behaviour. In chapter 2, we found significant correlations between total number of sensory reactivity differences and both behaviours that impede and facilitate learning. However, in chapter 4, we found no significant correlations between the SAND and the BASC-SOS (correlations results detailed in chapter 4 supplementary material D). Nevertheless, we found a trend in Chapter 3, thus partially replicating the findings from Chapter 2.

Example two of a failure to replicate is within the same study. The same measures (all IEQ measures, and BASC-SOS) were conducted at four different time points, by the same researcher. However, a significant corelation between sensory overload and behaviours that facilitate learning)was only found at one of the four time points. Additionally, a significant correlation between temperature and behaviours that facilitate learning only emerged in a repeated measures correlation including all 4 time points. If data had only been collected at time point 1, or time points that are close together as it has been done in previous work (Kinnealey et al., 2012; Keith et al., 2019) then the results might have led us to believe the role of sound and sensory overload on classroom behaviour were clear, however this study shows that, at time points spanning the school year, this relationship is not as straightforward and warrants more investigation for clarity. The relationship between sound level and behaviour may be more complicated that just sound level e.g. pitch or sound source may be more important.

5.4 Practical implications

The three studies within this thesis provide evidence practical and useable recommendations for those working in, or designing, classrooms for autistic students with high support needs. These key takeaways are summarised below.

Chapter 2 demonstrated that an autistic student who might be struggling to engage in classroom activities may be experiencing increased sensory reactivity differences. Students could benefit from an objective assessment of their sensory needs in order to help support them in the classroom. In particular, this study demonstrated that sensory hyporeactivity may be having more of an impact in the classroom than has previously been thought. This has important implications for school staff to be aware of the needs of students experiencing hyporeactivity and how to support them. Classroom support for sensory hyporeactivity differs from the support needed for sensory hyperactivity and sensory seeking. Sensory hyporeactivity support includes ensuring you have a student's attention before giving instructions, ensuring learning prompts are salient and clear, increasing tactile awareness with "messy play" activities, colour-coding schedules or key information/activities (Pearson et al., 2020). If hyporeactive students are not having their needs met then they will struggle to be able to engage in learning (as outlined in Maslow's hierarchy of needs) meaning they will be at increased risk for the academic underachievement that we know autistic students can face (Griswold et al., 2002; Mallory & Keehn, 2021) and in an SEN setting this could mean falling behind in vital life and independence skills (Howell et al., 2022).

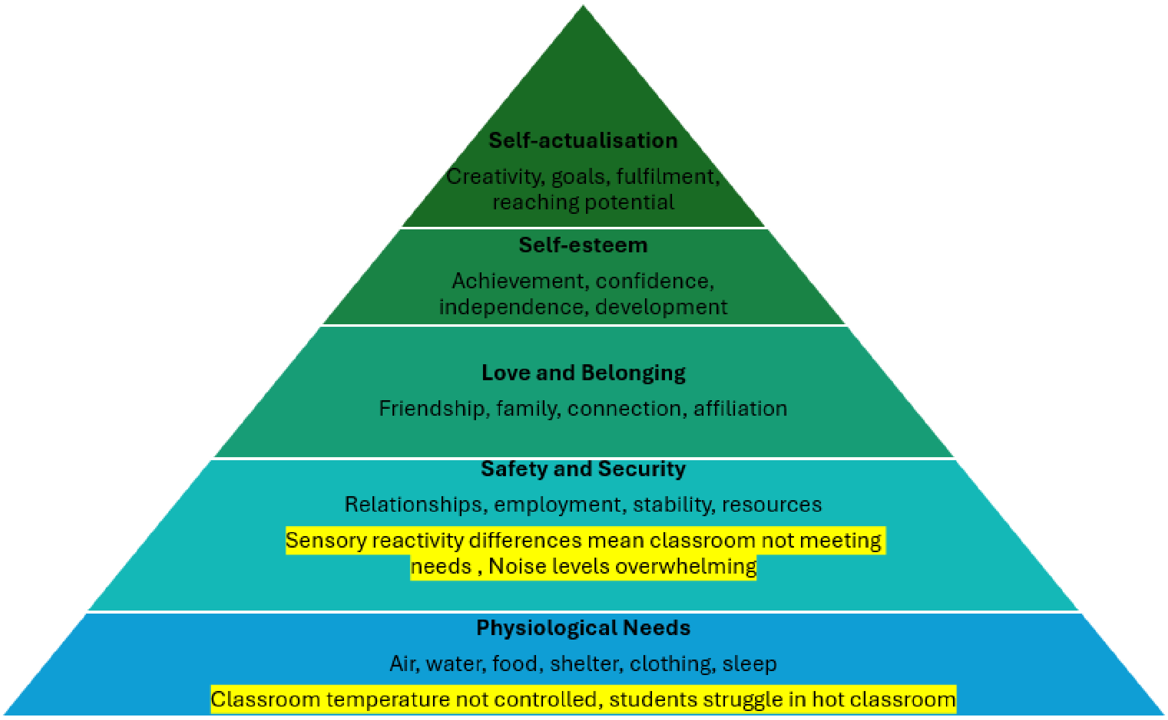
Chapter 3 highlighted aspects that SEN school staff feel are important to consider when designing classrooms for autistic students with high support needs. Key classroom design factors that emerged from this study include: a need for careful consideration of the location of a classroom (near facilities, away from noisy environments), need for immediate access to outside space from the classroom, clearly defined functional areas within the classroom, consideration of occupant density and the need for more space as age of students using the classroom increases, consistent use of colour and low arousal colours, a need for individual classroom control of temperature, flexible lighting and window options, minimal changing and use of wall displays, a need for increased storage and classroom partitioning options. Many of the findings from this study align with existing design guidance. For example, the Designated Functional Areas sub theme is similar to the Compartmentalisation criteria of Autism ASPECTSS™ Design Index (Mostafa, 2014), they both highlight need for spaces that have a clear functional use. There are also similarities between this work and the BSI, design for the mind (2022) guidance. However, as this guidance is not school specific the research in this chapter provides more detail about how the guidance might be applied to SEN schools. For example, the minimal visual displays are recommended in the BSI guidance for calm areas, the Displays subtheme in Chapter 3 details how staff believe a minimal visual display approach works best in classrooms for autistic students. Additionally, the BSI guidance details how increased space, to avoid people bumping or being crowded together, should be one of the top considerations when designing places for autistic people. This was echoed by the school staff in Chapter 2 who detailed the need for more space in classrooms, especially as the age of students increases. The BSI guidance also discusses how temperature control needs to be carefully considered to suit a wide variety of needs, and individuals should be able to alter room temperature. Chapter 3 demonstrated how this also applied to SEN schools- school staff described needing to be able to adjust classroom temperature to suit needs of their students who may have multiple medical conditions impacting their susceptibility to temperature. This study contributes to the field as it demonstrates that existing guidance is applicable to classrooms environments specifically (and how) as well as building the research evidence base for design guidance for autistic people, which is currently lacking (Manning et al., 2023).

Chapter 4 echoed the requests of the school staff in Chapter 3 by providing some empirical evidence which suggests the need for better temperature control within classrooms. Chapter 3 showed a significant correlation between increasing temperature and classroom behaviour. In order to provide autistic students with an optimum learning environment, classrooms need to have better temperature regulation. The time point 1 trends towards correlations between sound level and sensory overload with behaviour also suggest the classroom environment can have a negative impact on autistic students ability to engage in learning. We need to continue to research how we can minimise this impact.

Considering the results in a broader view this thesis aligned itself with the biopsychosocial model of disability (the idea that disability is created through a combination of biological, psychological and social factors)) and theoretical concepts such as Maslow's hierarchy of needs and Bronfenbrenner's ecological system theory. These concepts demonstrate the importance of considering the environment (which would fall under social factors) around an autistic student and how they are contributing to the difficulties experienced in the classroom. Chapter 1 provided some empirical evidence that sensory reactivity differences are impacting autistic students learning experience in the classroom, and provided more details about which sensory differences need focusing on. Study 2 and 3 have demonstrated that there is much work that needs to be done around the design of classrooms in order to minimise the impact of sensory differences. Figure 8 demonstrates how the findings of this thesis can be applied to social models of disability such as Maslow's hierarchy of needs, outlined in the introduction.

Figure 8.

Depiction of Maslow's hierarchy of needs with findings from this thesis incorporated in highlighted yellow text.



5.6 Strengths

The research within this thesis has a number of strengths. Firstly, this was a mixed methods thesis entailing both qualitative and quantitative methods. This thesis also took a cross-disciplinary approach using a multidisciplinary approach, incorporating methods from both the field of psychology (SAND, BASC-SOS) and the field of built environment studies (measurement of IEQ elements and tools). Secondly this thesis intended to include autistic participants from a population who are known to be underrepresented in research (Chakrabarti, 2017). Both the studies in Chapters 2 and 4 include autistic students with high support needs, therefore this thesis contributes to the limited research literature involving these participants. Linked to this, another strength of this thesis was the deliberate design and choice of measures utilised in order to fit inclusion of these participants. All studies were conducted in a way as to cause minimal disruption or distress to participants taking part. An example of this is in Chapter 4 where light measurement readings were only taken at 3 time points throughout each day rather than at each behaviour observation as originally intended. This was because it quickly became apparent that the researcher movement around the classroom to attain these readings was distracting to students in the classroom. The needs of the students were maintained as priority. Another strength of this thesis is the use of the SAND as the sensory assessment as this matched the needs of the students and did not require verbal communication from them. This play-based measure was also designed to capture sensory differences as defined by the DSM-5 for autism. This measure has also been specifically validated for use with autistic children (Siper et al, 2017). Ecological validity is also a key strength of this thesis. The study design of Chapters 2 and 4 allowed for research to be conducted in participants usual classrooms and whilst they were engaging in usual classroom activities (through the use of the BASC-SOS observation) rather than research taking place in an unfamiliar setting or with unfamiliar tasks. Finally, all the studies within this thesis contribute to the extremely limited research literature on creating environments for autistic people (Manning et al, 2023).

5.7 Limitations and directions for future research

In the interest of high-quality research, it is important that researchers can reflect upon limitations of their work. Whilst each chapters discusses the limitations of the individual study, there are some overarching limitations across this thesis. These limitations point to possible directions for future research.

Firstly, as mentioned in Chapter 2, the BASC-SOS may not be the most suitable measure of classroom/learning behaviour for autistic students. The BASC-SOS categorises behaviours based on neurotypical students learning so some behaviours e.g. fidgeting or leaving their chair may be inappropriately categorised for autistic students who may need to do those things to aid learning. Also, there is research demonstrating that key learning behaviours such as joint attention can look different in autistic children compared to neurotypical- autistic children can have difficulty turning their head or carrying out intentional actions, show sustained focus to one stimuli, as well as having potentially enhanced peripheral vision skills (Gernsbacher et al., 2008). This means they require different things from communication partners (in this case teachers or support staff), such as slower facial expressions and non-verbal cues to be able to engage in imitation and joint attention (Lainé et al., 2011). There is a clear need for a classroom behaviour measure specifically designed to appropriately measure autistic students' engagement. This need is even greater for autistic students with high support needs in special educational classrooms, as they spend large amounts of time engaging in activities such as sensory regulation, echolalia or speaking about topics not directly relevant to the lesson. These behaviours may be classed negatively in a behaviour classification system based on neurotypical behaviour, but within a SEN setting could be completely appropriate, and acceptable. Future research should involve school staff and other professionally working with this group to ascertain what good classroom engagement looks like for this population. The lack of a more appropriate measure meant the BASC-SOS was the best option available for this thesis.

Additionally, the IQ test used in Chapter 4 may not have been an accurate reflection of students' ability as, even though measures of non-verbal cognition are widely used, very few studies have demonstrated validity with these in autistic school-aged children (Kasari et al., 2013). Furthermore, in Chapter 4, we wanted to use a reaction time task to see if there was a link between performance on this and the IEQ of classrooms. In the end this proved unfeasible because of a lack of reaction time task that was suitable for the participants. The ReactionPacked app tasks were nearly suitable e.g. bubble popping, however they went on for too long (having to pop 50 bubbles) meaning most students lost focus and did not complete. There is a need for a standardised reaction time task that is suitable for this population, with short engagement time and simple task, that can be taken to them rather than requiring participants to come to a lab. Chapter 3 was the only study to not directly involve autistic students. The study did aim to recruit autistic teenagers to discuss their views on classroom environments, however recruitment was not successful (possibly due to recruitment period falling during COVID-19 pandemic). Future research should aim to further understand the views of autistic students, particularly those with high support needs.

A limitation in both Chapter 2 and 3 is that we did not account for any other potentially confounding variables that might impact classroom behaviour. Factors such as strength of staff and student relationship are known to be important to learning (Howell et al., 2022). Colleting data on medications students might be taking, incorporating adaptions already in place in classrooms such as a student wearing ear defenders or a weighted blanket. There is lots going on in classrooms which may impact behaviour, and future research should try to account for as many of these variables as possible. Additionally, it widely recognised that autistic children behave differently in different settings, for example how they present at home may be different to behaviours seen in school (Schaaf et al., 2014; Kidd & Kaczmarek, 2010). It would be beneficial for future research to collect behavioural data across multiple settings that students experience to determine which setting students appear more comfortable/engaged. Anecdotally, during the data collection of this thesis it was noted that some autistic student's behaviour was significantly different upon the entering the classroom, compared to their presentation in residential settings. For example, placing themselves much closer to staff for reassurance and safety, something they do not do when in their residential home. Just collecting data on behaviour within the classroom does not capture this picture or difference in behaviour.

This thesis identified and provided evidence for multiple classroom design adaptions. Future research would benefit from taking an intervention approach to assess the effectiveness of employing some of these interventions. For example, does reducing classroom temperature in summer increase classroom engagement for autistic students? As Lane (2020) describes there has been very little published and standardised research that tests the impact of modifying the sensory environment to help those with sensory reactivity differences. Future research would benefit from conducting intervention studies where the design of the classroom is altered to suit the sensory profile of the students and measure the impact on classroom engagement or learning.

Additionally, it would be interesting for future research to utilise the same measures and conduct similar research in mainstream schools to examine the impact of the indoor environment. We could then compare the needs of mainstream and SEN students to see if there are any similarities and differences, perhaps the need for better temperature control may be applicable to all schools.

A final direction for future research is to investigate the other levels of measurement outlined in the He et al. (2023) sensory taxonomy and their relationship to the classroom environment. This thesis focused on affective and behavioural levels of measurement, however the classroom environment may impact at a physiological level as well. This could be measured through watches or wearable devices that measure heart rate or skin conductance. This would allow for data collection on autistic students unobservable, internal, reactions to environments. This would be particularly meaningful for students with high support needs, as many would be unable to self report on how they are feeling internally.

5.8 Conclusion

In conclusion, this thesis has empirically demonstrated that sensory reactivity differences are impacting autistic students with high support needs in the classroom. Across two studies (Chapters 2 and 4) there was evidence that sensory hyporeactivity differences are having the most impact. Chapter 3 has provided some much-needed research demonstrating support for current design guides and that these can be applied to classrooms for autistic students. With Chapter 4 this thesis has provided evidence that the IEQ of classrooms is related to autistic students' engagement in learning, specifically that temperature and noise control measures may help to create a better learning environment.

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