AURAL DIVERSITY IN SOUNDSCAPE PERCEPTION: COMPARING ADHD, AUTISTIC, AND NEUROTYPICAL LISTENERS ON THE ISO 12913 CIRCUMPLEX

Paul Magrath[1], Samantha E. A. Gregory[2], William J. Davies[1]
[1] *Acoustics Research Centre, University of Salford, Salford, UK*
[2] *School of Health and Society, University of Salford, Salford, UK*

Abstract

Soundscape research generally assumes a uniform listener, yet people differ in how they process sound. This study tested whether neurotype shapes soundscape perception by comparing ADHD, Autistic and Neurotypical listeners ($n = 30$ per group) on ten field-recorded soundscapes, delivered online as binaural stereo and rated on the ISO 12913-2 perceptual circumplex through a calibrated interactive task. Across the pooled soundscapes, ADHD listeners rated the soundscapes as less eventful than Neurotypical listeners ($p = 0.043$, though not significant once the repeated-measures structure was modelled), while pleasantness was unaffected; no significant differences were found when all three groups were compared together. The ADHD effect was small but consistent, appearing in the same direction in eight of the ten soundscapes rather than being driven by any single soundscape. ADHD listeners also showed a non-significant trend towards more extreme responding. Consistent with recent evidence of preserved global auditory processing in autism, the Autistic group closely resembled the Neurotypical group on every measure (SPI = 92.4). The findings provide empirical support for an aural diversity framework for soundscape research, showing that neurodivergent groups differ from one another and should not be treated as a single category.

Keywords: *soundscape, aural diversity, autism, ADHD*

1. Introduction

The circumplex model of soundscape perception was developed and validated with ‘typical’ listeners [1], and subsequent soundscape research has continued within this paradigm, treating the listening human as if they were an interchangeable component of the study. Its applicability to neurodivergent listeners has received little attention. However, one recent result suggests that sensorineural hearing loss alters soundscape perception [2]. There are also many other different types of hearing and listening differences between groups and individuals, such as the auditory processing differences observed in autistic and ADHD laboratory participants [3], [4]. Aural diversity is a recent concept that seeks to replace the binary model of normal/impaired hearing, with a model of a diverse spread of different hearing types [5]. From an aural diversity perspective, averaging the response of all listeners recruited to a soundscape study (and tacitly labelling the mean response as typical) is likely to hide interesting differences between different types of listener. Exploring these differences might lead to new insights about soundscape perception and the soundscape of different types of locations.

This research explores how individuals with attention deficit hyperactivity disorder (ADHD), autism, and typical development (NT) interact with recordings of real-world acoustic environments presented online. The recordings included natural, human and man-made sounds, all expected to be rated as calm and pleasant. The aim here was to see if this held across neurotypes. An interactive web-based version of the traditional circumplex model was developed, and participants from the three neurodevelopmental groups located a selection of these recordings on the two axes of the model: pleasant to unpleasant and eventful to uneventful. In addition to exploring the perceptions of three different groups of listeners, this research tests an assumption that has been left implicit in much of the soundscape research to date, namely that the listener is a fixed entity, and investigates the impli-

Corresponding author: *p.a.magrath@edu.salford.ac.uk*

cations for the circumplex model should this not be the case.
The research is informed by an aural diversity framework and includes all neurodivergent individuals within its scope. The perceptions of neurodivergent individuals are recognised as being different to those of Neurotypical individuals and not less than or inferior [6].

2. Method

2.1. Design

The mixed-design study used neurotype (ADHD, Autistic, Neurotypical) as a between-subjects factor and soundscape (the same ten soundscapes) as a within-subjects factor, and all participants rated all soundscapes.

2.2. Participants

Ninety adults took part in the study in total, thirty in each of the three diagnostic groups. The participants were recruited through the online human-subjects platform Prolific. They were assigned to groups on the basis of a self-reported formal diagnosis. Participants also completed items from the Adult ADHD Self-Report Scale (ASRS-v1.1) [7], the Autism Spectrum Quotient (AQ-10) [8], and a demographic and neurotype questionnaire. Responses to five of the six ASRS Part A items were collected using an adapted four-point scale, so no standard ASRS screening classification was reported. Participants completed the study in their own desktop Chrome browser and were asked to wear wired headphones. The study had been approved by the University of Salford ethics panel (Ref. 6785), and participants completed the online study after providing their consent for participation.

2.3. Soundscape stimuli and audio processing

Since the online experiment took place entirely within a browser, the original first-order Ambisonic field recordings could not be distributed directly. The four-channel ACN/SN3D AmbiX 96 kHz WAV recordings were decoded offline in REAPER 7.35 using the `ambix_binaural_o1` decoder with the icosahedron 3h3v preset, preserving both azimuth and elevation cues within the reproduced sound field [9], [10]. The binaural renderings were then encoded as 44.1 kHz stereo WAV using UHJ (Stereo Summation of Holography), which delivers spatial audio in a conventional two-channel format whilst retaining substantially more spatial information than standard stereo. Stereo UHJ soundscape reproduction has been shown to achieve a level of ecological validity comparable to surround-sound presentation, supporting its use for online soundscape research where laboratory listening conditions cannot be controlled [11].
All soundscapes were normalised, after binaural decoding, to an integrated loudness of −18 LUFS with a conservative true-peak ceiling of −1.0 dBTP, in accordance with AES guidance for audio distributed by streaming and as files over networks [12] (AES TD1004.1.15-10). This balances consistent playback across recordings against the preservation of sufficient dynamic range for perceptual evaluation, prevents clipping and codec-induced overshoot, and ensures that any perceived difference is attributable to the soundscapes themselves rather than to differences in playback level between them.
The ten normalised binaural stereo stimuli, individual processing records, and analysis code are archived and openly available at https://doi.org/10.5281/zenodo.20997635 [13].

2.4. Response measures

Two instruments were completed online for each of the ten soundscapes via the Gorilla Experiment Builder, the interactive circumplex (IC) first. The IC (ISO 12913-2 [14]) was the primary measure: participants rated each soundscape on two dimensions, pleasant/unpleasant and eventful/uneventful, by indicating a single point, whose X and Y coordinates formed the data analysed for each soundscape. Prior to analysis the IC interface was calibrated against a series of reference points to establish the mapping between interface coordinates and circumplex coordinates, and participant responses were then projected onto the Pleasantness and Eventfulness dimensions that form the principal axes of the model.
For validation, participants rated each soundscape on four seven-point bipolar semantic-differential scales: Pleasant–Annoying, Calm–Chaotic, Monotonous–Eventful, and Blend (clashing–harmonious). These were analysed separately: the ISO Pleasant and ISO Eventful coordinates were derived from the IC click coordinates alone.

2.5. Analysis

Analysis was carried out in Python 3.11 in two stages: the pooled data across all ten soundscapes first, then per-soundscape comparisons. Circumplex coordinates were oriented so that the highest eventful scores plot at the top of the ISO 12913-2 (2018) circumplex. The Soundscape Perception Index (SPI), a context-dependent measure of soundscape perception that plots in the two-dimensional space of the circumplex [15], was calculated. The two-dimensional SPI distributions of the three listener groups were compared with a bivariate Kolmogorov–Smirnov test [16], and were modelled as multivariate skew-normal distributions [15], [17] fitted by maximum likelihood using a differential-evolution global optimiser with the random seed fixed for reproducibility.
As the data were non-parametric, the pleasantness and eventfulness ratings for the different soundscapes were compared between the three listener groups with a Kruskal–Wallis test followed by pairwise Mann–Whitney U tests, first on the pooled data across all ten soundscapes and then separately for each soundscape, with the p-values for the per-soundscape comparisons corrected for the false discovery rate by the Benjamini–Hochberg method [18]. The extremity of individual listeners' responses was calculated as

Table 1: Pooled comparison on both circumplex dimensions across all ten soundscapes ($n \approx 291$–296 per group). Mdn is the group median (A = ADHD, Au = Autistic, NT = Neurotypical); KW H and KW p are the Kruskal–Wallis statistic and p-value across the three groups; the final three columns give pairwise Mann–Whitney p-values.

Dimension	$\mathrm{Mdn}_{\mathrm{A}}$	$\mathrm{Mdn}_{\mathrm{Au}}$	$\mathrm{Mdn}_{\mathrm{NT}}$	KW H	KW p	A–NT p	A–Au p	Au–NT p
ISO Eventful	0.38	0.44	0.44	4.88	0.087	**0.043**	0.077	0.756
ISO Pleasant	0.69	0.68	0.68	1.04	0.594	0.493	0.317	0.765

the radial distance from the origin of the circumplex model, $r = \sqrt{P^2 + E^2}$, and compared with the same tests. All statistics were computed with SciPy [19], the circumplex scatter and density plots with Soundscapy [20], and the two-dimensional kernel-density estimates of the SPI distributions with SciPy's Gaussian kernel-density function.

3. Results

3.1. Eventfulness

Not every participant rated every soundscape, giving 294 (ADHD), 296 (Autistic) and 291 (Neurotypical) eventfulness responses from the 90 participants, with each soundscape rated by at least 28 of the 30 participants in each group.

Analysis of the eventfulness ratings showed that the ADHD group rated the soundscapes as less eventful than the Neurotypical group (median ISO Eventful 0.38 versus 0.44; Mann–Whitney $U = 38{,}640$, $p = 0.043$). The omnibus tests, the pleasantness comparisons and the per-soundscape tests after correction were all non-significant. There was no significant difference between the Autistic and Neurotypical groups ($U = 42{,}428$, $p = 0.756$), and a Kruskal–Wallis test comparing all three groups was non-significant ($H = 4.879$, $p = 0.087$). Because each participant rated up to ten soundscapes, the contrast was repeated in a linear mixed-effects model with participant as a random intercept: the difference remained in the same direction but was not significant (estimate -0.037, $z = -1.19$, $p = 0.232$; ICC = 0.24).

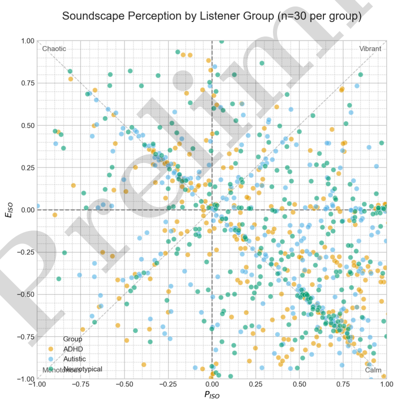

Figure 1: Pooled circumplex responses for the three groups; each point is one soundscape response on the calibrated ISO circumplex.

The same tests were then applied soundscape by soundscape on both dimensions. No individual soundscape reached significance after correction (all FDR-corrected $p > 0.38$); the single nominally significant pairwise result, on the pleasant axis at Seahouses Harbour ($p = 0.039$), did not survive correction ($p_{\mathrm{FDR}} = 0.386$). On the eventful dimension the ADHD median fell below the Neurotypical median in 8 of the 10 soundscapes, and the Autistic median in 4 of the 10, consistent with a small, general effect rather than one driven by any single soundscape. Full per-soundscape statistics are available in the archived dataset [13].

3.2. Pleasantness

Pleasantness ratings for all three groups were very high, with all soundscapes placed within the pleasant end of the ISO Pleasant space, and the centroids for all three groups falling within the pleasant region. A Kruskal–Wallis test revealed no significant differences between the three groups ($H = 1.042$, $p = 0.594$), and a Mann–Whitney U test between the ADHD and Neurotypical groups likewise found no significant difference ($U = 44{,}178$, $p = 0.493$).

3.3. Quadrant distribution and circumplex structure

All three groups' distributions of soundscape perceptions had their modal location within the calm quadrant of the model space (ADHD 53.7%, Autistic 49.7%, Neurotypical 48.8% of responses), with skew-normal location parameters ξ in (ISO Pleasant, ISO Eventful) coordinates of $(0.889, 0.454)$, $(0.988, 0.293)$ and $(0.923, 0.228)$ respectively. On the eventful axis the ADHD median fell below the Neurotypical median (0.38 versus 0.44), a difference also visible in the group density distributions (Figure 2).

3.4. Response extremity

All three groups produced extreme ratings, but to differing degrees (Figure 3). The median radial distance from the circumplex origin was largest for the ADHD participants ($r = 0.77$), intermediate for the Neurotypical ($r = 0.71$) and smallest for the Autistic ($r = 0.68$), but the difference was not significant (Kruskal–Wallis $H = 5.494$, $p = 0.064$), and neither the ADHD-versus-Neurotypical contrast ($p = 0.056$) nor the Autistic-versus-Neurotypical contrast ($p = 0.672$) reached significance. A larger sample would be needed to settle whether the trend is genuine.

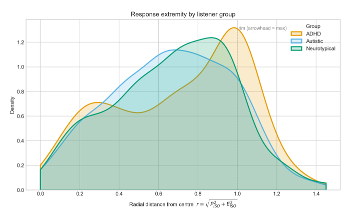

Figure 3: Radial response distance from the circumplex origin; larger values indicate more extreme judgements.

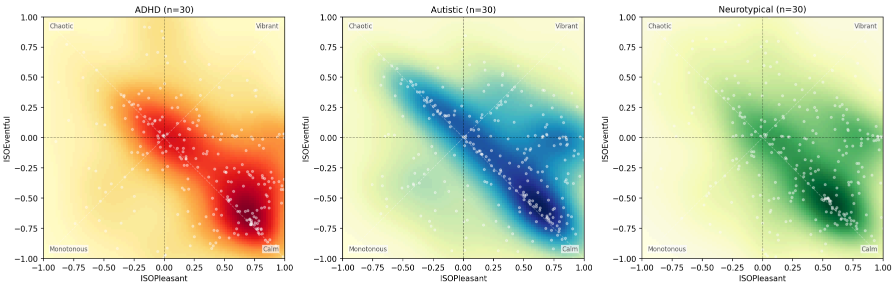

Figure 2: Group-specific density heatmaps illustrating regions of highest response concentration within the circumplex space.

3.5. Distributional overlap

The Soundscape Perception Index (SPI) for all soundscapes combined was calculated from the bivariate Kolmogorov–Smirnov distance between the distributions of the listener groups, and so compares those distributions as a whole. Those of the Autistic and Neurotypical listeners were highly similar ($\mathrm{SPI} = 92.4$; $D = 0.076$; $p = 0.580$), whereas the ADHD distribution showed greater deviation from both of the others, most of it from the Neurotypical listeners on the eventful axis ($\mathrm{SPI} = 87.7$; $D = 0.123$; $p = 0.083$). The distributions on the pleasant axis were negatively skewed for all three groups and clustered on the positive (pleasant) side of the scale, with the ADHD and Autistic skews larger than the Neurotypical (-0.47, -0.46 and -0.35 respectively).

3.6. Semantic-differential validation

The semantic differential supported the circumplex findings, in that the majority of the stimuli were found to lie in the calm and monotonous quadrant of the model. The semantic-differential questionnaire showed no differences between listener groups (Kruskal–Wallis, all $p > 0.55$). Its Pleasant–Annoying and Monotonous–Eventful ratings converged with ISO Pleasant ($\rho = -0.58$) and ISO Eventful ($\rho = 0.57$), respectively ($n = 881$); the two most extreme stimuli matched those from the circumplex comparison: Robin Wood's Rock was perceived as the most pleasant soundscape, and Peel Park Bridge (Bin and Bike) as the most eventful.

4. Discussion

Much soundscape research treats the perceiving listener as fixed or interchangeable. The results of this study support this view only in part: the ADHD group evaluated Pleasantness similarly to the Neurotypical group but rated the soundscapes as less eventful ($p = 0.043$), the only dimension on which either neurodivergent group deviated from the Neurotypical pattern.

The differences were quite small. No individual soundscape reached significance once corrected for multiple comparisons, yet the ADHD medians fell below the Neurotypical medians for 8 of the 10 soundscapes, by a small margin of typically around 0.05 on the ISO Eventful scale.

One interpretation consistent with this pattern is that the difference lies in how event content is registered rather than in how it is evaluated. Under Dunn's model of sensory processing, ADHD is associated with low registration, a higher threshold for taking in sensory information, so that events in a soundscape are noticed less readily [21]. Arousal-based accounts of ADHD, in which suboptimal cortical arousal alters responses to sensory stimulation, make a compatible prediction [22]. A listener who registers fewer of a soundscape's acoustic events might therefore locate it lower on the Eventfulness dimension whilst evaluating its Pleasantness in a similar way, broadly consistent with the pattern observed here, though the study was not designed to distinguish between competing mechanisms. The response-extremity trend points tentatively in a compatible direction: ADHD listeners used the outer edges of the circumplex somewhat more than the other groups, as though responding more categorically, though this remained a non-significant trend.

The findings for the Autistic group are less dramatic but no less important. A sensory-sensitivity account would have predicted that Autistic listeners, if anyone, would diverge most strongly [21]. They did not. On every axis and on the distributional measures, the Autistic group tracked the Neurotypical group closely ($\mathrm{SPI} = 92.4$), and more closely than the ADHD group tracked either. These findings suggest that there is no simple category of 'neurodivergent': rather than treating neurodivergent listeners as a single homogeneous group, ADHD and autistic listeners should be considered as distinct populations with different patterns of soundscape perception, and this supports the need for an aural diversity perspective in soundscape research.

The circumplex requires listeners to integrate multiple acoustic sources into an overall judgement, making it fundamentally a task of global auditory processing rather than a set of responses to individual soundscape components. The autism perception literature distinguishes local-biased from global processing: Weak Central Coherence proposes a detail-focused style in which local information is preferentially processed [23], while Enhanced Perceptual Functioning proposes enhanced local processing alongside preserved global capacity, particularly within the auditory domain [24]. A recent systematic review and meta-analysis of twenty-five studies involving more than 500 autistic participants found that global auditory processing did not differ significantly between autistic and neurotypical participants (Hedges' $g = -0.05$), whereas local auditory processing showed a modest advantage in autism (Hedges' $g = 0.29$, $p < 0.05$) that was attenuated after removal of outlying studies [25]. The close correspondence between the Autistic and Neurotypical groups here is therefore consistent with autistic listeners retaining intact global auditory processing despite enhanced local processing, rather than representing an unexpected null finding. Autistic listeners may therefore differ primarily in the processing of local auditory features rather than in global soundscape evaluation, which future research could examine alongside overall circumplex judgements.

Taken together, the findings offer qualified support for the study's premise. The listener is not perfectly interchangeable: at least one neurodivergent group perceived Eventfulness differently, consistently, and in a direction consistent with a recognised model of sensory processing. More broadly, variation within the listener population may contribute to variation in circumplex outcomes: soundscape assessments may reflect characteristics of listeners as well as of places, a possibility future research will need to address directly.

4.1. Limitations

The non-significant omnibus tests on both dimensions do not, by themselves, support the claims made here; the support rests on a single pairwise contrast for the ADHD group that was not predicted in advance, is of modest magnitude, does not survive modelling of the repeated-measures structure, and requires confirmation in a pre-registered replication. Restricted to the 73 participants who rated all ten soundscapes, the ADHD-below-Neurotypical direction holds in 6 of the 10 soundscapes rather than 8. Group membership was self-reported, the sample was self-selected through an online panel, and with thirty participants per group the extremity and SPI trends may simply be underpowered. The corroboration between the IC and the semantic differential lends some confidence that the coordinates reflect perception rather than interface behaviour.

Online delivery is increasingly common in soundscape research, yet it inherits a long-standing problem with web-based listening: the experimenter cannot control how loudly, or on what equipment, a participant hears the stimuli [26]. Normalising all soundscapes to a recognised broadcast loudness target (−18 LUFS, −1.0 dBTP) [12] removes a between-soundscape level confound, which matters here because the principal finding is a difference in eventfulness across soundscapes; it does not remove the variation in each listener's own playback chain, and it assumes a constant playback volume throughout, which could not be verified beyond the wired-headphone requirement. The meta-analytic evidence cited above [25] was not gathered on soundscape stimuli, and no comparable body of evidence yet exists for complex, multi-source auditory scenes. This points to a broader limitation of the circumplex model itself for aural diversity research: it reduces a soundscape to two aggregate coordinates and cannot, on its own, distinguish a listener who arrives at a coordinate through typical integration of the whole scene from one who arrives at the same coordinate by a different perceptual route. Two groups landing on the same point of the circumplex, as the Autistic and Neurotypical groups did here, are not necessarily using the same underlying process to get there. Establishing that would need methods sensitive to individual- or trial-level processing, rather than the aggregate, group-level judgements the circumplex model was designed to produce.

5. Conclusion

This study demonstrates the value of the circumplex for capturing global soundscape perception. A small difference in Eventfulness between ADHD and Neurotypical listeners emerged in the pooled analysis, although it was not significant in the mixed-effects model. Autistic and Neurotypical listeners nevertheless produced closely aligned global judgements. These findings underline both the value and the scope of the circumplex: similar positions within it should not be taken as evidence of identical perceptual processing. As soundscape research embraces aural diversity, the task is not only to ask whether groups differ, but to ensure that the methods used are capable of answering the specific questions posed. Understanding the perceptual processes underlying these global judgements may require complementary approaches that extend beyond the circumplex.

6. Acknowledgements

This work was supported by the Leverhulme Trust through the LAURA (Leverhulme Aural Diversity) Doctoral Research Hub at the University of Salford. The authors thank the study participants recruited through Prolific.

References

[1] Ö. Axelsson, M. E. Nilsson, and B. Berglund, "A Principal Components Model of Soundscape Perception," *Journal of the Acoustical Society of America*, vol. 128, no. 5, pp. 2836–2846, 2010.

[2] N. Miller-Viacava, D. Lazard, T. Delmas, B. Krause, F. Apoux, and C. Lorenzi, "Sensorineural Hearing Loss Alters Auditory Discrimination of Natural Soundscapes," *International Journal of Audiology*, vol. 63, no. 10, pp. 809–818, 2024.

[3] K. O'Connor, "Auditory Processing in Autism Spectrum Disorder: A Review," *Neuroscience & Biobehavioral Reviews*, vol. 36, no. 2, pp. 836–854, 2012.

[4] P. Dwyer, Z. J. Williams, W. Lawson, and S. M. Rivera, "A Trans-Diagnostic Investigation of Attention and Diverse Phenotypes of Auditory Hyperreactivity in Autism, ADHD, and the General Population," *Journal of Attention Disorders*, 2026, doi: 10.1177/10870547251361226.

[5] J. L. Drever and A. Hugill, Eds., *Aural Diversity*. London: Routledge, 2023.

[6] W. J. Davies, "Autistic Listening," in *Aural Diversity*, J. L. Drever and A. Hugill, Eds., London: Routledge, 2023, pp. 90–100.

[7] R. C. Kessler *et al.*, "The World Health Organization Adult ADHD Self-Report Scale (ASRS): A Short Screening Scale for Use in the General Population," *Psychological Medicine*, vol. 35, no. 2, pp. 245–256, 2005, doi: 10.1017/S0033291704002892.

[8] C. Allison, B. Auyeung, and S. Baron-Cohen, "Toward Brief Red Flags for Autism Screening: The Short Autism Spectrum Quotient and the Short Quantitative Checklist in 1,000 Cases and 3,000 Controls," *Journal of the American Academy of Child & Adolescent Psychiatry*, vol. 51, no. 2, pp. 202–212, 2012, doi: 10.1016/j.jaac.2011.11.003.

[9] M. Kronlachner and F. Zotter, "Spatial Transformations for the Enhancement of Ambisonic Recordings," in *Proceedings of the 2nd International Conference on Spatial Audio (ICSA)*, Erlangen, Germany, 2014.

[10] F. Zotter and M. Frank, *Ambisonics: A Practical 3D Audio Theory for Recording, Studio Production, Sound Reinforcement, and Virtual Reality*. Cham: Springer, 2019. doi: 10.1007/978-3-030-17207-7.

[11] F. Stevens, D. T. Murphy, and S. L. Smith, "Ecological Validity of Stereo UHJ Soundscape Reproduction," in *Proceedings of the 142nd Audio Engineering Society Convention*, Berlin, Germany, 2017.

[12] Audio Engineering Society, "AES TD1004.1.15-10: Recommendation for Loudness of Audio Streaming and Network File Playback," New York, NY, USA, technical report, 2015.

[13] P. Magrath, S. E. A. Gregory, and W. J. Davies, "Aural Diversity Soundscape Stimuli — FA2026." [Online]. Available: https://doi.org/10.5281/zenodo.20997635

[14] International Organization for Standardization, "ISO 12913-2:2018 Acoustics — Soundscape — Part 2: Data Collection and Reporting Requirements," Geneva, Switzerland, technical report, 2018.

[15] A. Mitchell, F. Aletta, T. Oberman, and J. Kang, "Soundscape Perception Indices (SPIs): Developing Context-Dependent Single Value Scores of Multidimensional Soundscape Perceptual Quality," *Journal of the Acoustical Society of America*, vol. 156, no. 6, pp. 3694–3706, 2024, doi: 10.1121/10.0034417.

[16] G. Fasano and A. Franceschini, "A Multidimensional Version of the Kolmogorov–Smirnov Test," *Monthly Notices of the Royal Astronomical Society*, vol. 225, no. 1, pp. 155–170, 1987.

[17] A. Azzalini, "The Skew-Normal Distribution and Related Multivariate Families," *Scandinavian Journal of Statistics*, vol. 32, no. 2, pp. 159–188, 2005.

[18] Y. Benjamini and Y. Hochberg, "Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing," *Journal of the Royal Statistical Society: Series B (Methodological)*, vol. 57, no. 1, pp. 289–300, 1995.

[19] P. Virtanen and others, "SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python," *Nature Methods*, vol. 17, pp. 261–272, 2020, doi: 10.1038/s41592-019-0686-2.

[20] A. Mitchell, F. Aletta, and J. Kang, "How to Analyse and Represent Quantitative Soundscape Data," *JASA Express Letters*, vol. 2, no. 3, p. 37201, 2022, doi: 10.1121/10.0009794.

[21] W. Dunn, "The Impact of Sensory Processing Abilities on the Daily Lives of Young Children and Their Families: A Conceptual Model," *Infants & Young Children*, vol. 9, no. 4, pp. 23–35, 1997.

[22] G. Söderlund, S. Sikström, and A. Smart, "Listen to the Noise: Noise Is Beneficial for Cognitive Performance in ADHD," *Journal of Child Psychology and Psychiatry*, vol. 48, no. 8, pp. 840–847, 2007.

[23] F. Happé and U. Frith, "The Weak Coherence Account: Detail-Focused Cognitive Style in Autism Spectrum Disorders," *Journal of Autism and Developmental Disorders*, vol. 36, no. 1, pp. 5–25, 2006, doi: 10.1007/s10803-005-0039-0.

[24] L. Mottron, M. Dawson, I. Soulières, B. Hubert, and J. A. Burack, "Enhanced Perceptual Functioning in Autism: An Update, and Eight Principles of Autistic Perception," *Journal of Autism and Developmental Disorders*, vol. 36, no. 1, pp. 27–43, 2006, doi: 10.1007/s10803-005-0040-7.

[25] M. Zhu, F. Chen, Y. Zhang, Z. Zhang, and C. Guo, "Auditory Global-Local Processing in Autism Spectrum Disorder: A Systematic Review and Meta-Analysis," *Journal of Autism and Developmental Disorders*, 2025, doi: 10.1007/s10803-025-06901-0.

[26] T. J. Cox, "The Effect of Visual Stimuli on the Horribleness of Awful Sounds," *Applied Acoustics*, vol. 69, no. 4, pp. 691–703, 2008, doi: 10.1016/j.apacoust.2007.02.010.