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The impact of IEQ factors on people on the autism spectrum

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Abstract: This study is an exploratory investigation into whether differences in sensory processing impact the way people on the autism spectrum perceive the built environment, focusing on the effects of individual indoor environment quality (IEQ) factors. Adults on the autism spectrum (n=83) and neurotypical control adults (n=134) participated in an anonymous online survey and were asked about their home and workplace environments, experiences of the general built environment, and general sensory sensitivity. Autistic participants, who reported significantly higher sensory processing scores than control participants, consistently reported significantly higher discomfort due to IEQ factors in both their home and workplace, as well as a greater cause for avoidance of buildings in the wider built environment. While the control group indicated that thermal comfort had the greatest effects on them, the Autistic group was more concerned with people, noise and artificial lighting based factors. These results indicate a need for further research into how and why some IEQ factors have a greater effect on people on the autism spectrum to be able to suggest solutions to create a more accessible built environment. Improving IEQ for the most sensitive of the population is likely to improve the built environment for all users.

Keywords: Indoor environment quality (IEQ); autism; discomfort, avoidance.

1. INTRODUCTION

In New Zealand, 24% of the population identifies as having a disability of some kind (Statistics NZ, 2014). While the New Zealand Building Code (NZBC) outlines the importance of a built environment that is accessible to people of all abilities and function, there is often a large gap between these intentions and the current built environment. Accessibility is one of the eight outcomes specified in the New Zealand Disability Strategy as a priority for change in 2016-2026 (Office for Disability Issues, 2016).

This paper reports on the first survey of a sample of New Zealanders, including those on the autism spectrum, to evaluate how they respond to various aspects of the built environment. The analysis reported here deals with individual Indoor Environmental Quality (IEQ) factors, such as lighting, acoustics and thermal comfort.

1.1 Indoor Environment Quality (IEQ)

Exposure to poor IEQ can cause both short and long term effects, with links made to Sick Building Syndrome, mental health effects, allergies and asthma, and long-term illnesses (Bluyssen and Cox, 2002; Fisk, 2002). The indoor environment also affects the productivity of occupants, with Wyon & Wargocki (2013) reporting the reduction in productivity due to poor IEQ could be up to 5% in the lab and 10% in the field for adults, and could be over 20% for children in schools. Most studies of IEQ assess occupant comfort, well-being, and productivity in office work spaces, and not on the wider built environment, and therefore often only deal with the experiences of the working general population.

In their review of 303 studies of IEQ and productivity in office spaces, Al Horr et al. (2016) identified that thermal comfort, indoor air quality, layout and noise had the most significant effect on productivity. Similarly, Wargocki et al. (2012) analysed 10 years of data from the online CBE survey (see "2.1 Survey") and found that higher satisfaction with temperature resulted in the greatest improvement in self-estimated job performance, followed by noise and air quality. In an analysis on the data from 177 UK buildings from the Building Use Studies (BUS) survey, Leaman & Bordass (2007) found, in order of priority of importance to indoor environment satisfaction, temperature caused the greatest effect, followed by ventilation, lighting, then noise IEQ factors. Liebl et al. (2012) linked background noise that was of high intelligibility to a decrease in cognitive performance.

1.2 The autism spectrum

The autism spectrum is a neurodevelopmental condition that affects social skills and communication, as well as patterns of restricted and repetitive behaviour. A person without autism or any other neurodevelopmental condition is often referred to as 'neurotypical'; their brain has developed in a typical fashion ('normal' as a descriptor is avoided). Throughout this paper, the terms "Autistic" or "on the autism spectrum" are used to describe people on the autism spectrum, as these are the descriptors known to generally be preferred by the Autistic community (Kenny et al., 2016).

Autism is estimated to affect 1 in 66 people in New Zealand, based on American research, with a ratio of 4:1 male to female (Autism New Zealand, 2015). The estimate of incidence has been increasing over the past half century, though there is debate as to whether this is due to changes in diagnostic criteria picking up more people, a true increase in incidence due to environmental or other factor, or combination of the two. Approximately two thirds do not have an intellectual impairment, and approximately three quarters use verbal communication. In 2016 in the UK, only 16% of autistic adults were in full-time employment, with only 32% in any kind of paid employment (The National Autistic Society, 2016a).

1.2.1 Sensory Processing

Differences in sensory processing are now widely recognised among people on the autism spectrum, being part of the diagnostic criteria for ASD in the most recent revision of the diagnostic manual. These differences are observed in autistic people at all ages, and are not dependent on intellectual ability (Crane et al., 2009; Leekham et al., 2007; Minshew and Hobson, 2008; Tavassoli et al., 2014).

These sensory differences mean that the threshold for sensory overload is lower in people on the autism spectrum than in the general population. For example, while a nearby jet engine is likely to get a strong reaction from most people in the general population, for a person on the autism spectrum the same reaction could be caused by ordinary everyday noises, such as the hand dryer in a bathroom. In children, sensory overload is often seen as a meltdown or behavioural difficulties (The National Autistic Society, 2016b). In adults, who have often learned to manage their visible reactions, such noises (or other stimulus) can still cause hidden distress, anxiety and even pain.

1.3 Autism-friendly design

Despite there being extensive research into the differences in sensory processing in people on the autism spectrum, and extensive research into the effects of the indoor environment on the general population, there is limited systematic research that bridges these two areas. Design guidelines have been developed to create "autism-friendly" buildings, however these are often highly specific and are primarily used in specialist schools and residential centres for children on the autism spectrum who have very high support needs (Beaver, 2010; Humphreys, 2005; Vogel, 2008). Allowances for sensory processing difficulties are specified in all design guidelines, though to different degrees.

In the IEQ literature, lighting has often been assessed as a lower priority than other indoor environment qualities. However, in most of the autism-friendly design guidelines, there are some common specifics that regularly appear, including reduction of glare and avoidance of fluorescent lights due to flicker (Beaver, 2010; Hewitt et al., 2009; Humphreys, 2005). In early experimental studies, there was an observed increase in repetitive behaviours under fluorescent lights in children on the autism spectrum (Colman et al., 1976; Fenton and Penney, 1985). Acoustic consideration is also regularly specified in autism-friendly design guidelines, including the reduction of background noise, consideration of materials, and reduction in reverberation time (Beaver, 2010; Hewitt et al., 2009; Humphreys, 2005; Mostafa, 2008).

This study focuses on identifying issues that are currently faced in the built environment by adults on the autism spectrum. As IEQ literature primarily focuses on office environments, and autism-friendly design primarily focuses on educational settings, both areas of research largely overlook the wider built environment that is used by all people day-to-day. This is an exploratory study to identify specific areas of IEQ in need of further research to improve the built environment to meet the needs of all users.

2. METHOD

Participants completed a 15-20 minute long anonymous online survey regarding their perception of the indoor environment of their home, workplace, and the wider built environment. This included questions on discomfort, distress and avoidance, the effects of different IEQ factors, and their general sensory sensitivity. For this paper, the focus is on the survey sections regarding individual IEQ factors.

2.1 Survey

The survey for this project was based upon the two largest IEQ surveys used worldwide, the Building Use Studies Ltd.'s BUS Methodology, and the Centre for the Built Environment's (CBE) Occupant Indoor Environment Quality (IEQ) Survey

(Dykes and Baird, 2013). Questions about individual IEQ factors are asked in three sections of the survey. Participants asked to rate how much discomfort they felt different IEQ factors caused them in each of their home and work environments on a scale from "1 - No discomfort" to "7 - A lot of discomfort", as well as how much individual IEQ factors caused them to avoid buildings on a scale from "1 - Not at all" to "7 - A lot".

Similar to the CBE survey, this survey uses display logic, where questions are displayed to the participant based on answers to a previous question. For example, to be asked about which IEQ factors caused them to avoid buildings, the participant must have earlier answered either that they had avoided buildings due to the indoor environment, or desired to. Participants were asked about avoidance of buildings as part of a wider section on the general built environment,

The selection of which IEQ factors to ask about was based on Oseland's (2007) guide to post-occupancy evaluation survey design, which analysed 20 POE surveys, including the CBE and BUS above, and listed the most common IEQ factors addressed. As the guide applies to office spaces, evaluating a single building, for this survey the selected factors were relevant to a wide range of building types, including the home and public buildings.

A general sensory processing section was also included in the survey to check for differences in sensory sensitivity between the Autistic and Control groups, as well as measure general variance. Fifteen items based on an established sensory processing tool were each asked on a 5-point frequency scale (coded 0-4). When summed, this gave a maximum sensory processing score of 60, where a higher score means a higher level of sensory sensitivity. Differences in sensory processing outside hypersensitivity and over-responsivity are outside the scope of this project. To ensure that the survey would be accessible to participants on the autism spectrum, when developing the survey content consideration was given to the list of recommendations for research with autistic participants published by the Australian Cooperative Research Centre for Living with Autism (Autism CRC), which includes clear and concise language, consistency, and opportunities for elaboration (Autism CRC, 2016).

The data collected in the survey were ordinal, and many of the distributions were identified as skewed or non-normally distributed early in the analysis, therefore the data was treated as non-parametric in the analysis. For a measure of central tendency the median was used instead of the mean, and for testing between groups, Mann-Whitney U tests were used.

2.2 Participants

A total of 276 responses were collected over two months. The Autistic group (n=83) was defined as participants who identified as being on the autism spectrum. A further 59 participants identified having another condition that affected their sensory processing (e.g. blindness, epilepsy, ADHD) or as being related to someone on the autism spectrum, and were excluded from the Control group (n=134). For group analysis, only the Autistic and Control groups are considered.

Participants were recruited through social media, local businesses, word-of-mouth, disability advisory organisations, and autistic-led self-advocacy organisations. Autism New Zealand and Altogether Autism both shared the survey throughout their networks, including at adult support groups, local offices, and a conference.

There was a higher proportion of female responses (n=227) than male responses (n=44), with the 5 participants who identified as gender diverse being in the Autistic group. There was a similar distribution in ages between the Autistic and Control groups. Participants in the Autistic group were more likely to rent their homes (60%) compared to the Control group (28%). 60% of the Control group identified as being in paid full-time employment, compared to only 25% of the Autistic group. In total, 85% of the Control group were in either paid employment (full or part time) or self-employed, compared to 55% of the Autistic group.

3. RESULTS

The Autistic group reported significantly higher sensory processing scores than the Control group ($U = 10032.0$, $p < .001$). Scores from the Autistic group ranged from 12 to 60, with a median of 43, while scores from the Control group ranged from 0 to 45, with a median of 20. This difference in sensory processing was consistent with other studies (Crane et al., 2009; Leekham et al., 2007; Minshew and Hobson, 2008; Tavassoli et al., 2014).

While 96% of the Control group completed the workplace section of the survey (n=129), only 83% of the Autistic group did (n=69). This is likely due to the documented low employment rates for people on the autism spectrum, which were also found this study. The odds of an Autistic participant having ever avoided buildings was 8.8 [95% CI 4.0, 19.7] times greater than the Control group ($n_A = 65$, $p < .001$). 93% of the Autistic group completed the avoidance section of the survey (n=77) compared to 63% of the Control group (n=85). Therefore, while nearly all of the Autistic group qualified for this question, only two thirds of the Control group qualified, who are likely the most sensitive of this group (Table 1).

Table 1: Discomfort at home and work, and avoidance of buildings caused by 12 IEQ factors by condition

	Home Discomfort			Work Discomfort			Avoidance		
	M_A	M_C	U	M_A	M_C	U	M_A	M_C	U
People	2	1	3257.0†	5	2.5	2087.0†	7	5	1854.5†
People noise	4	1	2326.5†	5	3	2663.5†	7	6	2082.5†
Indoor/other noise	3	1	2786.5†	4	3	2798.0†	5	4	2392.0*
Glare	3	2	3368.9†	4	2	2928.0†	5	2	1859.0†
Electric light	3	2	3755.0†	4	3	3189.0†	5	4	2014.5†
Natural light	2	1	3633.5†	2	2	4247.5	1	1	2474.0*
Temperature	3	3	4996.0*	4	4	4114.0	5	5	2696.5
Air quality	3	1	3529.0†	3	3	3856.0	5	5	2983.5
Air movement	2	2	4209.5*	3	3	4301.0	3	4	2630.0
Smells	3	2	3446.0†	3	2	2934.5†	6	5	3007.5
Privacy	2	1	4022.5†	4	3	3180.5*	5	4	2349.5*
Colour	1	1	4783.5	2	2	3293.0*	4	2	2053.5†

Note. * = p <.05, † = p <.001. 95%. M_A = Autistic group median, M_C = Control group median

Overall, the Control group reported very low discomfort across all IEQ factors in the home environment (Table 1). Responses from the Autistic group were also primarily at the low end of the scale, however consistently higher than the Control group, reporting significantly greater discomfort in eleven of the twelve factors. The Control group reported a similar level of discomfort from most IEQ factors in the workplace environment as the Autistic group reported at home, primarily in the low- to mid-range of the scale. In the workplace, the Autistic group reported significantly greater discomfort in eight of the twelve factors than the Control group. Similarly, of the participants who identified that they avoid buildings, eight of the twelve IEQ factors caused respondents from the Autistic group to want to avoid buildings significantly more frequently than the Control group respondents. People, people noise, indoor/other noise, privacy, glare and electric light all had significant differences between the two groups across all three IEQ sections.

Both people and people noise have the largest magnitudes for both groups in the avoidance section, being the only IEQ factors with a median at the maximum end of the scale for people on the autism spectrum (Table 1). Despite people noise causing the Control group very low discomfort in the home, as a cause of avoidance it was their highest rated factor. In contrast, for the Autistic group, people noise was the IEQ factor that caused the greatest discomfort at home, while being equally highest with the people factor in both the workplace environment and as a cause of avoidance.

Responses to glare and electric light also had large differences between the Autistic and Control groups across all three IEQ sections (Table 1). Glare was rated equally across all three sections by the Control group, however for the Autistic group it was associated with increased discomfort in the workplace, and was highly rated as a cause for avoidance in the wider built environment. While there was a significant difference between the Autistic and Control groups at home and as a cause of avoidance, natural light had the lowest scores across all of the IEQ factors (Table 1).

Temperature was the only IEQ factor that had the same median for both the Autistic and Control groups across all three sections, with no significant difference between the groups in any environment (Table 1). It was the highest rated IEQ factor by the Control group at both home and work, while the Autistic group rated other factors as causing greater discomfort in both environments. A similar pattern is also seen in the air quality and air movement factors. As a factor, smells had a significant difference as a cause of discomfort in both the home and workplace environments, however did not have a significant difference as a cause of avoidance (Table 1). It was also the only factor that was rated at the same level of discomfort in both the home and workplace environments by both groups.

4. DISCUSSION

Based on the large and significant difference in sensory processing scores, the Autistic group in this study can be considered to be representative of the differences in sensory processing found across people on the autism spectrum. When examining the results of the IEQ factors across the home, workplace and avoidance sections, individual IEQ factors can be considered in two ways: in terms of magnitude (the size of the medians), or in terms of the difference between the two groups.

Given that many people live alone or with family, it was expected that other people are not such a problem at home but are a much greater problem in workplaces and other buildings where groups of people congregate. The large differences in discomfort and avoidance of people was expected, given that people on the autism spectrum often struggle with crowds and large numbers of people. Future research could examine whether it is density or number of people that is the largest problem. For example, in a large space with a medium number of people, there is lower density but higher numbers, while a smaller number of people in a small space would have high density despite having fewer people. This relationship could also assist in understanding the effects of people noise, which may be more dependent on number than density.

Noise is regularly reported as a factor that has a high impact on productivity and satisfaction in IEQ research (Al Horr et al., 2016; Liebl et al., 2012; Wargocki et al., 2012), which agrees with the findings in this study, where the noise-based factors were consistently rated highly. As people noise primarily consists of other people talking and is often highly intelligible, which has particularly high impact on cognition and well-being (Liebl et al., 2012), which likely explains why it was rated higher than indoor/other noise. While noise is difficult for all people, neurotypical people still have a greater ability to manage background noise than people on the autism spectrum, which the evidence shows have difficulties in being able to 'tune out' background noise effectively (Sarris, 2016), which could explain the large differences between the groups. Having identified that people and people noise are large problems for people on the autism spectrum, investigation into the move towards flexible desking, open plan offices with minimisation of footprint is needed, as these issues are likely to worsen in these new office environments, and further impact the low employment rates for people on the autism spectrum.

In existing research, there is disagreement on the relative importance of lighting on productivity and satisfaction, with Leaman & Bordass (2007) listing lighting as a factor of moderate importance behind thermal comfort, while others do not specify lighting as a factor with large effects on productivity, although they do not claim it has no effect either (Al Horr et al., 2016; Wargocki et al., 2012). Therefore, the finding in this study that the lighting factors have a moderate magnitude, albeit behind thermal and air quality environment factors for the Control group is in accordance with typical research findings. Both groups consistently rated natural light as a factor that caused little or no discomfort across both environments and was not a cause for the avoidance of buildings. A limitation of this study was how natural light was asked about; too much natural light usually manifests as glare, which was asked about separately and did have large group differences and magnitude, while usually too little natural light this would be asked about in terms of dissatisfaction as opposed to discomfort.

Lighting is referenced in many 'autism-friendly' design guidelines, most regularly in reference to the avoidance of fluorescent lighting and glare (Beaver, 2010; Hewitt et al., 2009; Humphreys, 2005; Vogel, 2008). The consensus on the avoidance of fluorescent lights appears to primarily be as a result of anecdotal evidence, with two studies performed in a time where fluorescent lights operated at a much lower frequency than today and were more susceptible to visible flicker (Colman et al., 1976; Fenton and Penney, 1985). In today's high-frequency ballast compact fluorescent lights, the flicker is not perceptible to the eye, however some researchers find that the sub-visible flicker can still cause visual discomfort in peripheral vision (Wilkins, 2015). However, while fluorescents should not visibly flicker in their specified lifetime, they can and do deteriorate at end of life, so the issue today could be more to do with poor maintenance than the lights themselves (Hewitt et al., 2009). There are also claims that fluorescents are too bright and unnatural by people on the autism spectrum, which could be a result of the 'white' light being produced by a limited light spectrum. Today, the building industry is moving toward LED lighting due to an emphasis on energy savings, which is even more directional than fluorescent lighting, however does have a more even colour spectrum. Investigation into the cause of artificial lighting problems and the implications of the move towards LEDs on people on the autism spectrum is needed.

Many studies have found that temperature had high impact on satisfaction and productivity, followed closely by ventilation and indoor air quality (IAQ) (Al Horr et al., 2016; Leaman and Bordass, 2007; Wargocki et al., 2012), which is consistent with the findings of this study for the Control group, where these factors were rated highly, particularly temperature. However, the profile of responses was different for the Autistic group, who consistently rated these factors similarly to the Control group, but rated other factors higher. It is not clear whether this is because thermal comfort is less of a problem for the Autistic group, or whether there they have greater issues with other factors. While temperature and IAQ are well documented in IEQ literature, they are rarely mentioned in autism-friendly design guidelines unlike lighting and acoustics. This may mean that no further consideration of thermal comfort for people on the autism spectrum is required than what already exists for neurotypical people, compared to other IEQ factors where further research and consideration for differences is needed.

Few problems with privacy in home environment were expected given that most people live in residential settings as family units or in small groups, while privacy has a much larger effect in the workplace where large numbers of people are often working in limited space. The large variation in the effect of smells between environments, rated as a mid-range cause of discomfort for both groups in both the home and workplace but rated highly as a cause of avoidance by both groups, and being the only factor that had a significant difference between groups at both the home and workplace but not as a cause of avoidance, may indicate that it is a factor that is particularly sensitive to building type.

Given the strong emphasis on colour as an important factor to consider in many design guidelines for 'autism-friendly' buildings, the relatively low medians for both groups and small differences was initially unexpected (Beaver, 2010; Hewitt et al., 2009; Humphreys, 2005; Vogel, 2008). However, when considering the environment, these guidelines are primarily for educational settings for children. Typical classrooms often are bright and visually stimulating, with bright posters and student work adorning the walls, so guidelines encouraging reduction of this are important for this type of environment. In the home environment, where the medians for both groups indicated no discomfort, the lack of significant difference for colour is likely due more to the typical design of a home environment, where bright or harsh colours are not frequently applied to surfaces. Again, comparatively workplaces and other buildings are also generally more subdued, so colour may be a less substantial problem in these environments than the classroom environment where great emphasis is placed in design guidelines.

While this study is limited to self-selected people on the autism spectrum who are able to use written communication to complete the survey, it is likely that many of the findings will be generalisable to people on the autism spectrum who are younger or have an intellectual impairment or other issue which prevented them from participating in this study due to the large difference between the groups in sensory processing score. Other limitations of the study include a gender bias towards females, and that the sample is non-random based on recruitment through social media and snowballing.

5. CONCLUSION

This study has been an initial step in understanding the effects of various IEQ factors on people on the autism spectrum, considering both the home and workplace environments, as well as the wider built environment. By surveying peoples' perceptions of the built environment, this study identified that people on the autism spectrum experience greater adverse effects of IEQ. Participants on the autism spectrum reported that people, people noise and indoor/other noise IEQ factors were the greatest causes of discomfort and avoidance, with much greater effects on them than neurotypical people, followed by glare and electric light. While the control group consistently rated temperature highest, the autistic group rated it similarly but rated other factors higher, indicating that thermal comfort may not be the most important factor for people on the autism spectrum.

The large group differences observed across many IEQ factors indicate the need for further study into understanding the nature of these effects and explore methods to improve environments to be more accessible to people on the autism spectrum. We must understand the mechanisms why different IEQ factors cause greater issues to be able to suggest solutions. While people on the autism spectrum have clear differences in sensory processing, there is still variance in sensory sensitivity among the general population. Across many of the IEQ factors, similar patterns in magnitude were often seen between people on the autism spectrum and neurotypical people. A question raised from this is, if a building was designed that took into account the needs of people on the autism spectrum, how would this impact on neurotypical people? In particular, would they also be more comfortable in an environment that takes into account the greater sensory sensitivity of people on the autism spectrum? If so, designing environments that are accessible to the most sensitive of the population would likely improve environments for all users.

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