Review

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Considerations of the built environment for autistic individuals: A review of the literature

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Abstract

Until recently, built environments have been designed exclusively to meet the needs of neurotypical populations; however, there is increasing recognition of the need to make built environments more accommodating for neurodiverse populations, including autistic individuals. This scoping review aims to comprehensively explore and synthesise this literature on the internal built environment for autistic individuals providing recommendations for designers, policymakers and clinicians. Five electronic databases were searched, resulting in a total of 28 studies being reviewed. Recommendations are provided for design and construction, lighting, sound, aesthetics, temperature and air quality. While in its early stages, evidence demonstrating the impact that particular qualities of light, colour, sound and spatial planning have on the human sensorium is emerging. In turn, this new knowledge is informing design decisions that are progressing interior environments towards inclusivity. Understanding the positive and negative impacts of decisions made in the design of the built environment has the potential to facilitate the participation and inclusion of autistic individuals.

Lay abstract

Factors related to the interiors of buildings, including the layout of rooms, colours, smells, noises, temperature, ventilation, colour and clutter, among other things, can change the way we interact with our environment and the people around us. Autistic individuals can have differences in processing sensory information and may find aspects of the built environment (BE) over-whelming and difficult to navigate. We reviewed the existing literature exploring the BE and autism. This study found that it is possible to make changes to the BE to create more inclusive and friendly environments for everyone, including autistic individuals. Findings from this study provide clear recommendations that can be used by interior designers, architects, builders, and clinical practitioners to make a positive difference. Key recommendations include using simple spatial layouts, compartmentalising and zoning spaces into specific activity sections and providing retreat spaces. The thoughtful placement of windows and blinds and the installation of dimmable lights, for example, will allow users to manage or reduce sensory over-stimulation caused by lights. Similarly, we recommend creating soundproofing and sound absorbent materials to reduce background noise and sound levels. We also recommend using neutral or simple colour palettes and restrained use of patterns. Finally, and most importantly, the BE needs to be flexible and adaptable to meet the unique needs of each person. This study provides a starting point for design guidelines and recommendations towards making a difference to the everyday experiences of the interiors of buildings.

Keywords

architecture, design, interior, sensory, space

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The physical environment is a fundamental aspect of the social determinants of health (Marmot et al., 2008) and ensuring access to inclusive public spaces is a key target of the United Nations Sustainable Development Goals (United Nations, 2015). Recently, there has been increasing recognition of the need for the building community to embrace accessible design (Heylighen et al., 2017). However, the difference between accessible design, which usually requires applying minimum standards set by building regulations, codes and policies; and inclusive design, which attempts to create solutions that make the end design as inclusive as possible, is vast (Ormerod & Newton, 2005). The application of accessible, rather than inclusive, design principles has led to a focus on improving accessibility and inclusion for individuals with physical disabilities (Iwarsson & Ståhl, 2003); yet, an exploration of how the BE may be made more inclusive for those with 'invisible' conditions such as autism remains limited.

Autistic[1] individuals commonly experience differences in sensory processing, including hyper- or hyposensitivity to sensory input from their surrounding environment, emanating from factors such as sound, lighting, visual features, temperature, textures, movement and tactile feedback (Robertson & Baron-Cohen, 2017). Divergent sensory processing in parallel with unpredictable environments can amplify stress and anxiety leading autistic individuals to restrict their participation in community-based activities and recreational occupations when compared to their peers (Egilson et al., 2017; Myers et al., 2015). Previous methods aiming to support the participation and functioning of autistic individuals have primarily focused on equipping autistic individuals with the tools to tolerate circumstances they might find uncomfortable. In contrast, altering environmental factors may offer a better solution, allowing for the construction of a more inclusive society that values all members (de Schipper et al., 2015). Indeed, the participation of autistic individuals may be promoted if they are within environments in which they feel comfortable.

An awareness of the impact of the design of the BE on inclusive physical access has led to positive changes in the BE and legislation for new constructions (Baldiga et al., 2017). With this success the design community has now begun to develop approaches, which consider the diversity of human abilities including cognitive capabilities. Currently, the adoption of inclusive design is limited, particularly concerning the BE (Heylighen et al., 2017). Architects and designers are largely unfamiliar with autism inclusive design techniques, and a lack of clear guidance and understanding may contribute to difficulties and uncertainty when attempting to develop inclusive BEs. Recent work undertaken by Tola et al. (2021) explored how BEs impact autistic individuals and identified methods for designing or modifying them to accommodate the needs and differences of autistic individuals according to the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; *DSM*-V) diagnostic criteria. However, additional work is required to understand the experiences and perspectives of autistic individuals themselves about the impact of BEs and strategies to promote inclusion and participation through BEs. Both these bodies of work can then be used to inform evidence-based guidelines for the design of autism inclusive environments. Therefore, this review aims to scope and synthesise the literature examining the internal BE for autistic individuals.

Methods

A scoping review was determined to be the most appropriate approach in fulfilling the aims of this review (Arksey & O'Malley, 2005). This review utilised the methodological framework presented by Arksey and O'Malley (2005) and recommendations by Daudt et al. (2013) and Levac et al. (2010) in identifying the aims and objectives of the review, searching for relevant literature, systematically selecting literature, charting the data, collating, summarising and reporting the results (Arksey & O'Malley, 2005).

Search strategy

Electronic databases were searched to identify literature exploring environments specifically designed for autistic individuals. Searches were conducted for literature published between and including the year 2000 to 2020. Database searches including ProQuest, Web of Science, PsycINFO (Ovid), EMBASE (Ovid) and Google Advanced Search were searched based on recommendations provided by optimal database searches (Bramer et al., 2017). A combination of key terms and Boolean searches were conducted and tailored to each database. Key terms were truncated and grouped into two categories based on the population and design (Appendix A in Supplemental material). Database searches were developed with the assistance of an experienced health science librarian. Following database searches, reference lists of included publications were searched manually to identify relevant literature that was not included in the initial database searches.

Study selection

Studies were included if they (1) included exploration of relevance to autistic individuals; (2) described aspects of the BE, architecture or interior design; and (3) were published in English from the last 20 years. Studies were excluded if they (1) solely described urban or city planning more broadly, such as land-use and infrastructure (e.g. telecommunications); (2) reported equipment prescription or modification; and (3) described social skill development or social competence interventions or outcomes. No limits were placed on cognitive abilities of included participants, co-occurring conditions, age or gender. Authors independently assessed the relevance of the selected articles. Grey

literature was limited to comprehensive reports, theses and conference papers.

Charting the data

Data were gathered from included studies as recommended by Arksey and O'Malley (2005). The descriptive characteristics of each study including the study aim, year of publication, author(s), context or country, level of evidence and outcome measures used were charted (Appendix B).

Assessment of methodological quality

The methodological quality of studies was assessed using the Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields (Kmet et al., 2004). The assessment criteria consist of a checklist of 14 items for quantitative items and 10 items for qualitative studies, which guide calculation of the overall study quality. Study quality is determined by calculated scores, which are categorised as strong (> 80%), good (70%–80%), adequate (50%–69%) or limited (< 50%; Lee et al., 2008).

Collating and summarising the results

Descriptive analysis was used to identify and describe the characteristics of the studies including the aim, objectives, populations, year of publication, context or country, level of evidence and outcome measures used. Content analysis was used to explore BE considerations for autistic individuals.

Stakeholder consultation

To validate the study findings, stakeholder consultation was conducted with autistic adults (n = 2), caregivers of autistic adults (n = 2), and professionals with a background in BE (n = 2; Arksey & O'Malley, 2005). Stakeholders were provided with a summary of the findings (Appendix C in Supplemental material) and engaged in one group consultative discussion whereby stakeholders were provided with the opportunity to discuss and comment on the reviews' findings.

Results

Search results. A total of 1504 records were identified through the electronic searches of EMBASE (k = 138), PsycINFO (k = 101), ProQuest (k = 319), Web of Science (k = 946) and manual searches of Google Advance (k = 2). Following duplicate removal, 1481 articles were retained. The titles and abstracts of these records were screened, resulting in 41 articles being forwarded to full-text review. Twenty-two articles were excluded at full-text review, resulting in 19 articles included from the electronic database searches. An additional 9 articles were subsequently identified through manual reference list checks, resulting in a total of 28 records being included in the review (Figure 1).

Study context

Most studies were carried out in the United States (k = 10), followed by the United Kingdom (k = 4), Malaysia (k = 3) and Egypt (k = 3). Four studies examined multiple contexts across different nations, one study originated each from Canada, India, Belgium and Thailand. The impact of the BE on autistic individuals was examined in a range of environments, including schools (k = 16), homes (k = 5), varied or multiple settings (k = 4), workplaces (k = 1), plazas (k = 1) and vocational centres (k = 1; Appendix B in Supplemental material).

Study design and methodological quality

The majority (k = 15) of studies were qualitative, two studies used quantitative methods, nine studies used both qualitative and quantitative methodologies, two studies were literature reviews and one was a synthesis. Several research articles also included short reviews of the literature as components of their articles (k = 7).

The types of articles ranged from peer-reviewed journal articles to conference papers, reports and grey literature. As such, the assessment of methodological quality ranged from strong (k = 3), good (k = 5), adequate (k = 9) and limited (k = 8; Appendix B in Supplemental material), with three articles not being assessed as they were literature reviews or synthesises. Common limitations identified in the literature included an inadequate description of data analysis and gathering procedures, limited use of verification procedures and limited reflexivity of the account.

Aspects of the BE

Aspects of the BE were described under the following headings: design and construction, light, sound, aesthetics, air quality and temperature. The need for these design principles to be implemented in a flexible and adaptable manner, to meet the individual needs of autistic individuals (Cassidy, 2018; Grancich, 2014; Kanakri et al., 2017; Martin, 2016; McAllister, 2010; Nagib & Williams, 2017) and the way that users interact with them over time (Martin, 2016) was highlighted by several studies.

Design and construction. Aspects of the structural design of buildings were discussed in 26 studies: including layout, walls, building material, entrances and orientation.

Layout. Layout was discussed by 22 studies. Complex layouts, frequent level changes and long corridors were

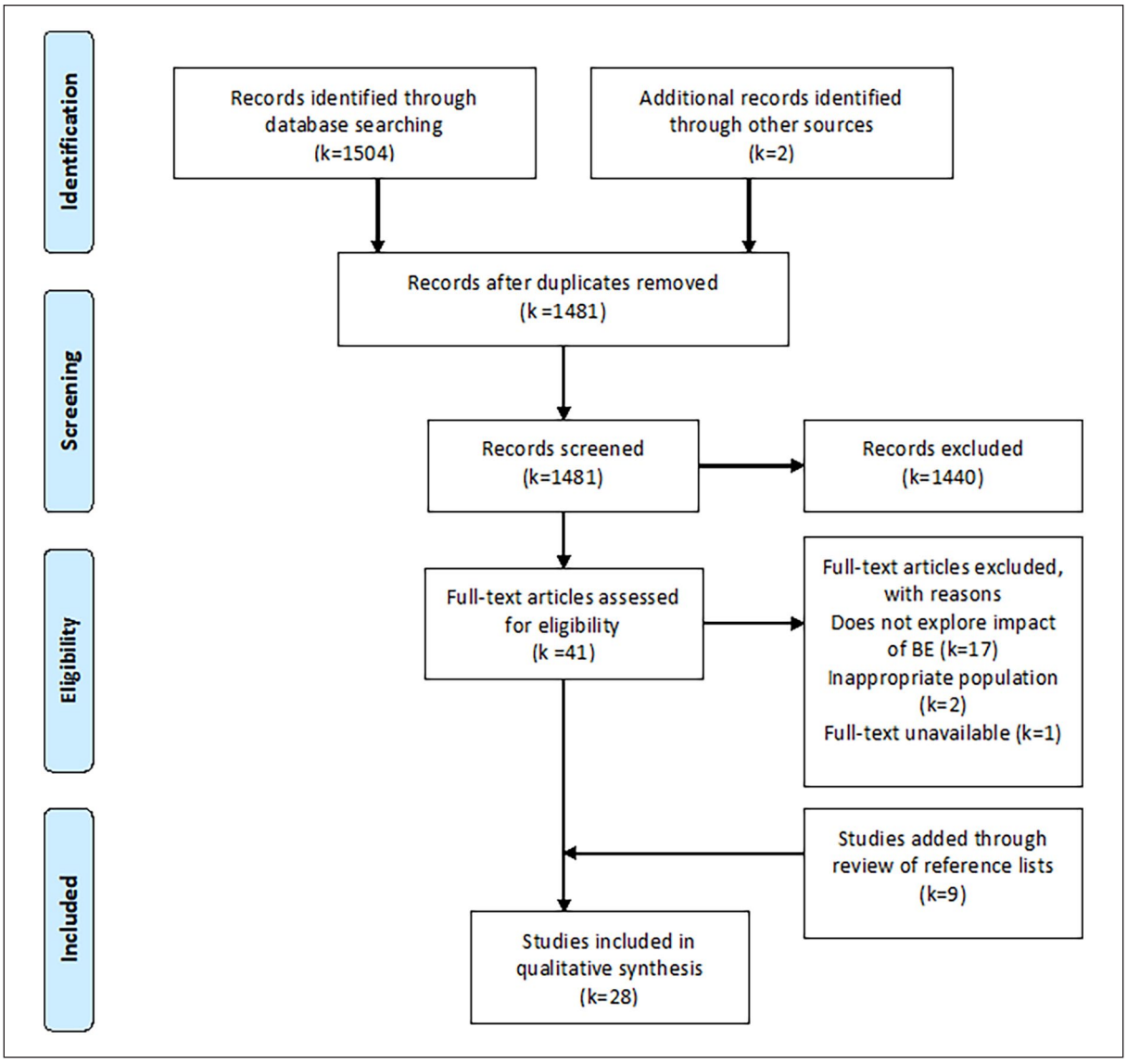

Figure 1. Flow chart of study selection process.

found to contribute to feelings of disorientation and anxiety in autistic individuals (Ahrentzen & Steele, 2009; Altenmüller-Lewis, 2017; Ghazali et al., 2018a, 2019). Easily legible routes (Scott, 2009), one-way or straightforward circulation within spaces and buildings (Grancich, 2014; Martin, 2016; Mostafa, 2008, 2010) and simple organisational layouts (Dival, 2019; Ghazali et al., 2018a, 2019; McAllister & Sloan, 2016; Scott, 2009) were suggested to support wayfinding. In circulation spaces, sudden corners, blind corners and abrupt transitions were reported to contribute to unpredictability for autistic individuals (Ahrentzen & Steele, 2009; Grancich, 2014). Within the one-way circulation space, it was recommended to organise areas and rooms in a sequential manner that reflect the user's daily routine (Mostafa, 2010).

Compartmentalising areas into clearly defined zones or clear boundaries were suggested (Manchala, 2014; Martin, 2016; Mostafa, 2008; Nagib & Williams, 2017). Spatial sequencing was reported as a way to group odours. For example, grouping pools, kitchens and dining areas together is a way to reduce odours in learning areas (Ghazali et al., 2019; Manchala, 2014). Smaller spaces were suggested to reduce potential distractions within a space (Ghazali, 2018a). However, contradictory research encouraged avoiding narrow spaces and secluded areas as these can cause children to feel isolated (Grancich, 2014; Martin, 2016).

Autistic children tend to find large schools disorienting and frightening (Ghazali et al., 2018b, 2019; Scott, 2009) with further research suggesting that open-plan multifunctional spaces are unfavourable (Mostafa, 2006), especially in classroom settings (Kanakri, 2014). Areas used for socialising were recommended to have ample space to reduce feelings of crowdedness (Clouse et al., 2020;

Kinnaer et al., 2016; Nagib & Williams, 2017). Larger areas for personal space (Grancich, 2014; Manchala, 2014; Nagib & Williams, 2017; Scott, 2009; Tufvesson & Tufvesson, 2009) and adequate space for support staff to assist a child in circulation spaces in school settings (Grancich, 2014; Martin, 2016; McAllister & Sloan, 2016) were recommended. In school settings, transition spaces to prepare children for the change in their school environment were also recommended (Ghazali et al., 2018a, 2019; McAllister, 2010; Scott, 2009). Scott (2009) suggests using a combination of open-plan and confined spaces to accommodate all needs.

Seventeen studies recommend the use of withdrawal spaces or sensory rooms (Ahrentzen & Steele, 2009; Altenmüller-Lewis, 2017; Clouse et al., 2020; Gaines et al., 2014; Ghazali et al., 2018b; Grancich, 2014; Kinnaer et al., 2016; Manchala, 2014; Martin, 2016; McAllister, 2010; McAllister & Sloan, 2016; Mostafa, 2006, 2008, 2010; Nagib & Williams, 2017; Scott, 2009; Williams & Vouchilas, 2013). These rooms were discussed as a means of supporting behaviour so that children do not feel overwhelmed, tired and distressed (Gaines et al., 2014; Ghazali et al., 2018a). Ahrentzen and Steele (2009) state that withdrawal spaces should have a defined sense of enclosure to promote feelings of safety and security. These spaces should be low stimulation or free of sensory stimuli to avoid over-stimulation (Ahrentzen & Steele, 2009; Altenmüller-Lewis, 2017; Clouse et al., 2020; Grancich, 2014; Kinnaer et al., 2016; Manchala, 2014; Martin, 2016; McAllister, 2010; McAllister & Sloan, 2016; Mostafa, 2006, 2008, 2010; Nagib & Williams, 2017; Scott, 2009; Williams & Vouchilas, 2013).

Walls. Wall design was discussed in 17 articles where findings supported the use of half walls and curved walls to create visible boundaries, prevent abrupt circulation spaces and to aid wayfinding (Ahrentzen & Steele, 2009; Ghazali et al., 2018a; Gopal & Raghavan, 2018; Grancich, 2014; Kinnaer et al., 2016; Manchala, 2014; Martin, 2016). The use of bevelled wall corners instead of sharp corners was also recommended to protect and reduce the likelihood of injury in individuals who may have higher support needs (Clouse et al., 2020; Manchala, 2014; McAllister, 2010; McAllister & Sloan, 2016).

Building material. Building materials were discussed by 12 studies. Building materials should be easily cleaned (Clouse et al., 2020) and free of toxic substances, should not emit chemicals or gases or hold dust to reduce unnecessary sensory stimuli (Kinnaer et al., 2016). Suggested materials include cork, cotton, porcelain and other natural materials as they may provide a calming effect (Altenmüller-Lewis, 2017; Clouse et al., 2020). Non-slip vinyl floor coverings were encouraged by Ghazali et al. (2019). Several studies discuss the importance of using durable materials to reduce damage caused by behaviours of concern and to promote safety (Ahrentzen & Steele, 2009; Clouse et al., 2020; Kinnaer et al., 2016; Scott, 2009). This includes fortified windows, durable wall paint and brick walls with impact-resistant plasterboard (Kinnaer et al., 2016).

Ceilings. Ceiling height was discussed by four studies, with lower ceilings found to increase feelings of calm and comfort (Manchala, 2014; Martin, 2016), while higher ceilings were suggested to be most appropriate for active, high energy areas (Martin, 2016). Dival (2019) recommended adopting various ceiling heights in separate spaces to create a sense of safety, while Clouse et al. (2020) specifically recommended a ceiling height of 9 feet to prevent against damage and harm in individuals with higher support needs.

Entrances. Building entrances were examined in two studies, suggesting that multiple entrances and exits assisted in reducing noise levels and socio-sensory barriers to activity and participation for autistic people (Clouse et al., 2020; Ghazali et al., 2019).

Orientation. Building orientation was explored in one study, suggesting that external landscape views for hypersensitive autistic people and echoic city views for hyposensitive autistic people in the workplace may be beneficial (Cassidy, 2018). Cassidy (2018) further recommends placing hypersensitive workers on the upper levels of a building, and hyposensitive workers on lower levels, with intermediate levels acting as a buffer to environmental noise.

Lighting. Light was explored in 23 studies. These studies explore the intensity, quality and other factors including the type of lighting fixtures or placement of lighting sources.

Light intensity. Lighting intensity was investigated in 17 articles, with recognition that sensitivity to intensity and brightness is common among autistic individuals, impacting on mood and arousal (Nagib & Williams, 2017; Shabha & Gaines, 2013). While reducing high-intensity lighting was suggested as preventing over-stimulation (Nagib & Williams, 2017; Shabha & Gaines, 2013), low-intensity lighting was seen as disruptive to autistic individuals with hyposensitivity to light (Nagib & Williams, 2017). Three studies recommended using lower-level lighting in schools and plazas (Gaines et al., 2014; Grancich, 2014; Mostafa, 2010); however, a further 11 articles recommend using dimmable or flexibly controllable lighting to meet the various needs of autistic individuals (Ahrentzen & Steele, 2009; Altenmüller-Lewis, 2017; Clouse et al., 2020; Davidson, 2010; Gaines et al., 2014; Ghazali et al., 2018b; Gopal & Raghavan, 2018; Martin, 2016; McAllister, 2010; Mostafa, 2010).

Light quality. A total of nine articles suggested avoiding artificial lighting, specifically fluorescent lighting, given the flickering can cause problematic behaviours, visual disruption and auditory disruption in autistic people (Ahrentzen & Steele, 2009; Davidson, 2010; Gaines et al., 2014; Ghazali et al., 2018b, 2019; Gopal & Raghavan, 2018; Grancich, 2014; Manchala, 2014; Nagib & Williams, 2017). Some studies suggested that if artificial lighting is to be used, it should be incandescent full-spectrum artificial light as it improves the behaviour of children, increases concentration and alertness and creates a more accessible environment (Davidson, 2010; Gaines et al., 2014; Shabha & Gaines, 2013; Williams & Vouchilas, 2013). Natural light was discussed in 11 articles, with recommendations favouring the use of natural, diffuse indirect light (Ahrentzen & Steele, 2009; Altenmüller-Lewis, 2017; Clouse et al., 2020; Gaines et al., 2014; Ghazali et al., 2019; Grancich, 2014; Manchala, 2014; McAllister, 2010; Mostafa, 2010; Nagib & Williams, 2017; Scott, 2009; Shabha & Gaines, 2013). Suggestions were also made supporting the use of natural light in conjunction with artificial non-fluorescent lighting (Manchala, 2014; Martin, 2016). Four studies stated that bright, direct lighting and glare were disruptive (Altenmüller-Lewis, 2017; Ghazali et al., 2018a, 2019; Tufvesson & Tufvesson, 2009) suggesting that adjustable window shades be used to control incoming natural light (Gaines et al., 2014; Ghazali et al., 2018a; Martin, 2016). While Gaines et al. (2014) promoted avoiding overhead lighting to avoid shadows, three articles advocated the use of overhead lighting to reduce the likelihood of glare (Ahrentzen & Steele, 2009; Clouse et al., 2020; Grancich, 2014). Pelmet lighting was suggested as an optimal method of providing artificial indirect, overhead lighting (Ghazali et al., 2018a). Martin (2016), Grancich (2014) and Scott (2009) encouraged the use of clerestory or above-eye-level windows to allow natural light while reducing the potential distraction from objects seen through a typical eye-level window.

Light fixtures. Five studies considered specific light fixtures. Hidden and pelmet lighting, where the light source is not visible was suggested to decrease distraction (Ghazali et al., 2018a; Manchala, 2014), while lamps that reflect upwards, as opposed to overhead lighting, were suggested to create less visual distortion and allow for task spotlighting (Clouse et al., 2020; Davidson, 2010; Gaines et al., 2014). Three studies considered light as a means of providing contrast or variance to provide adequate visual arousal and shape or place compartmentalisation (Clouse et al., 2020; Ghazali et al., 2018b; Gopal & Raghavan, 2018).

Sound. Sound was discussed in 24 studies, with the majority recognising that autistic individuals can be hypersensitive or hyposensitive to sounds leading to sensory overload, changes in temperament and reduced attention (Altenmüller-Lewis, 2017; Ghazali et al., 2018a; Gopal & Raghavan, 2018; Grancich, 2014; Kanakri et al., 2017; Manchala, 2014; Martin, 2016; McAllister, 2010; McAllister & Sloan, 2016; Mostafa, 2006; Nagib & Williams, 2017; Williams & Vouchilas, 2013).

Sound intensity. A total of 15 studies explored autistic individuals' sensitivity to noise and the need for low noise levels (Ghazali et al., 2018b, 2019; Grancich, 2014; Kanakri et al., 2017; McAllister & Sloan, 2016; Nagib & Williams, 2017; Williams & Vouchilas, 2013). Measurement of sound intensity thresholds, as they related to autistic individuals' experiences, behaviour, activity or participation were discussed in two articles (Kanakri, 2014; Kanakri et al., 2017). While an initial study found noise levels above 69 dB correlated with repetitive speech and hitting behaviour (Kanakri, 2014), a subsequent study recommended that average sound level to be kept at 50 dB or below (Kanakri et al., 2017).

Spatial sequencing was suggested as a technique to minimise sound transmission between spaces. Research findings support zoning rooms together according to sound levels and using transitional spaces or buffers, such as additional rooms or hallways, to reduce noise transmission (Dival, 2019; Kanakri et al., 2017; McAllister, 2010; Mostafa, 2006). Findings suggest cavity wall systems with soundproofing, acoustic panelling and sound reflection to be effective in filtering external noise (Kanakri et al., 2017; Mostafa, 2006, 2008, 2010; Nagib & Williams, 2017). In contrast, thick concrete walls with hard plaster finishes are recommended to minimise sound transmission (Dival, 2019). Open plan classroom layouts reportedly increase noise levels and subsequent distractions (Kanakri, 2014) with doors between larger common areas recommended as a strategy in reducing sound transmission (Williams & Vouchilas, 2013), although Mostafa (2010) suggested that the size and number of doors should be reduced as a means of decreasing noise levels

Sound quality. Sound quality was explored by 17 studies. Studies found appliances such as air conditioning units, heaters, ventilation fans, fluorescent lighting and other domestic appliances can produce disruptive noise (Ahrentzen & Steele, 2009; Davidson, 2010; Kanakri, 2014; Kanakri et al., 2017; McAllister, 2010; Mostafa, 2006, 2010; Shabha & Gaines, 2013). Studies suggested using underfloor heating to reduce the noise from heaters (Kanakri et al., 2017; Martin, 2016).

Sound from external sources, such as passing cars, adjacent rooms, rain, plumbing and general background noise, were invasive and should be minimised (Clouse et al., 2020; Davidson, 2010; Grancich, 2014; McAllister, 2010; Nagib & Williams, 2017; Shabha & Gaines, 2013). Findings supported sound dampening methods to control

noise, including acoustic tiles with a high noise reduction coefficient (NRC) in high noise-producing areas, carpeting on floors and other non-reflective sound absorbent materials on walls and ceilings (Dival, 2019; Ghazali et al., 2018a, 2019; Kanakri, 2014; Martin, 2016; Mostafa, 2010; Nagib & Williams, 2017; Williams & Vouchilas, 2013). Window coverings, such as draperies and curtains can minimise noise from external sources (Martin, 2016; Mostafa, 2010) with double-paned (Williams & Vouchilas, 2013) or triple-glazed windows (Mostafa, 2010) effectively reducing external noise levels.

It was suggested that unnecessary echoes, reverberation and noise intensity should be reduced to improve attention spans, response times and behavioural temperament in autistic individuals (Altenmüller-Lewis, 2017; Grancich, 2014; Kanakri et al., 2017). Kanakri et al. (2017) provided specific recommendations to maintain average noise levels at or below 50 dB. Reducing reverberation by utilising soft materials throughout the building was recommended (Altenmüller-Lewis, 2017; Clouse et al., 2020; Dival, 2019; Kinnaer et al., 2016).

Aesthetics. Aesthetics were explored in 19 articles, which discussed the use of pattern, windows, colour, texture and clutter.

Patterns. Patterns were discussed in 10 studies. Complex, bold and geometric aesthetic patterning were largely not advised as autistic individuals may have difficulty processing these patterns (Davidson, 2010; Gaines et al., 2014; Ghazali et al., 2018b; Grancich, 2014; McAllister, 2010; Shabha & Gaines, 2013; Williams & Vouchilas, 2013). Examples of these included stripes on radiators, grills and light diffusers (Shabha & Gaines, 2013). Instead, autistic individuals found simpler aesthetics more pleasurable (Grancich, 2014; Manchala, 2014; Martin, 2016; McAllister, 2010; Scott, 2009).

Windows. For some individuals, windows were distracting given their view to the outside rain, wind, traffic and falling leaves (Gaines et al., 2014; Nagib & Williams, 2017). Some research suggested the use of clerestory, above-eye-level windows or lower half window coverings, to minimise external visual distractions (Gaines et al., 2014; Ghazali et al., 2018b, 2019). Skylights provide natural light, but shadows may complicate the visual environment (Manchala, 2014).

Clutter. Six studies suggested reducing distractions, visual clutter and physical clutter within a space (Ahrentzen & Steele, 2009; Manchala, 2014; Martin, 2016; Nagib & Williams, 2017; Shabha & Gaines, 2013; Williams & Vouchilas, 2013), with Mostafa (2008) stating that clutter can cause undesirable behaviours for students in classrooms.

Colour. Fourteen studies considered the impact of colour on how autistic individuals interact with the BE (Ahrentzen & Steele, 2009; Altenmüller-Lewis, 2017; Davidson, 2010; Dival, 2019; Ghazali et al., 2018a, 2019; Gopal & Raghavan, 2018; Grancich, 2014; Kinnaer et al., 2016; Manchala, 2014; Mostafa, 2010; Scott, 2009; Shabha & Gaines, 2013; Williams & Vouchilas, 2013). Ten studies recommended the use of mild, low contrast and low arousal colours on walls, floors and ceilings; such as pastel shades, subdued or natural colours (Altenmüller-Lewis, 2017; Dival, 2019; Gaines et al., 2014; Ghazali et al., 2018b; Grancich, 2014; Manchala, 2014; Mostafa, 2010; Scott, 2009; Shabha & Gaines, 2013; Williams & Vouchilas, 2013). Five studies recommended against using bright colours, shiny or reflective surfaces (Ahrentzen & Steele, 2009; Altenmüller-Lewis, 2017; Ghazali et al., 2018b; Manchala, 2014; Nagib & Williams, 2017).

Seven studies discuss the use of distinct or contrasting colours (Davidson, 2010; Gaines et al., 2014; Gopal & Raghavan, 2018; Grancich, 2014; Kinnaer et al., 2016; Manchala, 2014; Martin, 2016). Of these, four recommend the use of distinct colours for colour coding and visual perception (Davidson, 2010; Gopal & Raghavan, 2018; Kinnaer et al., 2016; Manchala, 2014). Two studies recommend avoiding complexity in colour palette (Gaines et al., 2014; Martin, 2016) and it was reported that bright colours may be particularly disruptive for autistic individuals with co-occurring intellectual disabilities (Gaines et al., 2014). However, contrasting colours were shown to improve figure–ground perception (Gopal & Raghavan, 2018). Autistic students prefer soft and natural colours, such as blue and green, while others were attracted to red and orange (Gaines et al., 2014). Light blue was recommended as the most appropriate colour for classrooms (Ghazali et al., 2019), while Scott (2009) recommended the use of light green in entrances for a calming effect. Colour-coding specific areas into distinct zones were also found to aid navigation and wayfinding (Davidson, 2010; Kinnaer et al., 2016).

Texture. Texture was discussed by five studies. Sensitivity to textures was detailed in an autobiography that stated: 'Even the lightest touch can feel like an open wound or getting an electric shock' (Davidson, 2010, p. 309). A second study stated 'Depending on a child's particular sensitivity to a texture, some could experience an emotional meltdown, or aggressively rub and scratch a spot that came in direct contact with a particular textured surface' (Williams & Vouchilas, 2013, p. 35). Findings suggest soft textures are preferred, such as carpeting (Kanakri et al., 2017; Williams & Vouchilas, 2013). A balance of smooth and rough textures is encouraged (Mostafa, 2010) acknowledging that appropriate textures depend on the individual autistic person's sensitivities (Mostafa, 2010). Specific recommendations against using high shine or polished

tiles in favour of matte-finished flooring were reported by Manchala (2014).

Indoor air quality. Ten studies consider the environmental factor, indoor air quality. It was reported that autistic individuals can be sensitive to strong odours, which can cause discomfort, and as a result should be avoided (Ghazali et al., 2018b; McAllister & Sloan, 2016; Mostafa, 2010; Nagib & Williams, 2017; Williams & Vouchilas, 2013). The majority of the studies discuss methods for reducing odours (Ahrentzen & Steele, 2009; Ghazali et al., 2018b, 2019; Gopal & Raghavan, 2018; Manchala, 2014; McAllister & Sloan, 2016; Mostafa, 2010; Nagib & Williams, 2017; Williams & Vouchilas, 2013), including the use of ventilation and airflow (Gopal & Raghavan, 2018; Mostafa, 2010), special sequencing (Ghazali et al., 2019; Manchala, 2014) and plastic blinds (Ahrentzen & Steele, 2009) to reduce strong smells and odour build-up. One study recommended a ventilation standard of around 40 cubic feet per minute per occupant and carbon filters for the removal of particulate matter (Clouse et al., 2020).

Temperature. Nagib and Williams (2017) highlighted autistic individuals sensitivity to heat and cold, with six studies recommending providing effective heating, ventilation and air conditioning to enable temperature regulation (Clouse et al., 2020; Dival, 2019; Kanakri et al., 2017; Kanakri, 2014; Noiprawat & Sahachaisaeree, 2012; Scott, 2009). Studies discussed the need for adequate heating and cooling systems to provide for consistent temperature control (Clouse et al., 2020; Dival, 2019; Gopal & Raghavan, 2018; Kanakri et al., 2017; Kanakri, 2014; Nagib & Williams, 2017; Noiprawat & Sahachaisaeree, 2012; Scott, 2009). Specific suggestions were made to manage airflow and temperature; including using underfloor heating to provide consistent ambient temperatures (Dival, 2019).

Stakeholder consultation

Stakeholders' feedback validated the findings from the literature, with none of the results conflicting with their experiences. However, it was raised that some findings (such as a withdrawal space) while useful, may be impractical to implement in specific settings, particularly those where it may be difficult to filter or control those entering the space. Stakeholders also stressed that while some basic features should always be in place where practicable, BEs should be flexible to accommodate the range of sensory needs of autistic individuals.

Discussion

This scoping review has described the internal BE considerations for autistic individuals. While cumulatively, there is promising evidence for changes to the BE, which can make spaces more accommodating for autistic individuals, it is apparent that research is in its infancy and requires further investigation. Findings from this review highlight several BE factors that may be adapted to enable the functioning of autistic people, with key factors including design and construction, light, sound, indoor air quality, temperature and aesthetics found to be important considerations. Findings from this review expand beyond the results of Tola et al. (2021) by examining an additional 20 sources. Thirteen sources included in the study by Tola et al. (2021) were excluded from this review as they did not include the perspectives of autistic individuals (k = 10), did not discuss BEs (k = 1), were not written in English (k = 1) and the full text was not available (k = 1).

Due to the diverse nature of autism characteristics inherent in this spectrum condition, there are challenges in developing 'one size fits all' design recommendations. While these design considerations may provide guidance when designing BEs for autistic individuals, it is important to consider that the experiences of autistic individuals are incredibly broad and unique, and it is likely that there may be those whom these design principles may not apply. For the BE to positively impact autistic individuals, designers must allow for flexibility in BE design, and are urged to consider incorporating the recommendations found in this review, with emphasis placed on maintaining adaptability and user-controlled modification.

For any environment to be truly inclusive, it is essential that those accessing the environment be provided with the opportunity to provide input on its design. Co-design involves including stakeholders, such as those who will use the environment, in the design process. In this way, stakeholders are collaborators, informing the decision-making process and ensuring that the built design meets their needs (Sanders & Stappers, 2008). New methods of co-design are increasingly being developed. Examples include a photo-narrative approach, which has been used to co-design environments for older adults with mild cognitive impairment (Aflatoony et al., 2020). Gaudion (2015) has also presented potential tools to support the participation of autistic individuals with additional support needs in the design process.

While some of the considerations may involve large-scale structural changes, which may only be feasible to address in new constructions, other recommendations involve changes, which may reasonably be achieved by altering or renovating existing buildings. Removing visual clutter, changing lightbulbs or light fittings, changing colours, re-arranging how spaces are furnished and therefore how they are used, adding materials and products that absorb sound and re-thinking zoning of spatial programming are all reasonably affordable changes, which can be easily implemented, and yet can make a positive difference to ways in which autistic individuals are able to participate with less stress.

Given the sensory atypicalities commonly observed in autistic individuals, it is perhaps not surprising that many of the recommendations relate to the reduction of sensory stimulation. The majority of articles examined the reduction of sound and the limitation of background sound and echo. For hypersensitive individuals, increased sound intensity and background and unexpected sounds can be over-amplified, leading to distraction, stress and anxiety (Altenmüller-Lewis, 2017; Kanakri, 2014). For hypo-sensitive individuals, although often preferring louder sound intensity, background noise can be a barrier to sound discrimination and localisation (Ghanizadeh, 2009), and echo can promote loud noise self-stimulation, which may be disruptive to other users (Mostafa, 2008). Sound intensity and background noise can be reduced by decreasing the size and scale of rooms, and utilising sound absorbing and insulating building materials and wall treatments (Kanakri et al., 2017; Mostafa, 2006, 2008, 2010; Nagib & Williams, 2017). Broadly, lighting can be optimised by providing indirect natural light and avoiding fluorescent lighting (Ahrentzen & Steele, 2009; Altenmüller-Lewis, 2017). Although not discussed in the studies included in this review, over-stimulation from sensory processing can also place an additional load on cognitive processing resources (Marco et al., 2011), which may contribute additional difficulties in navigating ones' environment.

Visual aesthetics included the use of colour, minimising patterns and visual clutter, adopting neutral colour palettes, simplicity in design and limiting visual clutter. Simplicity should be considered during the selection of all elements of the BE. While many less obvious features (for example, stripes on a radiator) are overlooked by neurotypical users, they may pose a distraction to autistic individuals highlighting the need for collaboration with autistic individuals in designing inclusive BE (Davidson, 2010; Kinnaer et al., 2016). While most studies advocated for a neutral colour palette, contrasting colours was discussed as a means of 'colour coding' distinct areas and as enhancing the delineation between the wall and floor in the presence of visual perception difficulties (Davidson, 2010; Gopal & Raghavan, 2018; Kinnaer et al., 2016; Manchala, 2014).

Given the fast-paced nature of design and material development, designers, architects, and builders must also be mindful of new developments in the area. For example, while incandescent lighting was recommended by the literature presented in this review, light emitting diode (LED) lighting may present an alternative with additional properties including being directional, smaller and more energy efficient compared to incandescent lights, with the ability to generate a wide range of colours (Stouchlighting LED Lighting Solutions, n.a.). Similarly, the use of non-slip vinyl and carpeted flooring were recommended by some studies; however, it should be noted that these materials may contain toxins and carry health risks (Kraus & Senitkova, 2020), therefore alternatives should be considered.

The most-reported structural recommendations were the addition of withdrawal spaces or sensory rooms. These may facilitate the functioning of autistic people by allowing for withdrawal from environments that trigger sensory overload. However, as many of these studies were in school settings with child participants, it is uncertain whether this recommendation can be generalised. Building layout emerged as important in enabling straight-forward circulation and promoting sequential organisation of daily routines. While this poses significant challenges when designing buildings for larger populations, customisation was seen as key in designing BE (Cassidy, 2018). The significance of the impact of BE on autistic individuals functioning compared to neurotypical users, was highlighted in research demonstrating the impact of room size on increasing engagement in high- or low-energy activities (Mostafa, 2006; Scott, 2009), a factor generally disregarded by neurotypical users. While evidence suggests that proximity to nature, such as trees and plants are beneficial to autistic individuals (Bolten & Barbiero, 2020), to date, no study has examined access to nature in BE.

Implications for practice

Understanding the impact of BE factors in facilitating the functioning of autistic individuals has far-reaching consequences. However, in the early stages of research, BE factors are emerging. Recommendations from this review should be considered by architects, designers and builders and clinical practitioners alike.

For architects and designers, this review offers a document that can be referred to during both new builds and renovations of existing buildings. While considering these design principles, it is essential to also consider the purpose of the rooms and how design aspects may interact. For example, changing the ceiling height may also affect acoustics and lighting, reflectance and a sense of enclosure within the room. Failure to recognise the holistic nature of design may have undesirable consequences on the functionality and inclusive of the BE.

A clear recommendation from this review is the requirement to consult with and include autistic individuals directly in the design of BEs. Research in the United Kingdom has suggested that for those with additional support needs, it may be beneficial to additionally consult with others that may be influenced by the BE, such as residential support staff (Gaudion, 2015). Many of the recommendations offer simple changes to the design that can have wide-ranging positive impacts for autistic individuals. These results can be reasonably extrapolated to other neurodiverse populations, for example, individuals with attention deficit hyperactive disorder or sensory processing disorder. Indeed, accessible and inclusive design is beneficial for all individuals (de Schipper et al., 2015). A limitation of previous research has been the recommendation of changes that

are unrealistic or unviable due to prohibitive costs or green-building policy. To combat this, it is recommended that further research be undertaken, and policy change made to balance environmental and financial costs with the impact on individual functioning.

For clinical practitioners, this review offers an insight into the significant impact that environmental factors may have on their autistic clients. Findings suggest clients should be consulted and provided with mechanisms to customise their individual preferences. Generally, shared spaces such as clinics can be designed to facilitate the hypersensitive user with individual therapy spaces adapted to those with other sensory preferences. Clinical practitioners may use this review as a basis for conversations with clients about their BE preferences and enable simple low cost changes. This review may also be used by designers as evidence for change in settings, such as learning environments, residential settings, workplaces and healthcare facilities.

Recommendations for future research

While this review analysed and collated existing research, there remains significant gaps in the evidence available on this topic. Autism by definition is a spectrum condition (American Psychiatric Association, 2013) challenging the ability to accommodate the unique needs of numerous autistic individuals in a single BE context. Some research in the United Kingdom has explored how individuals with additional needs may be supported to be involved in the design process providing tools, which may facilitate participation in the design process (Gaudion, 2015). Further co-produced research into the breadth of the experiences and perspective of autistic individuals is needed. Advances in personalised technologies (enabling individuals to control and tailor aspects of their environment) and new building materials need to be studied. Ultimately, this agenda could inform the development of evidence-based building guidelines promoting the inclusion and accommodation of autistic individuals in BEs.

Limitations

There are several limitations related to this scoping review. Only English language literature was included in this review limiting diversity of the study contexts. Most of the research explored the BE of schools and homes, with little research being conducted in hospitals, shopping centres and workplaces among many others, limiting the diversity of research regarding the BE settings. A significant portion of included studies did not include the first-hand experiences of autistic individuals, rather they sought the opinions and experiences of other individuals, such as caregivers or clinicians, making it difficult to ascertain the accuracy of these accounts.

Conclusion

This review comprehensively synthesised the literature exploring BE considerations for autism. The BE principles explored in this review can both positively and negatively impact engagement in everyday life activities. The findings of this scoping review inform future research, evidence-based practice and the development of future autism-friendly building standards. A further understanding of the wide array of autistic experiences from the perspective of autistic people themselves is crucial in developing accurate guidelines for inclusive design. Ultimately, to meet the unique needs of each autistic individual, the BE must be designed for flexibility to allow the user to adapt and create their own environment.

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Supplemental material

Supplemental material for this article is available online.

Note

1. Autistic is used throughout as this preferred terminology of the autistic community, acknowledging that many autistic individuals view autism as an inherent and important part of their identity.

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