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Human diversity in acoustics. Towards a more inclusive sound environment.

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ABSTRACT

The study of human responses to sound generally recognises the great importance of taking into account the diversity existent in sounds and acoustics environments, but it rarely adopts the same approach with respect to the diversity in human beings and their responses, providing results as averages meant to represent the 'normal' response, and disregarding discrepancies as 'outliers'. In this paper, neurodiversity and autism is presented as part of the aural diversity factors that can lead to having different experiences of sounds, and an ongoing doctoral research project aiming at representing autistic people's experiences of the acoustic environment is introduced. Differences in perception of sounds can entail different challenges and needs, that are not currently contemplated in acoustics and soundscape research. The authors believe that all these aspects ought to be considered to widen our understanding of the field, to improve research and practice, and to create acoustic environments that are not just designed for a limited part of the population.

1. INTRODUCTION

Methods used in research on the perceptual evaluation of sound and other stimuli are often oriented to collect quantitative data from a cohort of participants, where data is processed through statistical analysis. After this analysis, experiences that deviate significantly from the average response are normally categorised as outliers. While these methods and analyses can facilitate the implementation of more cost-efficient research and policies in the short-term, they can result in problematic conclusions on a theoretical and a practical level when solutions and standards are based on "the average response", and when this response is subsequently identified as "typical".

In addition, common and important environments like homes, schools, healthcare facilities or offices, are usually designed using the required values in acoustics standards as targets, when instead these are intended as minimum quality standards or limits beyond which organisations and authorities have the obligation to take actions [1,2]. Moreover, these limits and recommendations do not prevent negative effects, especially in the vulnerable population and people with higher sensitivity [3,4].

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Autistic and other neurodivergent people are likely to have significant sensorial differences, such as an increased auditory sensitivity. This kind of aural diversity [5] is usually not considered in the design of regulations and standards in environmental and building acoustics, which base their requirements on average values representing "standard" hearing capabilities and sensitivity. Thus, the psychological and physiological response of vulnerable groups and people with higher sensitivity to noise is not appropriately taken into account, which can result in high levels of long-term distress and other important negative effects of noise for health and well-being.

1.1. Project overview

The project presented in this article seeks to understand common challenges and positive aspects of the acoustic environment, addressing some of the consequences of the lack of diversity in sound perception studies, with the aim of developing recommendations to be considered for the creation of more inclusive spaces.

The findings from the project should ultimately identify solutions that will allow controlling the acoustical sensorial inputs in the design of acoustic environments that can constitute a barrier for autistic people.

It is important to note that it is not the intention of the proposed research to form generic conclusions about the experience of all autistic people with sound. As with other factors involving perception, experiences and effects can vary significantly from one person to another, as well as in different moments in life or even in the same day for the same person.

2. BACKGROUND

This section presents the main aspects considered within the fields involved in the project, including some of the most relevant background literature covering them. Some of these aspects are perceptual evaluation of sound in acoustics, the consideration of vulnerable groups in noise guidelines, sensorial differences in autistic people and some of the health risks associated to higher noise sensitivity.

2.1. The evaluation of acoustic environments

The standardised techniques used in acoustics to evaluate the adequacy of environments are based on measurements of physical parameters such us sound pressure levels during different periods, reverberation time, or sound level reduction provided by walls, floors, windows, and other building elements.

These numerical values are often adapted to the standardised model of "typical" human hearing through the application of frequency A-weighting, but they do not consider individual subjective perception or non-acoustical factors related like appropriateness, expectations and meaning, which have been shown to play a crucial role in human responses to sound [6–9]. These techniques are therefore not sufficient to determine people's physiological and psychological responses or short and long-term effects.

There is an increasing number of studies showing a low correlation between many of the main single number quantities required by standards to guarantee well-being and acoustic comfort and the subjective perceptual evaluation in laboratory and real settings [10–13]. This discrepancy may result in failing at preventing the negative effects of noise, such as interference in sleep and performance [14,15], annoyance, stress, health problems and decreased life expectancy [16,4,17,3,18–22].

The mismatch between the fulfilment of numerical requirements and the level of satisfaction of the population has been a constant since early investigations of the effects of road, aircraft and railway noise [23–28], where questionnaires and other social studies methods were introduced to complement the data from measurements in order to understand the different problematics involved and trying to reduce the negative impact of noise.

The study of the perceptual quality of the sound environment, the elements involved in the subjective assessment and the creation of a common terminology for this assessment, constitutes a great part of the recent research related to the evaluation of acoustic environments, manifesting the importance of cognitive, contextual and sensorial factors in the perception and responses to sounds [29].

2.2. Consideration of vulnerable groups in perceptual research

Sounds from any source and with any loudness can increase the levels of discomfort and stress on a daily basis, especially in vulnerable populations. This issue has been examined by research in the past decades, evaluating the perception and effects of sound in, for example, children, the elderly, and healthcare patients [30,31,3].

Berglund et al. [16] state that "we cannot ignore our duty of care for vulnerable groups", in their Guidelines For Community Noise, and the WHO acknowledges that "protective standards are essentially derived from observations on the health effects of noise on 'normal' or 'average' populations. […] usually adults […] selected because of their easy availability. However, vulnerable groups of people are typically underrepresented".

In the Environmental Noise Guidelines for the European Region [32], it is also noted that "the recommended guideline values might not lead to full protection of the population, including all vulnerable groups".

However, the lack of specific consideration and representation of these vulnerable groups is still observable in more recent research in acoustics, and perceptual evaluation studies only including participants with "normal hearing" are the norm [33]. Meanwhile, research and design guidelines considering the needs of groups with specific hearing or sensitivity profiles primarily focus on specialised settings.

Architectural design for schools and other facilities for autistic children do include important aspects on acoustics and sounds [34–36], and there are important efforts in increasing the autonomy of people who live in adapted facilities through room acoustics and sensors [37,38]. Other projects have addressed several aspects of autistic people's sensory need to compile recommendations for care settings [39] and the home environment [40]. These projects are valuable examples of research observing the priorities of the communities they are serving, including their active participation from the initial phases of the research.

It is fundamental, however, that human diversity is addressed and included in general studies on perception and building guidelines for the whole population, in the same manner that the importance of diversity in sounds and acoustical characteristics of spaces for human response is widely acknowledged in research and practice. In addition, this responsibility is reinforced by the legal obligation of fulfilling duties under the Equality Act [41].

2.3. Perceptual differences in autistic people

Although analysis of acoustic parameters and human responses to sound are based on general models, sensorial perception is a highly individual experience, and therefore assuming that all the

members of a group or a community will share experiences and effects can have undesired outcomes when applying design solutions based on this assumption.

One of the vulnerable groups with possible significant differences in perception is represented by neurodivergent people, especially autistic individuals. Neurodiversity refers to the natural diversity in cognitive functioning [42]. Neurodivergent people are individuals who have a different neurotype in comparison to what is considered as "typical". These differences include autism, ADHD (Attention Deficit and Hyperactivity Disorder), dyslexia, and dyspraxia. This cognitive diversity often involves significant sensorial and perceptual differences, with some theories suggesting that autism is a difference in how the information from the world is perceived, filtered, and processed [43], as well as entailing different preferences in interactions and social style [44–46], as opposed to the medical model, which regards autism as a set of deficits and impairments [42,47,48].

Research and lived experience accounts suggest that autistic people show consistent sensorial differences [49–54], often involving an enhanced perceptual capacity [55–58], which can lead to both avoiding and seeking sensory stimuli, and also enjoyment from sensory experiences [52].

This difference can be manifested in a high prevalence of auditory hyposensitivity and, more often, hypersensitivity [59–61], which shows to be related to a difference in the response to sounds rather than to the functioning of the auditory system itself [59]. This response can lead to higher levels of annoyance and less tolerance to loud sounds or high/low frequencies sounds [61,62], "an unusual intolerance to ordinary environmental sounds" [63], but also, among others, to a superior pitch perception [64], "enhanced, stable and highly accurate representation of auditory events in the pitch and time dimensions" [65] identification and memorisation of musical notes [66] and detailed analytical listening of the surrounding soundscape [67]. These responses, however, are not related to "atypical" results in audiometry tests, since most of the participants in these studies present "normal hearing" in standard tests.

In [49], 94.4% of the autistic participants reported extreme levels of sensory processing on at least one sensory quadrant of the Adult/Adolescent Sensory Profile (AASP). In [68], autistic participants reported significantly more sensory sensitivities than their non-autistic peers, and higher levels of auditory perceptual capacity were correlated with higher levels of sensory sensitivities, which have practical implications in education, employment, social integration and participation, health and well-being.

The consequences of sensory overload are multiple and can have a strong impairing impact in autistic people's lives, "a negative impact on employment outcomes" [62], as well as a negative impact on the ability to cope at university, as reported in [69]:

"The noise was impossible to filter out, and I couldn't cope with the shared kitchen [. . .] I can't figure out what people are doing in kitchens – you have to constantly predict movement and intentions, and I couldn't, I felt like I was always getting in the way."

"So much going on, but there was a few bars at the union, and one of those was quiet, there was no blaring machines, no loud music or anything, and that's where we tended to congregate."

Many autistic people make use of individual coping mechanisms like noise cancelling headphones, ear defenders or tinted eyeglasses to reduce the level of perceived stimuli, but some can have negative effects in hearing, and not everyone can afford them or make use of them.

Noise levels can also affect the access of autistic people to basic services like healthcare. In a recent study [70] identifying the main barriers to healthcare and adverse outcomes for autistic adults, 90%

of autistic participants marked one or more sensory challenges related to healthcare environments, compared to 29% of non-autistic respondents. The most common challenge for autistic individuals was noise in the waiting room (63% of respondents marked it, compared to 12% of non-autistics), followed by crowded waiting areas, which can be related to the noise levels. Autistic respondents also reported more adverse consequences related to avoided or delayed healthcare treatment than non-autistic people.

There are also added barriers that can prevent people from having the right support and understanding of their needs due to stigma and lack of knowledge in society [71,72]. Recent research recognises that most autistic people are adult, with no intellectual disability, and do not know that they are autistic, which can lead to unnecessary struggles [73]. There are also common negative consequences of disclosing an autism diagnosis in the workplace, like active discrimination and disadvantages in recruitment [74,71].

2.4. Noise sensitivity and health risks

Noise sensitivity has been identified as an influencing factor and introduced as a moderator in numerous studies, usually showing significant differences in the results for level of annoyance and other responses independently of the noise levels [75–80], although there have not been major changes in guidelines and policies taking these results into account [30,81,82].

In [83], cortisol levels were shown to be more influenced by sensitivity to noise than by the level of regular road traffic noise, and in [84], self-reported noise sensitivity was found to be significantly correlated with blood pressure level and annoyance ratings due to noise from neighbours, road traffic noise and railway noise.

Far from constituting a minor nuisance, noise sensitivity can lead to individuals feeling overwhelmed, struggling to cope with changes and having control over their lives [85], and it has been associated with a higher risk of suffering negative effects of noise exposure, like hypertension, cardiovascular diseases and premature death [20,86,87,87–89].

3. STUDY ON EXPERIENCES OF AUTISTIC PEOPLE WITH ACOUSTIC ENVIRONMENTS

The main details of the initial study being carrying out for this doctoral project (PhD) are briefly presented in this section.

3.1. Semi-structured interviews with autistic people

The ongoing study consists of a series of semi-structured online interviews to autistic adults living in the UK. The questions are intended to provide an overview of their individual lived experiences, of their perception of the acoustic environment and its effects on their life, observing both negative but also positive elements.

In order to compensate for the lack of representation of less typical perspectives and increasing the visibility of different perceptual experiences and its consequences, the use of qualitative methods such as interviews has been considered to be more suitable for an initial investigation.

The objectives of these interviews are to identify:

- Common challenges that may not be addressed by current research on acoustics and perception in the general population.
- Elements that represent an “aural barrier” and need more attention.

- Common coping strategies.
- Elements with a beneficial effect in different contexts.
- Potential actions that could improve autistic people's daily life.

Personal interviews can provide detailed information about the kind of circumstances that can be more frequent and have a bigger impact, negative or positive, in participants' life. Interviews allow participants to express themselves with their own words. This can add some complexity to the analysis of the replies, but it also gives a more personal perspective, which helps to identify issues that may not be covered by standard surveys. Even when the replies are varied, personal accounts cover common points and experiences that can serve as a starting point for future studies.

The analysis of the responses of the interviews will form the base for the development of the next phases of the project. These phases will have a focus on providing a practical and first-hand perspective that is meant to be considered by planners, developers, and organisations. There will be an emphasis in creating supportive environments, preventing negative effects, and facilitating beneficial ones if possible. These improvements can have a positive impact not only in many aspects of autistic people's life, but also in many more people, since the effects of noise are widespread in the population [22,90].

3.2. On the need for participatory design

Autistic people are asking to have higher involvement in research related to them from an early stage, especially in the design of the research questions [91]. It is often the case that research is focused on autistic children, where their parents and carers are the informants. Even when they may be well intended, this can lead to undesired consequences, like misinterpreting the reasons of reactions, causes of distress, or mental health issues as a consequence of basing the discussion on wrong assumptions [92].

Most research on sensorial perception in autistic people, for example, evaluates children's responses in laboratory settings. This presents different potential limitations, from challenges in the ecological validity of the experiments to the exclusion of autistic people's perspective [48].

Thus, it is important to have the participation from other parts of the autistic population, including adults and elderly people, which will possibly have different needs and, therefore, experiences and individual, first-hand insights. As stated in [93], "inclusive research practice is both a moral obligation and a practical imperative".

This project acknowledges the importance of the above, and will take it into account in the development of further studies, within the limitations of a PhD project.

4. CONCLUSIONS

There is an ethical and legal need to create more inclusive environments from a sensorial perspective. Sensory differences can constitute a major issue for some groups of people, and have a significant impact on their health, social integration, financial security and overall well-being.

The doctoral project outlined in this article is focused on the experiences of autistic people in acoustic environments, investigating differences in perception, sensitivity, and effects of sounds.

As an initial step to explore these experiences, a series of semi-structured interviews with autistic adults are being performed. The responses from the participants will help to determine concerns,

barriers and possible solutions to improve acoustic environments. They will also be by themselves a compilation of individual experiences that are not often considered in acoustics.

The results of the interviews will be used to develop further studies intended to investigate design solutions and the needs and preferences of autistic people, with the aim of contributing to the inclusion of a wider perspective in the design of acoustic environments.

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6. REFERENCES

1. European Parliament and Council, Directive 2002/49/EC of the European Parliament and of the Council of 25th June 2002, relating to the assessment and management of environmental noise. Official Journal of the European Communities, L189, 2002.
2. Statutory Instruments, "The Noise Insulation Regulations 1975. SI 1763, London: The Stationary Office.," Westlaw, https://www.legislation.gov.uk/uksi/1975/1763/contents/made, 1975.
3. Brown, A. and Kamp, I. van, "WHO Environmental Noise Guidelines for the European Region: A Systematic Review of Transport Noise Interventions and Their Impacts on Health," *IJERPH* 14(8):873, 2017.
4. Guski, R., Schreckenberg, D., and Schuemer, R., "WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Annoyance," *International Journal of Environmental Research and Public Health* 14(12):1539, 2017.
5. Drever, J.L., "'Primacy of the Ear' – But Whose Ear?: The case for auraldiversity in sonic arts practice and discourse," *Organised Sound* 24(1):85–95, 2019.
6. Genuit, K., "The use of psychoacoustic parameters combined with A-weighted SPL in noise description," Florida, USA, 1999.
7. Guski, R., "Personal and social variables as co-determinants of noise annoyance," *Noise Health* 1(3):45–56, 1999.
8. Davies, W.J., Adams, M.D., Bruce, N.S., Cain, R., Carlyle, A., Cusack, P., Hall, D.A., Hume, K.I., Irwin, A., Jennings, P., Marselle, M., Plack, C.J., and Poxon, J., "Perception of soundscapes: An interdisciplinary approach," *Applied Acoustics* 74(2):224–231, 2013.
9. Bruce, N.S. and Davies, W.J., "The effects of expectation on the perception of soundscapes," *Applied Acoustics* 85:1–11, 2014.
10. Caniato, M., Gasparella, A., and Bettarello, F., "Acoustic classification of dwellings using national and international standard: a critical comparison," *Conference Proceedings* 7, 2018.
11. Caniato, M., Bettarello, F., Fausti, P., Marsich, L., Ferluga, A., and Schmid, C., "Low frequency noise and disturbance assessment methods: A brief literature overview and a new proposal," 032001, 2016.
12. Persson, K., Björkman, M., and Rylander, R., "Loudness, Annoyance and dBA in Evaluating Low Frequency Sounds," *Journal of Low Frequency Noise, Vibration and Active Control* 9(1):32–45, 1990.
13. Rychtarikova, M., Mülner, H., Stani, M., Chmelik, V., and Glorieux, C., "Does the living noise spectrum adaptation of sound insulation match the subjective perception?," *Proceedings - European Conference on Noise Control* 180–184, 2012.
14. Pawlaczyk-Luszczyńiska, M., Dudarewicz, A., Waszkowska, M., Szymczak, W., and Sliwińska-Kowalska, M., "The impact of low-frequency noise on human mental performance," *Int J Occup Med Environ Health* 18(2):185–198, 2005.

15. Persson Waye, K., “Low frequency noise pollution interferes with performance,” 10, 2013.
16. Berglund, B., Lindvall, T., Schwela, D.H., and World Health Organization Occupational and Environmental HealthWorld Health Organization Occupational and Environmental Health, “Guidelines for community noise,” World Health Organization, 1999.
17. Persson, K. and Björkman, M., “Annoyance due to low frequency noise and the use of the dB(A) scale,” *Journal of Sound and Vibration* 127(3):491–497, 1988.
18. Park, S.H. and Lee, P.J., “Effects of floor impact noise on psychophysiological responses,” *Building and Environment* 116:173–181, 2017.
19. Begeny, C.T., Ryan, M.K., Moss-Racusin, C.A., and Ravetz, G., “In some professions, women have become well represented, yet gender bias persists—Perpetuated by those who think it is not happening,” *Science Advances* 6(26):eaba7814, 2020.
20. Babisch, W., Pershagen, G., Selander, J., Houthuijs, D., Breugelmans, O., Cadum, E., Vigna-Taglianti, F., Katsouyanni, K., Haralabidis, A.S., Dimakopoulou, K., Sourtzi, P., Floud, S., and Hansell, A.L., “Noise annoyance — A modifier of the association between noise level and cardiovascular health?,” *Science of The Total Environment* 452–453:50–57, 2013.
21. Babisch, W., Beule, B., Schust, M., Kersten, N., and Ising, H., “Traffic Noise and Risk of Myocardial Infarction:,” *Epidemiology* 16(1):33–40, 2005.
22. European Environment Agency, Environmental noise in Europe, 2020.
23. Broner, N., “The effects of low frequency noise on people—A review,” *Journal of Sound and Vibration* 58(4):483–500, 1978.
24. Schultz, T.J., “Synthesis of social surveys on noise annoyance,” *The Journal of the Acoustical Society of America* 64(2):377–405, 1978.
25. Westman, J.C. and Walters, J.R., “Noise and Stress: A Comprehensive Approach,” *Environmental Health Perspectives* 41:291–309, 1981.
26. Job, R.F.S., “Community response to noise: A review of factors influencing the relationship between noise exposure and reaction,” *The Journal of the Acoustical Society of America* 83(3):991–1001, 1988.
27. Miedema, H.M. and Oudshoorn, C.G., “Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals.,” *Environ Health Perspect* 109(4):409–416, 2001.
28. Van Gerven, P.W.M., Vos, H., Van Boxtel, M.P.J., Janssen, S.A., and Miedema, H.M.E., “Annoyance from environmental noise across the lifespan,” *The Journal of the Acoustical Society of America* 126(1):187–194, 2009.
29. Andringa, T.C., Weber, M., Payne, S.R., Krijnders, J.D. (Dirkjan), Dixon, M.N., Linden, R. v.d., Kock, E.G.L. de, and Lanser, J.J.L., “Positioning soundscape research and management,” *The Journal of the Acoustical Society of America* 134(4):2739–2747, 2013.
30. Kamp, I. van and Davies, H., “Noise and health in vulnerable groups: A review,” *Noise Health* 15(64):153, 2013.
31. Brown, B., Rutherford, P., and Crawford, P., “The role of noise in clinical environments with particular reference to mental health care: A narrative review,” *International Journal of Nursing Studies* 52(9):1514–1524, 2015.
32. Weltgesundheitsorganisation and Regionalbüro für Europa, “Environmental noise guidelines for the European Region,” ISBN 978-92-890-5356-3, 2018.
33. Drever, J., “The Case For Auraldiversity In Acoustic Regulations And Practice: The Hand Dryer Noise Story,” London, UK: 6, 2017.
34. Mostafa, M., “An An Architecture for Autism: Concepts of Design Intervention for the Autistic User,” *Archnet-IJAR : International Journal of Architectural Research* 2, 2008.
35. James, A. and Canning, D., “Acoustic requirements for special schools,” 10, 2010.
36. Ho, L., Kronka Mülfarth, R., and Prata-Shimomura, A., “Residences for people diagnosed with Autism Spectrum Disorder (ASD): architecture and requirements.,” 2020.

37. Bettarello, F. and Caniato, M., “Acoustic Comfort for Spaces Used by People with Cognitive Impairment A Starting Point for the Application of Acoustic Event Detection and Sound Source Recognition Systems,” 14, 2019.
38. Bettarello, F., Caniato, M., Scavuzzo, G., and Gasparella, A., “Indoor Acoustic Requirements for Autism-Friendly Spaces,” *Applied Sciences* 11(9):3942, 2021.
39. Newton, K., Memmott, A., Corbyn, J., and Williams, G., “‘It’s Not Rocket Science’: Considering and meeting the sensory needs of autistic children and young people in CAMHS inpatient services,” 2021.
40. NDTI, “Considering and meeting the sensory needs of autistic people in housing,” 2020.
41. The Stationery Office, Equality Act 2010, 2010.
42. Chapman, R., “Neurodiversity, Epistemic Injustice, and the Good Human Life,” 2021.
43. Donnellan, A., Hill, D., and Leary, M., “Rethinking autism: implications of sensory and movement differences for understanding and support,” *Frontiers in Integrative Neuroscience* 6:124, 2013.
44. Milton, D.E.M., “On the ontological status of autism: the ‘double empathy problem,’” *Disability & Society* 27(6):883–887, 2012.
45. Crompton, C.J., Ropar, D., Evans-Williams, C.V., Flynn, E.G., and Fletcher-Watson, S., “Autistic peer-to-peer information transfer is highly effective,” *Autism* 24(7):1704–1712, 2020.
46. Crompton, C.J., Sharp, M., Axbey, H., Fletcher-Watson, S., Flynn, E.G., and Ropar, D., “Neurotype-Matching, but Not Being Autistic, Influences Self and Observer Ratings of Interpersonal Rapport,” *Frontiers in Psychology* 11:2961, 2020.
47. Bottema-Beutel, K., Kapp, S.K., Lester, J.N., Sasson, N.J., and Hand, B.N., “Avoiding Ableist Language: Suggestions for Autism Researchers,” *Autism in Adulthood* 3(1):18–29, 2021.
48. Pellicano, E. and Houting, J. den, “Annual Research Review: Shifting from ‘normal science’ to neurodiversity in autism science,” *J Child Psychol Psychiatry*, 2021.
49. Crane, L., Goddard, L., and Pring, L., “Sensory processing in adults with autism spectrum disorders,” *Autism* 13(3):215–228, 2009.
50. Robertson, A.E. and Simmons, D.R., “The Sensory Experiences of Adults with Autism Spectrum Disorder: A Qualitative Analysis,” *Perception* 44(5):569–586, 2015.
51. Grandin, T., “A Personal Perspective of Autism,” *Handbook of Autism and Pervasive Developmental Disorders*, John Wiley & Sons, Ltd, ISBN 978-0-470-93935-2: 1276–1286, 2005.
52. Jones, R.S.P., Quigney, C., and Huws, J.C., “First-hand accounts of sensory perceptual experiences in autism: a qualitative analysis,” *Journal of Intellectual & Developmental Disability* 28(2):112–121, 2003.
53. Leekam, S.R., Nieto, C., Libby, S.J., Wing, L., and Gould, J., “Describing the Sensory Abnormalities of Children and Adults with Autism,” *J Autism Dev Disord* 37(5):894–910, 2007.
54. MacLennan, K., O’Brien, S., and Tavassoli, T., “In Our Own Words: The Complex Sensory Experiences of Autistic Adults,” *J Autism Dev Disord*, 2021.
55. Ames, C. and Fletcher-Watson, S., “A review of methods in the study of attention in autism,” *Developmental Review* 30(1):52–73, 2010.
56. Bouvet, L., Mottron, L., Valdois, S., and Donnadieu, S., “Auditory Stream Segregation in Autism Spectrum Disorder: Benefits and Downsides of Superior Perceptual Processes,” *J Autism Dev Disord* 46(5):1553–1561, 2016.
57. Remington, A. and Fairnie, J., “A sound advantage: Increased auditory capacity in autism,” *Cognition* 166:459–465, 2017.
58. Remington, A.M., Swettenham, J.G., and Lavie, N., “Lightening the load: perceptual load impairs visual detection in typical adults but not in autism,” *J Abnorm Psychol* 121(2):544–551, 2012.
59. Lucker, J.R., “Auditory Hypersensitivity in Children With Autism Spectrum Disorders,” *Focus Autism Other Dev Disabl* 28(3):184–191, 2013.

60. Stiegler, L.N. and Davis, R., "Understanding Sound Sensitivity in Individuals with Autism Spectrum Disorders," *Focus Autism Other Dev Disabl* 25(2):67–75, 2010.
61. Williams, Z.J., Suzman, E., and Woynaroski, T.G., "Prevalence of Decreased Sound Tolerance (Hyperacusis) in Individuals with Autism Spectrum Disorder: A Meta-analysis," *Ear Hear* 42(5):1137–1150, 2021.
62. Robertson, A.E., "Sensory experiences of individuals with Autism Spectrum Disorder and autistic traits: a mixed methods approach," PhD, University of Glasgow, 2012.
63. Baguley, D.M., "Hyperacusis," *J R Soc Med* 96(12):582–585, 2003.
64. Bonnel, A., Mottron, L., Peretz, I., Trudel, M., Gallun, E., and Bonnel, A.-M., "Enhanced pitch sensitivity in individuals with autism: a signal detection analysis," *J Cogn Neurosci* 15(2):226–235, 2003.
65. Stewart, M.E., Griffiths, T.D., and Grube, M., "Autistic Traits and Enhanced Perceptual Representation of Pitch and Time," *J Autism Dev Disord* 48(4):1350–1358, 2018.
66. Heaton, P., Hermelin, B., and Pring, L., "Autism and Pitch Processing: A Precursor for Savant Musical Ability?," *Music Perception* 15(3):291–305, 1998.
67. Davies, W.J., "Autistic Listening," Leicester, UK, 2019.
68. Brinkert, J. and Remington, A., "Making sense of the perceptual capacities in autistic and non-autistic adults," *Autism* 24(7):1795–1804, 2020.
69. Cage, E. and Howes, J., "Dropping out and moving on: A qualitative study of autistic people's experiences of university," *Autism* 24(7):1664–1675, 2020.
70. Doherty, M., Neilson, S., O'Sullivan, J., Carravallah, L., Johnson, M., Cullen, W., and Shaw, S.C.K., "Barriers to healthcare and self-reported adverse outcomes for autistic adults: a cross-sectional study," *BMJ Open* 12(2):e056904, 2022.
71. Buckley, E., Pellicano, E., and Remington, A., "'The Real Thing I Struggle with is Other People's Perceptions': The Experiences of Autistic Performing Arts Professionals and Attitudes of Performing Arts Employers in the UK," *J Autism Dev Disord* 51(1):45–59, 2021.
72. Crompton, C.J., Hallett, S., Ropar, D., Flynn, E., and Fletcher-Watson, S., "'I never realised everybody felt as happy as I do when I am around autistic people': A thematic analysis of autistic adults' relationships with autistic and neurotypical friends and family," *Autism* 24(6):1438–1448, 2020.
73. Royal College of Psychiatrists, "The psychiatric management of autism in adults," https://www.rcpsych.ac.uk/improving-care/campaigning-for-better-mental-health-policy/college-reports/2020-college-reports/cr228, 2020.
74. Romualdez, A.M., Walker, Z., and Remington, A., "Autistic adults' experiences of diagnostic disclosure in the workplace: Decision-making and factors associated with outcomes," *Autism & Developmental Language Impairments* 6:23969415211022956, 2021.
75. Ellermeier, W., Kattner, F., and Marquis-Favre, C., "Annoyance due to vehicle sounds is moderated by individual noise sensitivity," *Forum Acusticum*, Lyon, France: 505–506, 2020.
76. Park, J., Chung, S., Lee, J., Sung, J.H., Cho, S.W., and Sim, C.S., "Noise sensitivity, rather than noise level, predicts the non-auditory effects of noise in community samples: a population-based survey," *BMC Public Health* 17(1):315, 2017.
77. Park, S.H., Lee, P.J., and Jeong, J.H., "Effects of noise sensitivity on psychophysiological responses to building noise," *Building and Environment* 136:302–311, 2018.
78. Pedersen, C.S., Møller, H., and Waye, K.P., "A Detailed Study of Low-Frequency Noise Complaints," *Journal of Low Frequency Noise, Vibration and Active Control* 27(1):1–33, 2008.
79. Smith, A., "The concept of noise sensitivity: Implications for noise control," *Noise & Health* 5:57–9, 2003.
80. Kamp, I. van, Job, R.F.S., Hatfield, J., Haines, M., Stellato, R.K., and Stansfeld, S.A., "The role of noise sensitivity in the noise–response relation: A comparison of three international airport studies," *The Journal of the Acoustical Society of America* 116(6):3471–3479, 2004.

81. Heinonen-Guzejev, M., Jauhiainen, T., Vuorinen, H., Rantanen, T., Koskenvuo, M., Heikkilä, K., Mussalo-Rauhamaa, H., and Kaprio, J., "Noise sensitivity and hearing disability," *Noise and Health* 13:2011: 51–8, 2011.
82. Kamp, I. van and Davies, H., "Environmental noise and mental health. Five year review and future directions," 2008.
83. Kim, A., Sung, J.H., Bang, J.-H., Cho, S.W., Lee, J., and Sim, C.S., "Effects of self-reported sensitivity and road-traffic noise levels on the immune system," *PLoS ONE* 12(10):e0187084, 2017.
84. Park, S.H. and Lee, P.J., "Effects of indoor and outdoor noise on residents' annoyance and blood pressure," *Conference Proceedings* 8, 2018.
85. Landon, J., Shepherd, D., Stuart, S., Theadom, A., and Freundlich, S., "Hearing every footstep: Noise sensitivity in individuals following traumatic brain injury," *Neuropsychological Rehabilitation* 22(3):391–407, 2012.
86. Baliatsas, C., Kamp, I. van, Swart, W., Hooiveld, M., and Yzermans, J., "Noise sensitivity: Symptoms, health status, illness behavior and co-occurring environmental sensitivities," *Environmental Research* 150:8–13, 2016.
87. Baudin, C., Lefèvre, M., Babisch, W., Cadum, E., Champelovier, P., Dimakopoulou, K., Houthuijs, D., Lambert, J., Laumon, B., Pershagen, G., Stansfeld, S., Velonaki, V., Hansell, A., and Evrard, A.-S., "The role of aircraft noise annoyance and noise sensitivity in the association between aircraft noise levels and hypertension risk: Results of a pooled analysis from seven European countries," *Environmental Research* 191:110179, 2020.
88. Heinonen-Guzejev, M., Vuorinen, H.S., Mussalo-Rauhamaa, H., Heikkilä, K., Koskenvuo, M., and Kaprio, J., "The association of noise sensitivity with coronary heart and cardiovascular mortality among Finnish adults," *Science of The Total Environment* 372(2):406–412, 2007.
89. Stansfeld, S., Clark, C., Smuk, M., Gallacher, J., and Babisch, W., "Road traffic noise, noise sensitivity, noise annoyance, psychological and physical health and mortality," *Environmental Health* 20(1):32, 2021.
90. Herranz-Pascual, K., Aspuru, I., Iraurgi, I., Santander, Á., Eguiguren, J.L., and García, I., "Going beyond Quietness: Determining the Emotionally Restorative Effect of Acoustic Environments in Urban Open Public Spaces," *International Journal of Environmental Research and Public Health* 16(7):1284, 2019.
91. Fletcher-Watson, S., Adams, J., Brook, K., Charman, T., Crane, L., Cusack, J., Leekam, S., Milton, D., Parr, J.R., and Pellicano, E., "Making the future together: Shaping autism research through meaningful participation," *Autism* 23(4):943–953, 2019.
92. Botha, M. and Frost, D.M., "Extending the Minority Stress Model to Understand Mental Health Problems Experienced by the Autistic Population," *Society and Mental Health* 10(1):20–34, 2020.
93. Fletcher-Watson, S., Brook, K., Hallett, S., Murray, F., and Crompton, C.J., "Inclusive Practices for Neurodevelopmental Research," *Curr Dev Disord Rep*, 2021.