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DIVERSITY IN SOUND PERCEPTION IN SURVEY TO NOISE SENSITIVE PEOPLE AND RELEVANCE FOR EXPERIMENTAL AND FIELD STUDIES

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ABSTRACT[*]

Many daily life environments can be acoustically inadequate for some groups of people, like people with hearing or visual differences, or with higher noise sensitivity. With the aim of increasing acoustical inclusivity, the study presented in this paper explored the experiences of 311 noise sensitive participants, 59% of them (N=183) neurodivergent, through a mixed methods survey in English and Spanish. The survey investigated aspects related to individual perceptual characteristics such as habituation and capacity to filter out background sounds, the use of coping strategies, and perceived helpfulness of measures to reduce negative impacts. The partial results presented show a wide range of diversity among the participants in perception and preferences, as well as significant differences between the neurotypical and the neurodivergent groups. For most participants noise sensitivity was reported to increase with age, and many highlighted frequent dismissal and lack of understanding of their experiences throughout their lives, as well as inaction from organisations and authorities. The findings indicate that guidelines and recommendations could become more inclusive by accounting for perceptions and responses that go beyond the "average ear". Such adjustments would not only address the needs of individuals with heightened sound sensitivity but also benefit a broader population.

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1. INTRODUCTION

While it is acknowledged that the human response to sound is far from unique, common approaches and methodologies often regard diversity in human responses to sound as statistical noise, with the additional effect of the common exclusion of people without "normal hearing" from studies. Considering that "normal hearing" corresponds to the typical response to sound frequencies in people from 18 to 25 years old [1], this narrowness in scope can lead to generalisations that do not represent the perceptual characteristics and needs of many groups of people, including people with hearing, perceptual and/or sensory differences [2]. A characteristic that some people with these differences usually exhibit is a heightened sensitivity to sound, or noise sensitivity (NS), understood as a more intense psychophysiological response to sound rather than a heightened auditory acuity [3]. High NS is common in, for example, autistic and other neurodivergent people, people with hearing loss and other hearing differences, older people, or children [4–6], and has been associated to higher annoyance and more negative health outcomes due to noise exposure [7–9].

The study presented in this paper is part of a doctoral project exploring the experiences of people with high NS in real-life situations, to assess common challenges, the impact of inadequate acoustic environments on their personal and professional life and overall well-being, and recommendations for improvements. In this paper, part of the results of an online survey are presented, with the aim of illustrating the potential diversity in experiences reported by participants, and possible differences with respect to typical participants in experimental and field studies.

2. METHODOLY

This study was developed and the focus determined using knowledge gained from a prior interview study [10]. A heightened sensitivity to sound was identified as one of the most important factors in participants' perception of the acoustic environment, therefore the focus of this study was to capture both qualitatively and quantitatively the lived experiences of people with high noise sensitivity. An online survey was developed and distributed through multiple channels and types of audiences, calling for volunteers over 18 years old who considered themselves noise sensitive.
The survey aimed to explore:
- Sound sensitivity: the extent and effects of heightened sound sensitivity in daily life.
- Perception and response to sounds: how individuals perceive and react to different sounds in their daily environment, and the influence of key non-acoustic factors.
- Challenging spaces: identify environments that are particularly disabling due to their acoustical characteristics.
- Pleasant sounds and environments: identify the types of sounds and environments that are restorative or enjoyable.
- Coping strategies: identify the methods used to manage or mitigate the impact of challenging acoustic environments.
- Preferences for solutions: which solutions, not necessarily acoustical, could have a positive impact in experiences in different environments, without undermining other aspects like health, socialisation, career, etc.
- Solutions' availability: how often participants find such solutions already in place, as well as exploring their experiences when requesting changes and accommodations.
- Barriers to change: perceived obstacles to implementing solutions and improvements.
- Agency and context: the role of choice, control, and context in positive experiences with environments or solutions.
- Neurotypical vs. Neurodivergent differences: potential contrasts in the above areas between neurotypical and neurodivergent participants.

Most of the situations, strategies and measures were selected from the ones mentioned by participants in the previous study [10].

3. RESULTS AND DISCUSSION

The results presented below have been considered to be among those with a higher relevance for sound perception studies, helping to illustrate the substantial range of diversity within the replies of the whole group of participants, and also between the three groups formed according to neurotype: the group with Autistic participants, all Neurodivergent participants (which includes the autistic group), and Neurotypical participants.

3.1 Participants

311 people (61% women, 9% from 18 to 25 years old, 32% over 45 y/o) completed the survey.
Neurodiversity: 35% were neurotypical (N=108), 59% were neurodivergent (N=183), including autistic people, who were 46% (N=143) of the total. The number of participants in each group did slightly differ in different questions, as some (very few) items were not replied by some participants. Respondents not specifying neurotype were excluded (n=17) from comparative analyses.
Aural diversity: 56% had no known hearing differences. Among the rest, 20% reported to have tinnitus, 17% had auditory processing disorder, 15% had hyperacusis, 9% had hearing loss with or without hearing aids, 1% had diplacusis, and 9% had other hearing conditions.

3.2 Variation of noise sensitivity with age

66% of participants reported that their NS increased with age, with only 5% of respondents perceiving that it decreased. There is a slightly higher percentage of Autistic and Neurodivergent participants who replied that NS increased with age for them (69%), while for 28%-26% NS had not changed. These results (Fig. 1) are in line with the findings in studies such as [11], although in this case it was found that ratings for NS were higher for middle-aged participants, with authors suggesting that this finding could be associated to general higher levels of stress for these group.

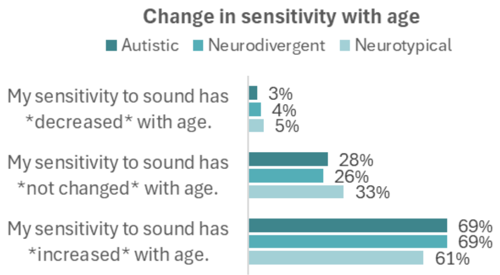


Figure 1. Change in sensitivity with age.

As the current study does not include enough participants of all ages to test this hypothesis, it is unclear whether the same pattern exists in noise sensitive populations. However, our results and those in the literature importantly contradict the belief that it is common to become less sensitive to noise with age. For example, if applied to autistic people, this belief can result in a focus on the adaptation of the sound environment in spaces for autistic and other neurodivergent children, while disregarding the experiences and needs of autistic adults.

3.3 Filtering out background noise

As shown in Fig.2, almost all Autistic and Neurodivergent participants report that they cannot filter out background or irrelevant sounds, or struggle to do it, compared to 77% of Neurotypical participants who reported the same (p=0.000, Neurotypical vs Neurodivergent participants). None of the Autistic participants find it easy to ignore them, while 14% of Neurotypical ones considered they can easily do it.

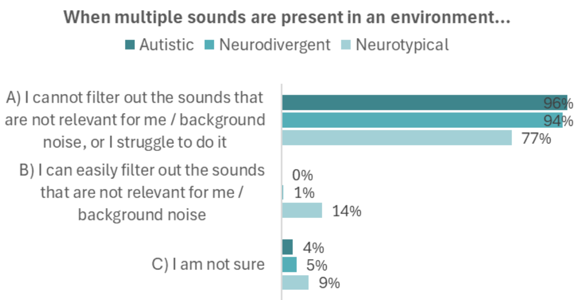


Figure 2. Capacity to filter out background noise.

Other questions also offer data on possible differences in perceptual profiles between Neurodivergent and Neurotypical participants, and, as in many of the results obtained in this survey, it could be possible that this difference is more accentuated in the case of Neurotypical participants who are not noise sensitive. Fig. 3 and 4 show differences between Neurodivergent and Neurotypical participants in the level of agreement with two of the statements proposed, although overall most people in both groups agree with them to some degree. Other specific scenarios included in the survey show in most cases both, a degree of diversity within the groups and also differences between Neurotypical and Neurodivergent participants. These scenarios are representative of some of the most common circumstances presenting challenges for people with heightened sound sensitivity, including people with hearing loss with or without hearing aids. Moreover, experiencing situations where an important amount of cognitive effort needs to be dedicated to trying to "block" background noise usually results in increased tiredness and stress, which in turn can increase NS, especially in Neurodivergent participants [11,12]. Differences in perceptual profiles can lead to differences in preferences for certain spaces and interventions in the acoustic environment, such as reducing the number of auditory stimuli to prevent overstimulation, annoyance and tiredness, as well as for facilitating conversations and focus.

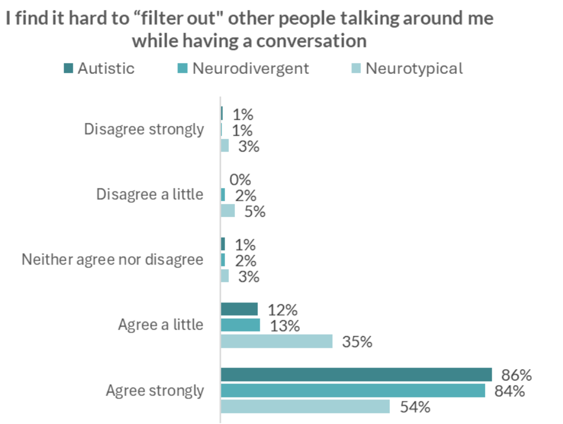


Figure 3. Capacity to filter out irrelevant speech while having a conversation.

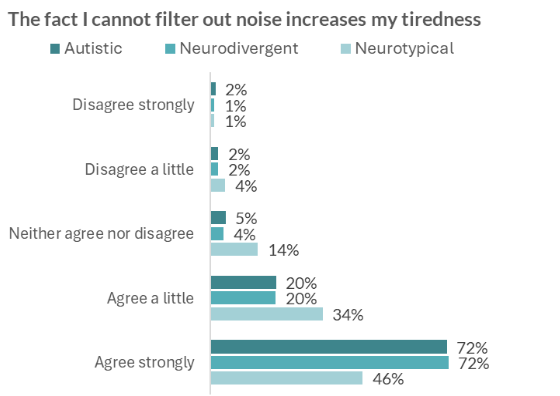
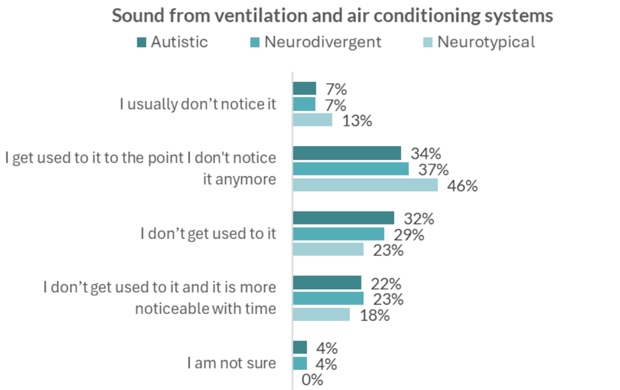


Figure 4. Impact of perception of background noise on tiredness.

3.4 Habituation

Additional situations explored included the perceived habituation to constant background noise. Participants were asked to what point they could notice and get used to certain sounds like the sound from ventilation and air conditioning systems, traffic, or background music. The results again show a high degree of diversity within the three groups, with Autistic and Neurodivergent participants not getting used to the proposed sounds, or even noticing them more with time, in a higher proportion than Neurotypical participants (Fig. 5).

(a)



(b)

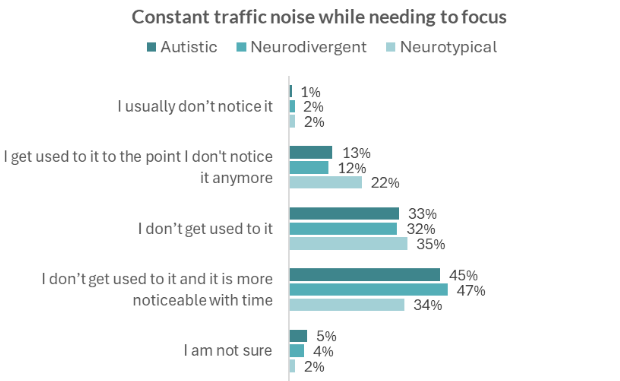


Figure 5. Habituation to constant noise: sound from ventilation and A/C systems (a) and traffic (b).

Differences in perceptual profiles leading to a lack of habituation to constant, steady sounds can also be reflected in how often certain measures are helpful to reduce sound environment-related challenges. These preferences were assessed through a list containing common measures mentioned in the previous study and the literature. For example, the proportion of Neurodivergent participants finding always or often helpful the removal of music in shops and supermarkets was higher than for Neurotypical ones (56% vs 39%). These preferences point to a need for fewer auditory stimuli in certain circumstances, since a lack of habituation can lead to a constant, higher sensory load [13], and potentially lead to reduced performance, higher heart rate [14], stress and sensory overload [15–18].

3.5 Pleasant sounds and annoyance

Importantly, a lower degree of habituation to sounds that cannot be filtered out easily can as well mean a lower degree of relief and reduced annoyance in situations where sounds considered pleasant by the individual are present together with sounds considered annoying, as it was noted in the interviews. The replies for the question investigating this possibility were highly diverse for all groups (Fig. 6), with a slightly higher proportion of Autistic participants strongly disagreeing with the statement "I feel less bothered by annoying sounds when I can also hear pleasant sounds" (27% vs 20% of Neurotypical participants). Overall, there are around 10% of respondents more in all groups disagreeing in any form rather than agreeing (46% vs 44% vs 45%, and 35% vs 36% vs 35%, respectively).
This finding is highly relevant when considering interventions aiming to improve the perception of the acoustic environment through the addition of sounds, as they may risk increasing the sensory load for some people.

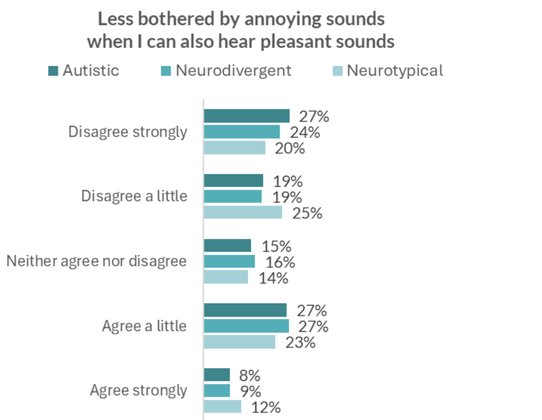


Figure 6. Effect of "pleasant" sounds on annoyance.

3.6 Response to familiar noises

In the interviews of the previous study [10], it was found that many participants felt a higher degree of annoyance and stress in situations where the sounds and/or types of sound sources producing the annoyance had previously subjected them to frustrating situations. This frustration was induced by the sounds and in many cases also by a negative experience (often traumatic) that occurred when attempting to communicate their discomfort. The survey included a question aimed at examining the experience of the participants in this regard, and the results showed a similar trend to the accounts from previous interviews, with over 70% of participants (78% of Neurodivergent vs 71% of Neurotypical participants) reporting being more annoyed by sounds that have bothered them in the past (Fig. 7). Interestingly, the group with a higher proportion of respondents strongly agreeing with that fact was the Neurotypical participants. It is also reasonable to consider that past negative experiences have the potential of influencing the perception and response to sounds also in the case of people who would not be considered noise sensitive, as suggested for example in research on the experience of people chronically exposed to aircraft noise [19].

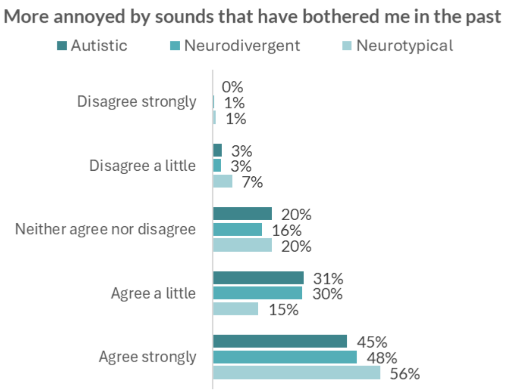


Figure 7. Effect of past experiences on annoyance.

3.7 Relevance for experimental and field studies

3.7.1 Considerations for the design of auditory scenarios and interpretation of experimental and field data

Part of the significance of the results of this study lies on the fact that they are based on participants' lived experiences, rather than on simulated scenarios partially recreated in a laboratory setting. This can represent a limitation related to recollection of memories and how this can affect the accounts of perceptual experiences in the past, but relying on lived experiences has the benefit of reflecting real emotional responses to real situations and environments, that possibly are being recalled due to the impact they had for the individual. Responses to most daily sounds rarely depend solely on the acoustical characteristics of sounds, as there are numerous factors that influence our psychological and physiological responses to sounds. As indicated in some of the replies in this study, as well as in other studies analysing the human relationship with sound (e.g., [20–25]), there are multiple non-acoustic factors that significantly moderate this relationship, and that can differ in the short or long term for the same person. Many of these factors can be present or left out of the labs when people are asked to imagine a hypothetical scenario and to listen to a series of sounds, or when brought to the streets of a city or to a building to report their individual perception of the acoustic environment. These can be not only contextual factors like real investment in the activity being performed or expectations, but also those related to the perceived degree of control over the sounds, which is one of the most important aspect moderating noise annoyance and frustration due to helplessness [24,26]. Personal factors such as past experiences with the sounds, tiredness, health, or level of stress also have a significant impact on these and other consequences, especially for people with higher noise sensitivity [8,10]. Thus, the assessment of common descriptors such as perceived loudness or annoyance can be highly impacted by the exclusion or inclusion of key non-acoustic factors in laboratory and field studies.

In addition, the perception of complex auditory scenes can greatly vary depending on the perceptual profile of the listener. In the cases where some sounds are introduced as "background noise" in simulations, it can be helpful to consider that, as shown in the results, those sounds can be more easily ignored by some people than others who can potentially perceive them in a similar level of prominence than more meaningful sounds. This could have implications for assumptions on the level of attention "grabbed" by different sounds or sound types, the capacity of people/participants to ignore them, and the impact that interventions based on the addition of masking sounds can have. For example, adding different types of masking sounds in open-plan offices can contribute to make "irrelevant" sounds (like speech, footsteps, keyboards, doors, or coffee machines) easier to ignore, increasing the capacity to focus and the average performance [27–29]. However, added sound can represent another layer engaging the attention of

people with higher perceptual capacity that discriminate different "sound streams" present in an environment to a higher degree, as it is the case for many autistic people or musicians, among others [30,31].
Assuming habituation to certain sounds, whether they are supposed to be in the background or being the most salient, can also lead to flawed generalisations in the interpretations of the data, which in turn can lead to misguided recommendations and interventions in practice.

3.7.2 Inclusion of higher diversity in participants

In this and the previous study, the majority of quantitative and qualitative results show a rather wide range of diversity in the experiences of the participants involved, and also a contrast with standard assumptions in research, practice and policy. Common assumptions are habituation to background sound, selective attention to auditory stimuli, positive effects of masking sounds, "desensitisation" in settings with loud sounds, or similarity in psychophysiological responses and preferences in certain demographical groups, for example. Besides noise sensitivity, studies on noise annoyance have indeed found differences in certain experiences depending on factors such as home ownership, financial situation, environmental sensitivity, or stress levels [11,23,24,32–34].
While demographic characteristics such as gender are now considered and reported more often, diversity in age, for example, has been traditionally not seen as relevant in laboratory studies assessing responses to sound. Instead, the exclusion criteria related to not having a "normal hearing" is almost universally used [35,36], but it is not necessarily associated to reduced auditory acuity, lower annoyance or different perception of loudness across all frequencies [37,38]. This purposeful exclusion can be particularly problematic in cases where the goal is to predict responses and repercussions on the general population and design needs in the built environment.
The consideration of higher levels of diversity in participants groups could help increase the understanding of the different human responses to sounds and the relevance of research findings for policy and practice. This diversity may include demographic factors such as age or culture, and also past experiences with the types of sounds being used in the studies, noise sensitivity, auditory processing profiles, neurodiversity and aural diversity, among others. However, even when care is taken to ensure a higher degree of diversity in participants, it is also worth reflecting on the effects of the most common statistical analysis practices performed over experimental data, and how these analyses can oversimplify and misrepresent the diversity existent in that data, including the data obtained and presented in this study. Further research is therefore needed also to develop methodologies and analyses that can reflect and uphold a variety of experiences as much as it can be feasible, while still being aligned with the main goals of the particular research questions.

4. CONCLUSIONS

An online survey with 311 noise sensitive participants was designed to investigate the impact of noise sensitivity in daily life, considering the most relevant scenarios and factors affecting the response to sound identified in a previous study and the literature. Some of the findings are presented here, and are discussed from a lens of providing insights for a higher and active consideration of diversity in the design of studies and recruitment of participants. An increase in annoyance due to certain sounds instead of experiencing habituation, struggling to filter out background or irrelevant noise, and perceiving and processing a higher sensory load due to these and other perceptual characteristics, can result in important differences in the way acoustic environments are experienced and evaluated. The inclusion of more diverse groups in explorations of perception and psychological and physiological responses to sound can help enhancing scientific rigour and successful outcomes in the application of research findings.

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