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RESEARCH ARTICLE

Neurodiverse-friendly preschools: Aligning inclusive pedagogy and spatial design

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Abstract With at least 15% of children meeting the diagnostic criteria as neurodivergent, inclusive preschool environments are crucial for supporting engagement in education and a smooth transition to mainstream schooling. Although Universal Design for Learning has advanced inclusive pedagogical approaches, its intersection with the design of inclusive physical environments, particularly in early-year educational settings, remains underexplored. This study addresses this gap by drawing on insights from ten experts in education or built environment design, using a qualitative Delphi method to identify spatial features and design processes that support neurodivergent preschoolers aged three to five. Findings highlight sensory and spatial considerations, such as managing smell and noise in dining areas, reducing clutter through cabinetry and storage, providing flexibility with visual structure, and protecting personal space in circulation zones and classrooms. Experts emphasised the importance of aligning inclusive pedagogies with spatial design by developing competencies through spatial predictability and diversity and supporting self-regulation with transitional and retreat spaces. The study also critiques reliance on special-purpose spaces, which may unintentionally reinforce segregation. Finally, it underscores the importance of co-designing with educators and children—both to inform design and retrofitting, and to raise awareness of how different spaces can accommodate diverse needs in inclusive preschools.
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1. Introduction

It is estimated that 15 to 20 percent of children meet diagnostic criteria for one or more behavioural, mental or neurodevelopmental disability, and the number is rapidly rising (National Cancer Institute, 2022). This population thinks and processes sensory information of their environment differently from neurotypical people. They may experience exclusion from mainstream educational settings or be allowed to participate only in a limited number of hours or activities (Tape, 2023).

A well-rounded body of educational policy and pedagogy literature on Universal Design for Learning principles aims to include neurodivergent children in educational settings (CAST, 2024). This highlights the importance of curriculum adjustments via multiple means of engagement, representation, and action/expression (Carrington et al., 2020). However, there has been less attention to well-designed neurodiverse-friendly *physical environments* that support inclusive pedagogies (McAllister and Sloan, 2016; Mostafa, 2014). The most recent systematic reviews note sparse evidence on the physical environmental characteristics that can impact task engagement, learning outcomes and well-being of neurodivergent children (Danker et al., 2016; Dargue et al., 2021; Leifler et al., 2021).

In particular, the value of inclusive physical environment in preschool settings (ages 3—5) has yet to be considered. Research consistently shows that social, developmental and spatial needs of preschoolers differ markedly from those of older students, with implications for the design of early learning environments. For example, Lehnung et al. (1998) found that 5-year-olds tend to rely predominantly on proximal cues (local, immediate landmarks) when orienting in unfamiliar environments, whereas by age 10, children increasingly use distal cues (farther landmarks), are more flexible under rotations or cue deletion, and make fewer working- or reference-memory errors. Similarly, Montroy et al.'s (2016) research showed that self-regulation develops nonlinearly, with rapid gains during the preschool years. These findings suggest that younger children benefit from environments that provide more scaffolding that can ease their transition into formal schooling.

The paper draws on the theory of "person-environment fit" to discuss the (mis)alignment between neurodivergent children and their preschool physical environment settings. We report on a Delphi-style study that sought the perspectives of experts in the international field of inclusive built environment design, experts in inclusive education and high-level decision-makers in inclusive childhood service provision. The paper offers new insights into preschool physical environment design that can support neurodivergent children, design processes that ensure inclusive design is implemented, and finally, the alignment between inclusive architectural design and inclusive pedagogies.

1.1. Inclusive educational environments: Theory, policy and practice

Inclusive education is a major public policy worldwide (Ainscow, 2020; Boyle and Anderson, 2020). International treaties, including the UN Convention on the Rights of the Child (1989) and the Convention on the Rights of Persons with Disabilities (2008), have recognised the right of children with a disability to education. Exclusion occurs when students are directly or indirectly denied access to education due to their membership in a specific diversity group (Mezzanotte, 2022). In education systems, this has historically taken the form of segregation by placing students with disabilities in separate special schools, or integration, where students are enrolled in mainstream schools but taught in separate classes due to limited staff training or resources (Francisco et al., 2020; Rapp and Corral-Granados, 2024).

Although segregation and separate classes may provide tailored support, they can also isolate neurodivergent students from society (Francisco et al., 2020). Inclusive practices instead celebrate diversity, ensure equal access to mainstream education, and support participation and achievement for students with varied learning and behavioural needs (Benade, 2019). This approach challenges the myth of the "normal" child and aims to prepare educators to respond effectively to neurodivergent learners (Cook, 2024).

The theory of person-environment fit can explain the support the environment can offer to accommodate the needs of neurodivergent students in an *inclusive* preschool environment. The theory explores the congruence between the environmental attributes (e.g., physical characteristics and social values) and the personal attributes (e.g., needs, desires, behaviours, and cognitions), and when there is a mismatch, energy is likely to be spent adjusting personal demands or the environment in order to find a better fit (Zimring et al., 1987). During the process, an individual may suffer misfit or incongruence, which has the potential to cause physiological or psychological stress and undermine their sense of well-being.

The theory does not polarise the medical view or the social model of disability (Lai et al., 2020). The former views neurodivergence as a disability that requires treatment, while the latter views the disability as "an outcome of the interaction between a person with an impairment and the social, political and environmental barriers that impede their access and participation" (Graham, 2020, p.12). According to this model, a neurodivergent child's difficulty with sensory sensitivities and behavioural or emotional regulation is not an indication of their inherent disability but rather a result of a poor person-environment fit (Vanderburg et al., 2024). Drawing on the person-environment fit theory, this study raises awareness of the possibilities for improving universal design in preschool environments and offers insights into how addressing environmental issues can facilitate the implementation of Universal Design for Learning principles for educators.

1.2. Neurodiverse-friendly learning environments

The literature on learning spaces has identified physical environmental characteristics that cater to neurodivergent children (Table 1). Multiple studies examined sensory experiences that had a negative impact on neurodivergent individuals (Howe and Stagg, 2016). Acoustics have been found to have the greatest influence on the behaviour of this population, as described by students (Howe and Stagg, 2016; McAllister and Sloan, 2016; Mostafa, 2008). In Danker

Table 1 The literature on neurodiverse-friendly educational environments.

Design features	Author(s)	Method (context)	Sample
Acoustics	Howe and Stagg (2016); Kanakri et al. (2017); Mostafa (2008); Shabha and Gaines (2013); Danker et al. (2019); McAllister and Sloan (2016)	Observation, questionnaires, focus groups, photovoice	5—18 yrs
Lighting	Shabha and Gaines (2013); Pence et al. (2019); McAllister and Maguire (2012)	Observation, questionnaires, focus groups	5—10 yrs (some studies age not specified)
Clear layout	Mostafa (2008); Yuill et al. (2007); McAllister and Sloan (2016); Gaines et al. (2014)	Observation, questionnaires, focus groups	5—18 yrs
Compartmentalisation	Mostafa (2008); McAllister and Maguire (2012)	Observation, questionnaires, focus groups	5—12 yrs
Retreat spaces	Friedman and Morrison (2021); Li et al. (2019); McAllister and Maguire (2012); McAllister and Sloan (2016); Shimokura et al. (2023); Fahy et al. (2021)	Observation, interviews, focus groups, behaviour mapping	2—19 yrs
Natural environment	van den Berg et al. (2017); Friedman and Morrison (2021); Li et al. (2019); Droboniku and Mychailyszyn (2021)	Observation, interviews, questionnaire, meta-analysis	3—17 yrs
Clear sightlines	McAllister and Maguire (2012); McAllister and Sloan (2016)	Questionnaire, focus groups	5—17 yrs

et al.'s (2019) study of children with autism, half of the participating students reported that noise and echoes in school were a barrier to their sense of wellbeing. Similarly, teachers and caregivers in Shabha and Gaines's (2013) study indicated significant and consistent adverse effects of echoing, high and low pitch sounds, sudden and impact sounds, and background noise levels on children's behaviour. This finding was confirmed by Kanakri et al.'s (2017) observational research, which revealed a correlation between noise levels and the frequency of target behaviours in children with autism (i.e., repetitive movement, hitting response, producing loud sounds, blinking eyes, complaining, covering ears and repetitive speech). Several of the identified behaviours occurred more frequently in this study as decibel levels increased.

Lighting has been shown to be another sensory dimension that can influence the behaviour of neurodivergent children (Shabha and Gaines, 2013). Teachers and caregivers reported that bright colours and glare had a significant and consistent negative impact on this population (Shabha and Gaines, 2013). McAllister and Maguire (2012) recommended high-level windows to the exterior for access to natural light with careful placement to avoid glare and silhouetting—a design recommendation developed as a result of their research into teachers' proposals for ASD-friendly classrooms.

Spatial sequencing and clarity of school layout have also been identified as architectural factors that improve the predictability of an environment, a quality preferred by neurodivergent children (McAllister and Sloan, 2016). Mostafa's (2008) observational study revealed that creating a routine through the layout had a positive impact on children's behaviour (i.e., response time, attention span and behavioural temperament) at times of sensory imbalance. Similarly, Yuill et al.'s (2007) study of children with ASD in playgrounds indicated the need for a clear structure for their movements through play activities, which resulted in more social engagement and group play. A sense of structure and keeping the environment neat and orderly can reduce sensory inputs present in the space and thereby behavioural problems (Gaines et al., 2014). Circulation areas need to offer sufficient space and time for navigation, allowing users to pause, reflect, converse, observe others, and plan their next move—opportunities that cannot be afforded in narrow corridors or stairwells (McAllister and Sloan, 2016).

The literature also suggests compartmentalising learning zones with different sensory stimulation as well as incorporating transition zones or thresholds in between to ease difficulties when behavioural patterns are disrupted (McAllister and Maguire, 2012). The findings from teachers' workshop in McAllister and Maguire's (2012) study identify threshold as "the point of exchange" and a "place in its own rights" that helps the child recalibrate their senses as they progress from one level of stimuli to the next. The same study indicates the need for different teaching zones with different, identifiable characters so that students can associate activities with each zone.

The need for a withdrawal or retreat space has also been discussed by multiple studies on neurodiverse-friendly learning spaces. Dedicated playgrounds or small terraces with direct access to classrooms can offer "therapeutic" spaces for autistic children (Shimokura et al., 2023). Access to outdoors can provide "a choice of different places" and meet their "need for additional space in shared areas" in which they feel comfortable (McAllister and Maguire, 2012; McAllister and Sloan, 2016). Parents in Li et al.'s (2019) study believed that their children needed a break outside every 20—30 min at school. The unstructured nature of parks and green spaces, with little social demands, allowed

children to release energy and anxieties (Li et al., 2019). Furthermore, outdoor spaces with sensorimotor play opportunities (such as jumping, running, sliding, swinging, or climbing) have been highly valued by this population (Fahy et al., 2021). Friedman and Morrison (2021) demonstrated that children with ASD needed to move or fidget freely around to release energy and tension when necessary, yet still listen without interfering with their peers' learning.

Research in educational settings further demonstrates the benefits of exposure to nature for children's attention restoration (van den Berg et al., 2017). Outside educational settings, time spent in wild nature helps children maintain their deep interests, adapt to change, support their creative and imaginative play, improve their executive functioning and calm down (Galbraith and Lancaster, 2020; Schutte et al., 2017). While natural settings can be less controlled than indoor environments and may present some challenges to neurodivergent children, they can help children with autism process and tolerate information (Li et al., 2019). Children with autism exhibit more adaptive functioning when interacting with animals compared to toys (Droboniku and Mychailyszyn, 2021).

Finally, the literature recommends maintaining clear sightlines in learning environments to facilitate supervision (McAllister and Sloan, 2016; McAllister and Maguire, 2012). Disrupted sightlines can make it difficult for staff to pay immediate attention to students in blind spots if they become agitated or distressed. Clear sightlines, on the other hand, can allow staff to intervene before the student becomes overly distressed.

Although the literature has identified physical environment features that can facilitate or hinder learning for neurodivergent children, the primary focus has been on school environments (K-12) and students aged 6 to 18. Compared to school environments, preschool settings allow educators greater control over their practice and provide children with more freedom and agency in how they engage with learning (Einarsdottir, 2006). Furthermore, adaptation issues may vary due to the age of the children and the distinct characteristics of the learning environment. For example, young preschoolers require immediate access to calming sensory and play spaces for regulation, whereas older students benefit from calmer rooms and greater spatial independence that support their growing autonomy (Shimokura et al., 2023). To understand the role of physical environment design in neurodiverse-friendly educational settings for early years, we proposed three research questions.

RQ1: What *physical environment features* can support neurodivergent children in preschools?
RQ2: How does inclusive physical environment design align with *inclusive pedagogies*?
RQ3: What *design processes* ensure inclusive design is implemented?

2. Method

2.1. Qualitative delphi

This study used a qualitative Delphi exercise to consult with a purposive sample of experts with design and/or education backgrounds and practice-based knowledge of the topic. The Delphi method has been described as a systematic approach to capture experts' informed judgment on a particular topic, which has been designed with a series of meticulously crafted questions, combined with summarised information and opinion feedback received from earlier respondents (Turoff, 1970). The method is shown to be a useful technique when research is limited, when logistics or ethics are challenging, or when the evidence is contradictory (Nasa et al., 2021). While a large number of modifications to the Delphi method have been developed, the method is traditionally used to identify the current state of knowledge, educate the respondent group on the various aspects of the topic, and seek out information that may resolve controversial judgments (Niederberger and Spranger, 2020; Turoff, 1970).

We employed the Delphi method, which involved a focus group of five experts followed by five individual interviews (Table 2). The participants were purposefully selected to ensure both disciplinary diversity and senior-level expertise. They had over 10 years of leadership experience in inclusive built environment design, early childhood education or special education. The focus group included high-level stakeholders from the early childhood sector and an architect specialising in neuro-inclusive design. For the individual interviews, we invited four internationally recognised experts in inclusive architecture and education, with a specific focus on neurodiverse-friendly learning spaces, based on their extensive publication record and international standing. Local participants were identified through the research team's multidisciplinary networks, which spanned early-childhood education and learning environment design. A therapist/psychologist with extensive early childhood intervention experience was recruited via snowball sampling and introduced by one of the focus-group participants.

The study followed Nasa et al.'s (2021) Delphi tool to ensure quality use of this methodology. Each consultation began with the research team's presentation of our current understanding of inclusive physical environment design and practice in educational settings, as informed by the literature and the experts consulted earlier in our study. We then added up the findings and shared our accumulated

Table 2 The consultation stages and participants.

Stages	Participants
Stage 1: One focus group	• 1 senior Lecturer, special education advisor • 1 early childhood intervention practitioner • 2 early childhood education leaders • 1 architect/interior designer
Stage 2: Five individual interviews	• 1 early childhood intervention practitioner • 1 Professor of design, architect • 1 architect, senior Lecturer • 1 Lecturer, special education • 1 therapist and psychologist

knowledge in the next round of consultation to gain new insights. The consultation questions in the focus group were broad, but as we proceeded with the individual interviews, we refined them to obtain more nuanced perspectives (Table 3). Feedback from each round was anonymised so that no expert was identified to others.

2.2. Analysis

Inductive thematic analysis was performed after each consultation (Leech and Onwuegbuzie, 2008). We then synthesised and anonymised the key points raised, and presented this synthesis at the start of the next consultation to allow experts to refine, challenge, or extend the findings. Agreement across experts on the main themes emerged through this process and was documented in the thematic analysis. Similar transcript phrases were categorised to form the themes and then the sub-themes (Table 4).

3. Results

The results report on the expert insight into the characteristics of neurodiverse-friendly preschools. The main

Table 3 Focus group/interview questions and their alignment with the research questions.

Research questions	Focus group questions	Interview questions to the designers	Interview questions to the educators
RQ1: What physical environment features can support neurodivergent children in preschools?	- Are there inclusive design principles that we have not mentioned?	- What are the current practices for designing inclusive learning environments? - How should we prioritise design features while responding to the conflicting needs of users (e.g., hypersensitivity vs hyposensitivity; security without compromising privacy)?	- What architectural features are most important for educators working directly with children? - In your practical work with schools, how do you manage the gradient of interventions within a manageable budget?
RQ2: How does inclusive physical environment design align with inclusive pedagogies?	- What types of support the physical environment can provide to children to scaffold their inclusion in the educational setting?	- What do we know about architectural features that support transition from an inclusive setting to a different setting (e.g., Preschools settings to mainstream schools)? - How do home rooms help with transitioning to mainstream schools? - How can we design flexible learning environments in preschools to accommodate changing adult-child ratios?	- What are the criteria that are useful to consider when grouping children? - How do home rooms vs retreat spaces work? How do home rooms work in enhancing inclusion and participation in the mainstream group?
RQ3: What design processes ensure inclusive design are implemented?	- How can we improve the design process to make early years educational settings inclusive? - What's the role of co-design in inclusive environment? Who needs to be at the table for the co-design process?	- What changes can we make to existing structures (from fine-tuning and trouble-shooting to reconstructing) to make them inclusive for neurodivergent students? - What are the challenges of co-design? - How should we involve key stakeholders in co-design process? - What design components make the ownership of space transferrable to other users who were not involved in the original co-design process? - How can we best manage the costs of construction and costs of retrofitting?	- How do you prioritise costs of retrofitting? - What needs to be done to make inclusion support funding conducive to architectural supports? - How do you communicate the importance of inclusive design to stakeholders or policymakers? - What are the challenges of co-design?

Table 4 Examples of experts' quotes which shaped the themes and sub-themes.

Theme	Sub-themes	Examples of experts' quote
Manage sensory sensitivities	Acoustics	- Definitely managing the **acoustics** is really important (early childhood intervention practitioner). - High ceilings can be problematic with **noise and sound bouncing** (early childhood education manager). - This material takes out the high frequencies, the low frequencies, and **allows for intelligible speech to still come through** (academic/architect 2).
	Visual distractions	- They **limit the clutter.** And it's very **bland** to the adult eye (early childhood intervention practitioner). - The **glare**, very, very overwhelming (early childhood education manager). - Lighting that doesn't **flicker** or, having **dimmers** … good curtaining, that manages shadows … that can be distractions, for children (early childhood intervention practitioner).
	Smell	- There's the challenge with the **smells** and sounds **from a kitchen** (early childhood intervention practitioner).
	Overcrowding	- Most of the time [the dining area] is very noisy, **very busy, very rushed** large groups of children at a table. Food is served for them all mixed together. A lot of services have separate lunchrooms, or they turn their classrooms or their verandas into a space to eat (early childhood education leader). - Why do we think all kids need to be like **really close** and with **no space** between the things … safety in the corridor is, for example, …would be some space between for some students. I Can go there without **too much contact with others** (academic/special education). - Those **adult bodies can dominate the smaller spaces** (early childhood intervention practitioner) - For this cohort **having really large rooms, is problematic** (early childhood intervention practitioner).
Develop competency	Spatial predictability	- These new flexible learning spaces, but they actually **don't necessarily give learners the structure** that they need (special education advisor). - Those kind of [open plan] environments are very conflicting for neurodivergent needs. They are too overwhelming. They're **not curated**, they're **not organised enough** (architect/academic 2). - The clearer the **visual cues**, the less the educators have to be organising children (early childhood intervention practitioner) - **Wayfinding** is one of the challenges, it's seldom visually supported (academic/special education). - **Sightlines** around those transitions as well, so that students can see when they're leaving one space and coming into another space so that they could sort of preview it in advance (architect/interior designer). - There was **provision of videos, maps**, sections … you could … visit the school and almost walk round the school, as if it was like a video game (architect/academic 1).
	Spatial diversity	- What **works for one student won't necessarily work for another learner** (special education advisor). - You provide **a spectrum of places** within the learning environment (architect/academic 1). - We **don't group by ability** in any way … having that ability for them to come in and out and go to where they got the interest works very well (therapist). - Purposely, **a range of different environments** that some would be slightly noisier than others, some would be quieter (architect/academic 1).

		- We want to encourage as much as possible [that] the child almost **pushes their boundaries** a little bit (architect/academic 1). - It creates almost a **bubble of a parallel micro class** within the larger class (architect/academic 1). - They feel safe, and they **don't want to go back to the mainstream classroom** (academic/special education).
Support self-regulation	Transitional spaces	- The need to have that point to stop before you're **transitioning into another space** … it's particularly critical where you get a change in light or a change in temperature (architect/interior designer).
	Embedded micro-retreats	- The place you go when you need to **step away and emotionally regulate** (architect/academic 2). - Create environments that are **as closest as possible to what one would find in the typical world** (architect/academic 2). - I Agree with the **biophilia connections**, enough nature (early childhood education manager).
Co-design	Designing with lived expertise	- At the moment is a lot of inclusive design is not done in **consultation with the relevant stake-holders** (special education advisor). - **Experts are those with the disability**, or with the impairment or the families or the practitioners. It's not the architectural profession (architect/academic 1). - Nor are teachers given the pedagogical sort of approaches that would be useful, or the students **aren't taught how they can use different spaces** (special education advisor). - [A digital model of a building] is a huge asset that the users of the building can tap into to allow the **virtual experiences** of students and teachers. You can **test out different configurations of a classroom** (architect/academic 2). - Finding out how to achieve that within the constraints of you know, budget and budget and the site conditions … it's a really **tricky** thing, and it's **a different language** as well. We probably thought that would be done in half the time that it's taken … there's **lots of back and forth** to respond to all the different demands (therapist).
	Retrofitting	- I Think that is fairly simple to **introduce transition spaces**, particularly at entry points. - **Escape spaces** don't have to be purpose built, fancy, expensive, sensory techie kind of spaces. - Sometimes it's just a question of **operating the building in a different way** … and this is the least expensive of the solutions (architect/academic 2).

themes suggest that an inclusive setting should be co-designed with lived expertise and will decrease learners' exposure to their sensory sensitivities, develop their competency, and empower them to self-regulate when faced with stressful situations. The sub-themes elaborate on the design principles that facilitate these experiences (Fig. 1).

3.1. Manage sensory sensitivities

The expert consultations identified four main types of sensory sensitivities that can "distract" neurodivergent children: noise, smell, visual distractions and overcrowding. They believed that children can better focus on learning if the physical environment design enables them to manage these sources of distraction.

3.1.1. Acoustics

Acoustics was "critical" to our participants with both design and education background. High ceilings and echo were raised as being problematic in preschools. Dining areas were mentioned by multiple participants as highly stimulating environments, which may require retrofitting and acoustic treatment as they are often very noisy. However, the experts did not define acoustics as "silencing of the space", but as "curation of the acoustical environment", which could offer access to "sound cues" a child may need to navigate the space. A design expert raised the issue about some acoustic materials which "just dampen[ed] all sound": "... everything becomes quieter, which in a classroom is not necessarily what you want, because you still have to make sure that speech and language can be heard clearly ... [instead] this material takes out the high frequencies, the low frequencies, and allows for intelligible speech to still come through".

3.1.2. Visual distractions

Participants questioned educational settings with "so much stuff in the rooms", which could be "very visually distracting" for children. They argued that cabinetry is a "basic" but "really critical" design feature to limit clutter. Although these settings may appear "bland looking" to an adult eye, they facilitate staff's efforts to manage the learning environment.

Glare and flickering lighting were another sensory stressor that educators found overwhelming to neurodivergent children. They believed that dimmers and good curtains within fire restrictions could help manage shadows, mitigate distractions, and thereby facilitate staff's efforts to manage the learning environment.

3.1.3. Smell

The educators pointed out smell as another sensory stimulation with which neurodivergent students usually struggle to cope. This sense was mainly raised in association with kitchens and dining areas, which were known as "a really important" part of the service in early years. One of the educators stressed the challenging relationship that neurodivergent children may have with food and that their families want their children to get more used to food and eating; however, kitchens and dining areas with smelly, busy and noisy environments could make sensory integration more demanding.

3.1.4. Overcrowding

Overcrowding is a further source of sensory overstimulation that children may experience particularly in dining areas and corridors, according to the participating educators. A special education advisor highlighted the importance of maintaining personal space for children in corridors to avoid unwanted contact and barriers to free movement, stating that "sometimes walking by a big group of students, [who are] loud, [and] not making [any] movements ... can be really fearful".

Crowding could be a consequence of a higher adult-child ratio in neurodiverse settings. The participating educators questioned the room size compliant with current

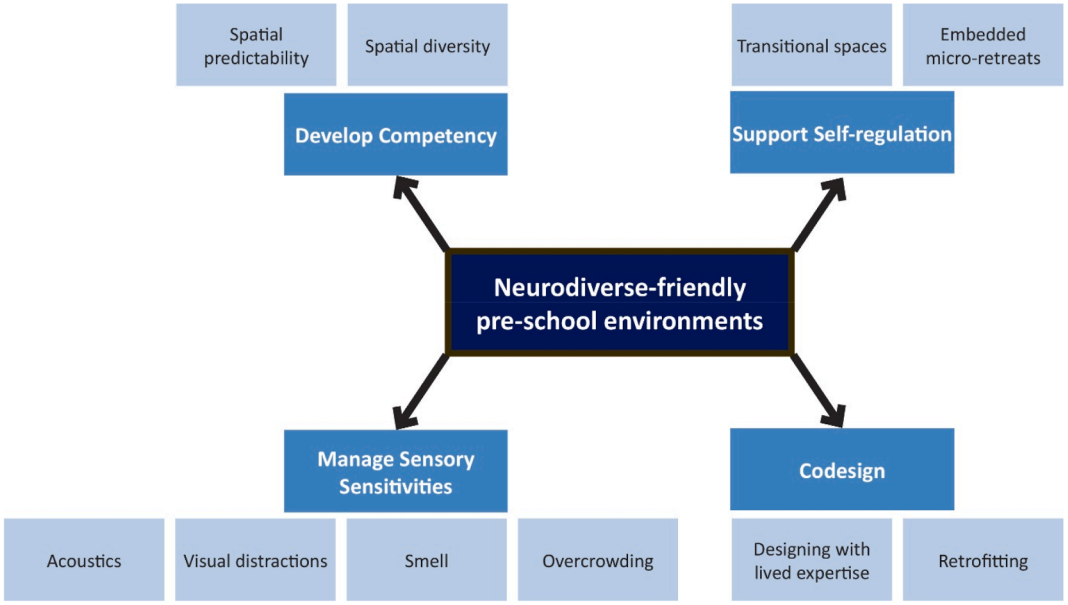

Fig. 1 The themes and sub-themes emerged from the expert consultations.

regulations, but felt too small with additional adult bodies in space: "we've got just 9 children in a space, but still with 3 adults, that's a lot of bodies in a room … you might have your therapist in there and your additional educator … those adult bodies can dominate the smaller spaces … humans can be part of the problem for the child" (Early childhood intervention practitioner).

3.2. Develop competency

The experts identified two consistent physical environment features important to children to demonstrate and grow their competency in their learning environments: 1) support for spatial predictability so that children can competently orient themselves around the environment; and 2) provision of spatial diversity to build up sense of competence. The discussion of these features highlights the support they provide to both neurodivergent and neurotypical children, enabling them to perform and function efficiently in an inclusive environment.

3.2.1. Spatial predictability

According to the experts, the space should be "defined", have a clear layout and give the learners sufficient clues to easily navigate around. The experts questioned open plan design, which they described as not "curated", or "organised enough". While these spaces give educators "flexibility" to organise the room according to the needs of each group, they did not necessarily give learners the "structure" that they needed, and therefore could be "very anxiety-inducing", "conflicting", and "too overwhelming" for neurodivergent learners. Visibility of the pathways was raised as another important dimension. An educator recommended "straight" hallways without anything "jutting out" into the space to maintain a clear line of sight down the corridor without distraction.

Open sightlines and opportunities to preview the space before entering were other important design considerations raised by our expert to increase the predictability of forthcoming scenes. The use of visual cues such as colour and texture was an important wayfinding design feature raised by a participating educator. They believed that the provision of signage in the built environment would relieve some pressure on the educators to instruct the learners how to operate in space: "for all children and the staff the clearer the visual cues, the less the educators have to be organising children and …, sort of institutionalising; line up here, gather there" (Early childhood education services). Finally, they emphasised the importance of providing these cues where they are noticeable from a young child's perspective: "It's down where the children are, so it doesn't help if those visual cues are at an adult height only".

Participating architects highlighted "media maps" as a valuable tool for easing children's transition into new learning spaces, as they offer a virtual preview of the environment. These digital maps were seen as providing "reassurance" for both children and parents, helping them anticipate upcoming experiences and adjust more comfortably to the actual space.

3.2.2. Spatial diversity

There was a consensus among the participants on the need for "diversity" of spaces in inclusive design as neurodivergent learner preferences were diverse and not necessarily compatible with one another. An interior designer voiced the challenge associated with accommodating the needs of this group: "there are certain children who just can never be put together not just due to age but due to conflicting needs … students that may be quite noisy, keeping them away from students that needed a certain amount of quiet". Participants, therefore, argued for the provision of "a spectrum of places" to curate a learning environment with a range of stimulation (e.g. noisy vs quiet). The interior designer also commented on the numbers of zones that should be determined to assure "adequate separation", depending on "the size of the cohort and the extent of the need and the extremes of the abilities".

The availability of multiple zones could further encourage the child to challenge themselves, "push their boundaries" and explore the environment beyond their comfort zone, thereby developing skills that support their transition to the real world. As an architect/academic illustrated: "you create a whole gradient of classrooms, some that have more mitigation, more control for those with more needs; and then other classrooms that are more typical. And you move through that gradient, and the hope is that we all want our students to be able to generalise the skills that they learn in the classroom outside in the real world".

Finally, stakeholder consultations reflected on the risks/benefits of creating separate spaces (e.g., satellite classrooms or homerooms), especially designed for neurodivergent children to optimise sensory stimulation. Children in these centres were given the option of attending their homerooms or mainstream classrooms, if adult ratios allow, and could thus retreat to their safe zone when they felt overwhelmed by the environment of mainstream classrooms. Educators who advocated for the use of these rooms highlighted the need to manage adult-child ratios, address staff shortages and justify catering fees to support these homerooms.

However, some other participants, both from design and education backgrounds, argued against these rooms exclusively allocated to neurodivergent users, questioning their role in creating an "inclusive" environment. They warned that these spaces can create "almost a bubble of a parallel micro class" and make the child "so attached and reliant on their aid" to the extent that they could not provide the essential "translational experience" to the real world. An educator elaborated on the long-term outcome of this practice and warned against over-reliance on these spaces that may hinder integration and independence: "They feel safe, and they don't want to go back to the mainstream classroom, since it's loud … my experience is that all these small group arrangements, very suddenly become permanent, and also the students that need this arrangement rise … so if they are 5 from the beginning, after 6 months they are 8, and then … And in 2 years' time there are 19 students that have to go to the small group arrangement. So,

we need to work more broadly with the mainstream physical environment and mainstream teachers' knowledge and help them out with strategies and methods that they can use".

3.3. Support self-regulation

While previous themes considered the environment as a source of stimuli, our expert consultants emphasised the importance of spaces that can facilitate self-regulation when children are emotionally unsettled or exhibit disruptive behaviour. They include transitional spaces and embedded micro-retreats.

3.3.1. Transitional spaces

Participants underlined the need for a "quiet" space, a "sensory perch", such as a veranda, where users can stop and "emotionally regulate" before transitioning into a different environment. These transitional spaces were known to be "particularly critical" with a change in light or temperature, e.g., when moving from inside to outside.

Transitional spaces were also recommended between the outdoor areas themselves. An architect elaborated on this design features: "So if you've got a playground … there will be those children who want to play in the playground and at the heart and centre of it, and there'll be others who want to be more peripheral …, and it's important to give them the opportunity, who might just want to watch, to just be on the edge … And that might help [to have] a transitional space, that over time they might go from being on the edge to dipping their toe in the water and wanting to get involved … Or if you're there, that people might come and talk to you which is really important … it's realising that different people at different times will want a different level of interaction" (architect/academic 1).

3.3.2. Embedded micro-retreats

The participants unanimously stressed the need for "safe spots" where the child gets a chance to withdraw from the main cohort, regulate their emotions and calm down when needed. Participants advised creating these spaces out of sub-spaces that could be accommodated within the main mainstream classrooms, that "one would find in the typical world", since there would not be escape spaces "designed" for the neurodivergent individuals. Examples of such retreat spaces offered by our experts include bean-type chairs, window seats, alcoves and nooks and crannies, individual benches under tree canopies, mounds and tunnels in the playground, and shrubbery where children can hide. Incorporating these spaces in the mainstream learning settings can also facilitate maintaining a clear line of sight and supervision across the whole cohort. Without clear sightlines, participants believed that child safety could be compromised, putting additional pressure on the teaching staff.

From our experts' perspective, retreat spaces can benefit from natural settings, art projection or physical play opportunities that incorporate vestibular and proprioceptive stimulation, as these elements offer both sensory regulation and sensory seeking. According to a participating architect, sensory experiences offered by nature can include sound and the tactility of water, the dappling effect of light created through the movement of the sun through leaves, or the aromas of a herbal garden. When nature is not available, projection of its physical appearance can be "soothing" or "stimulating" for children, although it cannot fully replace the multisensory experience of being immersed in nature. The use of swings, hammocks, and bouncers were also encouraged as they could function as a sensory and emotional regulator for neurodivergent users. Nevertheless, climbing risks should be mitigated as neurodivergent children tend to climb objects. Outside posts, pergolas, short structures such as retaining walls, fences and cubby houses were mentioned as potential climbing areas.

3.4. Co-design

Participants unanimously valued engaging the community of educators, children and parents in the design process when designing a learning environment as they have the lived expertise. Participants also highlighted inexpensive retrofits and operational flexibility as key design strategies for enhancing support for neurodivergent children in early learning settings.

3.4.1. Designing with lived expertise

Participating architects confessed that the architectural profession did not have enough expertise in neurodiversity; instead, neurodivergent individuals, their families and teachers and their invaluable insight should inform the design: "I think that's still a bit of a barrier to much of the profession. I think architects were an egotistical lot. And there's this idea that we know it all. and we don't at all". They viewed co-design with lived expertise as a "critical" component, particularly when it "comes down to those compromises". Co-design was underlined not only as a process that benefits design but also "educating" the stakeholders about the inclusive design principles and the difference they make to the education practice. As a Special Education advisor stressed, both educators and students should be taught how to use different spaces effectively.

An example of spatial needs often overlooked due to limited consultation with educators is the provision of additional staff facilities in inclusive early childhood settings—such as spaces for collaborative teaching and consultation suites. Participants criticised the design of early learning environments where staff areas were treated as an afterthought or omitted entirely, simply because "they're not that kind of space that you're generating revenue from". They emphasised that clearly defined adult spaces, separate from children's areas, are essential for staff wellbeing, which in turn supports the quality of care and education provided. As one educator put it, "the more complex the children they're working with, the bigger the difference that makes".

However, participants admitted that co-design can be lengthy with "lots of back and forth" and "quite challenging" due to the complexity of generating information with diverse stakeholders and user groups. A solution suggested by a participating architect was the use of digital

models of an educational environment as a medium to test different designs and configuration options of a learning space from the user's perspective, to identify those that work best for them. The same participant recommended observing teachers and neurodivergent children in educational settings to understand how they behave on-situ and change their environment to accommodate their needs: "Teachers, parents and autistic individuals themselves are the first designers of space … They have all without knowing it, redesign the spaces that they work".

3.4.2. Retrofitting

Since many preschools had not been purpose-built to support neurodiversity, consultations were also considered as a requirement to retrofit the space. However, the cost of retrofitting was mentioned as the clients' "number one priority" to the extent that they could not see any possibilities or potential in the environment within their limited capital expenditure budget. That said, a participating architect provided examples that can be easily done without being necessarily "prohibitively" expensive. Acoustic modifications were listed as being one of the most powerful through "inexpensively add[ing] strategic materials in strategic locations". Introducing retreat spaces was another "inexpensive" but "very helpful" retrofitting option. Participants insisted that a space can be as simple as a small, soft cushioned corner in a classroom or a small play tent that can be set up in the corner of a classroom.

Beyond physical modifications, participants emphasised that rethinking the "operational model" of the centre was an essential part of responsive design. This included rescheduling or reallocating activities to follow a logical flow of stimulation, moving from high-to low-intensity experiences throughout the day. Such changes, they argued, could be implemented without significant financial investment. Changing the operational model seems an inevitable practice when the children's cohort changes constantly in an inclusive, neurodiverse centre. Educators thus preferred a flexible space they could change based on the cohort needs: "We want to be able to make this space flexible to the needs. That changes with every cohort, depending on the children's need. Whereas when you're fixed, you're really restricted, and that can be difficult", a participating therapist explained.

4. Discussion

The current study extends our understanding of neurodiverse-friendly learning environments by focusing on early childhood spaces. Our expert consultations revealed a knowledge gap in the existing academic literature on universal design principles for inclusive preschools and confirmed that early years learning environments will require unique design guidelines that do not necessarily follow those implemented in schools.

Our response to Research Question 1 reveals educators' and designers' expert insight into the characteristics of inclusive preschools, designed or retrofitted to support neurodivergent children and inclusive learning. Responding to Research Question 2, the paper discusses how inclusive architectural design aligns with inclusive pedagogies. We finally offer insight into the co-design process, which has benefited the design practice to respond to Research Question 3.

4.1. Neurodiverse-friendly physical environment features

Our experts most frequently identified sensory sensitivities as the key impact of physical environment on neurodivergent children in preschools. While the impact of acoustics and visual control has been already recognised by previous studies, their influence on the performance of neurodivergent children were mainly investigated in school settings and in traditional learning environments such as classrooms (Kanakri et al., 2017; McAllister and Maguire, 2012). Our expert consultations extend the earlier findings to the flexible environments of preschool spaces such as kitchens and dining areas which they found very noisy and overwhelming to children. While open plan classrooms were condemned by previous literature for high intrusive noise levels and low speech transmission (Mealings et al., 2015), interestingly, our experts did not criticise open plan layouts for poor acoustics in the context of preschools, but for lack of visual structure, an issue which will be discussed further in the next section.

Smell is another sensory stressor that has been largely overlooked in the inclusive design literature. Eating is a multi-sensory experience; thus, neurodivergent children who have multi-sensory processing issues can exhibit mealtime behavioural problems (Petitpierre et al., 2022). Additional sensory stimulation, such as noise and smell, can easily disturb neurodivergent children in settings such as dining areas or the kitchen. Since these areas hold pedagogical significance in preschools and are usually integrated into the main learning environments, the negative impact of sensory sensitivity can extend beyond the lunchtime periods.

Our experts identified overcrowding as an additional challenge that neurodivergent children may face, particularly in the corridors and dining areas. Increased adult-children ratio in inclusive learning centres and adults dominating the space can exacerbate overcrowding experienced by children in preschools. This issue has been raised by previous studies, which recognised that neurodivergent school-age children require greater interpersonal distance compared to their neurotypical peers (Candini et al., 2017; Gessaroli et al., 2013); however, these studies used a stop-distance paradigm outside the context of everyday life. Future studies may measure the personal distance range in situ, as it may vary based on the context of the learning environment.

Our findings further highlight the importance of environments with spatial diversity for two major reasons: to cater to the diverse needs of neurodivergent children (e.g., neurotypical, hyposensitive and hypersensitive); and to encourage each cohort to challenge their limits and expand their comfort zone. The availability of diverse environments increases the chance that neurodivergent users will find spaces that better suit their needs, thereby enhancing person-environment fit.

To ensure a smooth transition between environments with varying levels of stimuli, it is essential to incorporate transitional spaces that moderate the experience, and in case the child is dysregulated, retreat spaces will facilitate withdrawal from the stimulating source and balance sensory overstimulation. This finding corroborates earlier literature on autism-friendly environments in school environments (McAllister and Maguire, 2012; Shimokura et al., 2023). Our study extends the earlier discussions of retreat spaces and emphasises the importance of integrating them into the design of mainstream learning environments, so that everyone regardless of their neurodevelopmental conditions can access them. This practice destigmatises the neurodivergent cohort and gives all students the opportunity to seek out moments of calmness when needed (Aminpour, 2023). These retreat spaces can incorporate elements of nature as well as opportunities to engage the vestibular and proprioception senses. Previous studies show that both nature and active play help children calm down and exhibit less disturbing behaviour (Ezpeleta et al., 2022; Friedman and Morrison, 2021).

Finally, our findings reinforce prior evidence that clear sequencing and layout improve the predictability of learning environments for neurodivergent children (McAllister and Sloan, 2016; Mostafa, 2008; Yuill et al., 2007). Our results further extend this knowledge by highlighting that open-plan classrooms, often promoted for educator flexibility (Benade, 2019), can feel uncurated, overwhelming and anxiety-inducing for neurodivergent learners, undermining the very predictability they need. Participants also drew attention to the importance of open sightlines and opportunities to preview spaces before entering, as well as the placement of visual cues at a child's eye level to reduce reliance on staff.

At a policy level, the participating architects unanimously agreed that although these physical environment features are generally considered "good practice", they are not mandated by design codes, preschool licensing standards or early-childhood education regulations. As a result, they can be easily compromised when conflicting priorities or budget constraints arise. Establishing a statutory basis for minimum spatial and sensory requirements would clarify the standards to which neurodivergent children have a right of access and would help guide both new construction and retrofitting projects.

4.2. Alignment of inclusive physical environments with inclusive pedagogies

This study argues that the role of the physical environment in creating neurodiverse-friendly preschools should be considered along with inclusive pedagogies. Findings from the expert consultations indicate that the four design themes identified in this study align directly with the three Universal Design for Learning (UDL) principles (Table 5). In CAST's UDL framework, Engagement focuses on reducing barriers to motivation, optimising individual choice and autonomy, and facilitating personal coping skills and collaboration. Representation ensures that multiple perspectives are incorporated, and information and experiences are communicated in a variety of ways. Action/Expression optimise access to support for planning and practice and managing resources.

Experts in our study highlighted the need to reduce acoustical overload, visual distraction, smells and overcrowding, measures that directly support "Engagement" by minimising distractions and providing calmer settings for sustained participation, a finding that is in line with previous studies on the impact of physical environment on neurodivergent student engagement (Dargue et al., 2021; Saggers and Ashburner 2019). Minimising sensory overload also responds to 'Action/Expression' by making it easier for children to manage information and resources within an environment that does not overwhelm their senses.

Table 5 Alignment between spatial design and CAST's UDL Guidelines.

Main theme from this study	Illustrative design features	UDL principles supported
Manage sensory sensitivities	Acoustics; visual distraction; smell; overcrowding	Engagement (minimise distractions) Action/Expression (facilitate managing information and resources)
Develop competency	Spatial predictability	Engagement (promote expectations and beliefs that optimise motivation) Representation (guide information processing and visualisation)
	Spatial diversity	Engagement (optimise individual choice and autonomy; vary demands and resources to optimise challenge)
Support self-regulation	Transitional spaces	Action/Expression (support planning and strategy development)
	Embedded micro-retreats	Engagement (facilitate personal coping skills and strategies)
Co-design	Designing with lived expertise; retrofitting and operational adaptability	Engagement (fostering collaboration and community) Representation (incorporating multiple perspectives)

This study also suggests that providing predictable layouts with clear cues improves spatial predictability and therefore, can promote expectations and beliefs that optimise motivation (UDL's Engagement). Consistent visual and spatial cues guide information processing and visualisation (UDL's Representation), supporting children's understanding of routines and transitions (Mostafa 2008). These characteristics make the environment "legible"—an attribute previously recognised as promoting children's competence in early childhood education settings (Maxwell, 2007; Trancik and Evans, 1995).

Our study further shows that offering a diversity of interconnected sub-spaces supports individual choice and autonomy while also varying demands and resources to optimise challenge (UDL's Engagement) by allowing children to select settings that match their current comfort or skill level. However, our study shows that pedagogical practices can either support or hinder these transitions depending on how the environment is operated. For example, while "satellite classes" can be used by all children, neurodivergent or neurotypical, as a safe zone to self-regulate (UDL's Engagement), assigning them exclusively to neurodivergent children can reinforce separation and hinder their transition to mainstream education—contrary to inclusive discourses that aim to provide all students with access to mainstream curriculum (Page and Davis, 2023). Sub-spaces integrated into the mainstream classrooms can create better connection to the main cohort and opportunities to engage with the mainstream community (Aminpour, 2022).

Facilitating smooth transitions is especially important in preschools, as children may spend between 20% and 35% of their day transitioning from one activity to another (Banerjee and Horn, 2013). Our expert consultations emphasised the importance of strategically planning both the activity flow and the spatial layout to minimise disruption (UDL's Action/Expression). They recommended allocating adjacent spaces to activities with similar levels of sensory stimulation and avoiding frequent transitions between environments with contrasting sensory stimulation.

Finally, experts stressed that an inclusive learning space must also foster collaboration and community (UDL's Engagement) and incorporate lived experiences (UDL's Representation). These aims can be achieved through co-design processes that involve educators, families and children, as well as through inexpensive retrofits and operational flexibility (Kelly et al., 2025; Mostafa, 2018).

4.3. Design processes to implement inclusion

To ensure inclusive design implementations, it is essential to co-design preschools with educators, children, and their families, as no one else could and should make assumptions about their needs and how they perceive their environment. This study acknowledges Bianchin and Heylighen's (2018) argument on "fair" and "just" design, which shifts the demand for equitability from the design output to the design process, and defines inclusive design based on "who participates in actual deliberations".

However, translating inclusive design principles into practice is a challenging task. Co-design is a time-consuming, iterative process that involves participants who often lack design experience, which can impede knowledge transfer (Van der Linden et al., 2019). Involving young children in mixed groups can also be difficult as some voices may dominate others (Valguarnera and Landoni, 2023). Our experts recommended using digital models and immersive Virtual Reality tools to engage end-users and examine their interaction with the space — an approach proven effective by previous research (Dane et al., 2024). Through simulated real-world situations, end-users can share insights with designers and help shape spaces that better meet their needs.

Design consultations should extend beyond the planning of new environments to include post-occupancy evaluations and retrofitting (Whittem et al., 2024). Many preschools were not originally designed to accommodate neurodiversity and therefore require retrofitting to fit the purpose. Our findings, consistent with previous studies (Mostafa, 2021), suggest that simple interventions such as acoustic treatments and embedded retreat spaces, especially when combined with visual supports and an improved layout, can improve experiences for neurodivergent children. These design interventions can reduce the need for educators' individualised adjustments and enable teachers to focus more on enhancing pedagogies. This, in turn, may address some of the issues facing what are currently called hard-to-staff settings.

The benefits of co-design go above and beyond creating a neurodiverse-friendly learning environment; they also raise awareness among designers, educators, and learners. Through participatory processes, designers learn about the needs of this population; educators learn how different spaces can accommodate various activities; and children learn how to use and navigate diverse settings. This wider engagement can foster public understanding of neurodiversity and counteract the historic underrepresentation of neurodivergent users in community decision-making (Gillespie-Lynch et al., 2020).

4.4. Limitations

This study explored the opinions of experts in the field who drew on their knowledge and experience of working with parents, children, teachers and other caregivers. While this knowledge is invaluable, designers should not create environments solely based on what adults believe are congruent and anticipate the needs of neurodivergent children (Zimring et al., 1987). Future studies will need to explore the person-environment fit from children's perspective for example through direct participatory methods, observational studies or child-friendly tools that elicit children's voices and experiences in situ. Including children's perspectives alongside adult expertise would strengthen the ecological validity of findings and ensure that the resulting design recommendations genuinely reflect the lived experience of neurodivergent learners.

The study consulted with a limited number of experts ($N = 10$) yet employed a multidisciplinary approach. The heterogeneous composition of the participants, spanning inclusive physical environment design, early childhood education and special education, has been important for drawing a conclusion on the alignment between inclusive physical environment design and inclusive pedagogies. Nevertheless, the small sample size may limit the generalisability of the

findings. Future research should triangulate and extend these insights through larger Delphi panels and complementary methods such as observational studies, case studies of existing early-childhood settings, or mixed-methods evaluations to validate and refine the themes identified here.

This study did not conduct iterative Delphi rounds and, therefore, cannot confirm the stability of the results, i.e., the consistency of responses between successive rounds of a study (Nasa et al., 2021). However, as the analysis demonstrates, in-depth discussions in interviews/a focus group supported the study to reach consensus on the major themes. This approach is consistent with other qualitative or modified Delphi studies, which use expert interviews rather than repeated surveys (Niederberger and Spranger, 2020).

5. Conclusion

This study investigated characteristics of neurodiverse-friendly preschool environments, which serve as a crucial foundation for children to successfully transition to mainstream schools. The findings point to a range of design features that could facilitate the integration of neurodivergent children into preschool, but also emphasise that the process of design is an important component of inclusive practice. By foregrounding sensory sensitivities, especially to noise, visual complexity, smell, and crowding, our findings extend existing knowledge beyond classroom-based research and into the more fluid learning environments of early years, such as kitchens and dining areas.

Physical design also needs to complement the pedagogical philosophies and practices of preschools. The study demonstrates that spatial layouts and operational decisions, such as how flexible spaces are used, how transitions are managed, and whether grouping reinforces separation or inclusivity, can either support or undermine inclusion. Design and pedagogy models must work in concert, with environments offering both flexibility and structure to meet varied learning and sensory needs. Ultimately, a participatory, co-design approach that involves educators, children, and families is crucial for creating environments that genuinely reflect diverse needs and foster a broader understanding of neurodiversity. While this study is limited in scope and does not capture children's direct perspectives, it provides a foundation for future research that further centres the voices and experiences of neurodivergent children in shaping inclusive environments.

Ethics statement

This study was approved by the Human Research Advisory Panel (HREAP) B at University of New South Wales, Approval No. iRECS0864, on November 13, 2023.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the first author used ChatGPT and Grammarly only to improve grammar and readability. After using these tools, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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