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ORIGINAL ARTICLE

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Emotional responses to environmental sounds: associations with self-reported well-being in adults reporting minimal hearing difficulties, some hearing difficulties, and hearing aid use

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ABSTRACT

Objective: The study investigated the association between emotional responses to environmental sounds and various well-being indicators.

Design: Participants rated 120 environmental sounds on valence and arousal and completed questionnaires assessing affect in daily life, emotional communication in hearing, pleasantness of everyday listening, and mental well-being.

Study sample: Forty hearing aid (HA) users and 90 individuals with self-reported normal hearing (NH) were recruited. The NH group was divided into two subgroups based on their hearing difficulties score on the Hearing-Related Lifestyle Questionnaire: 36 with no-to-minimal hearing difficulties ("NH no-difficulty" group) and 54 with some hearing difficulties ("NH some-difficulty" group).

Results: NH some-difficulty group reported greater challenges in emotional communication, reduced pleasantness of everyday listening, and poorer mental well-being compared to the NH no-difficulty group. HA users showed greater difficulties in emotional communication and lower listening enjoyment than both NH groups. Higher sensitivity to both positive and negative emotional sounds was linked to greater emotional communication difficulties. A more positive perception of typically negative sounds was associated with a more pleasant experience in everyday listening situations and better mental well-being.

Conclusions: Targeting how individuals interpret and manage emotional reactions to sound may help improve well-being outcomes, particularly for individuals with hearing difficulties.

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Emotion; environmental sounds; well-being; hearing loss

Introduction

Hearing loss is a widespread chronic health condition with consequences extending to various aspects of health and well-being that go beyond speech understanding. Hearing loss significantly impacts an individual's ability to hear and communicate, which in turn can negatively affect their social participation, personal relationships, and emotional well-being (Bennett et al. 2022). Individuals with hearing loss report negative social consequences, including social overwhelm, fatigue, a sense of loss, and exclusion (Bennett et al. 2022). This impaired ability to communicate often leads to avoidance of and withdrawal from potentially difficult social situations, which can stem from feelings of embarrassment or shame (Bennett et al. 2022; Heffernan et al. 2016). This withdrawal can in turn result in social disconnection, isolation, and loneliness, which are recognised as significant threats to both physical (Gopinath et al. 2013; Perissinotto, Stijacic Cenzer, and Covinsky 2012; Tomaka, Thompson, and Palacios 2006; Uchino, Cacioppo, and Kiecolt-Glaser 1996; Zhang et al. 2007) and mental health (Bassuk, Glass, and Berkman et al. 1999; Wang et al. 2002; Wilson et al. 2007).

Hearing rehabilitation devices, such as hearing aids, are primary interventions aimed at supporting hearing function (Ferguson et al. 2017). Their use has been generally associated with improved social outcomes, including higher social quality of life and decreased perceived social handicap (Hori et al. 2025). Research

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indicates that hearing aid use can lead to less anxiety and depression (Choi et al. 2016; Joore et al. 2002; Mulrow et al. 1990), and improved health-related quality of life (McArdle et al. 2005). Despite these benefits, evidence suggests that hearing aids alone may not fully support individuals in achieving their personal listening and communication goals (Boothroyd 2007; Hickson et al. 2014). Furthermore, while some research points to a moderate decrease in loneliness among hearing aid users, findings remain inconclusive due to the limited scope of studies on this topic (Hori et al. 2025). Notably, individuals using hearing aids may still face challenges in emotional communication compared to those with normal hearing (Singh et al. 2019).

While extensive research has explored the emotional and social impact of hearing loss, less is known about the direct association between individuals' emotional responses to various environmental sounds and their overall well-being. Emotional response to sound is commonly described along two primary dimensions: valence, which reflects the pleasantness of a sound, and arousal, which indicates the intensity or activation level it elicits (Russell 1980). Previous studies on emotional responses to sound have primarily focused on how hearing loss affects these responses, showing, for instance, a reduced range of valence ratings for emotional stimuli in individuals with hearing loss compared to those with normal hearing, indicating they are less affected by both pleasant and unpleasant emotional stimuli (Picou 2016). This degradation in emotional responses to sound does not seem to be improved by hearing aids (Tawdrous et al. 2022). Furthermore, the diminished ability to experience pleasant emotional responses to sounds has been linked to greater social disconnectedness and loneliness (Picou and Buono 2018). As discussed above, these forms of isolation and reduced social engagement, in turn, are recognised as significant contributors to a decline in various aspects of well-being. This suggests that emotional responses to sound may play a critical, albeit underexplored, role in the broader well-being consequences of hearing loss.

Research indicates that both musical and non-musical sounds—such as those from nature or soft human voices—can positively influence emotional resilience, well-being, and stress reduction (Feng and Wang 2025; Saskovets, Saponkova, and Liang 2025). Saskovets, Saponkova, and Liang (2025) emphasised the complex role of individual factors in determining the effectiveness of sound therapy, highlighting how personal preferences, emotional engagement, and past experiences shape responses to sound. Then, if individuals' emotional reactions to sounds—whether positive or negative—can predict their overall well-being, this insight could guide the development of interventions aimed at enhancing how people engage with everyday sounds. While this has implications for everyone, it may be especially valuable for people with hearing loss, including hearing aid users, who may require additional support throughout their rehabilitation process. By adopting a holistic perspective, these interventions could enhance quality of life and help users derive greater benefit from their hearing aids as they reacquaint themselves with the sounds of the world around them.

To that end, the primary purpose of this study was to investigate whether emotional responses to sound (valence and arousal) can predict various well-being outcomes, including positive affect and negative affect in daily life, emotional communication in hearing, pleasantness of everyday listening situations, and mental well-being. A secondary aim was to relate the measured well-being aspects and the measured emotional responses to sound to hearing aid use and to hearing difficulties experienced in everyday listening situations.

Methods

A waiver of ethical review for conducting the study was granted by the Research Ethics Committee of the Capital Region of Denmark (case no. 21035215). All the participants were informed about the purpose of the study and how their data would be handled in writing, and they gave their written consent to participate before entering the study.

The study was conducted online. The listening task and the questionnaires were implemented in PsychoPy (Peirce et al. 2019)—an open-source software package used to design and run experiments in psychology, neuroscience, linguistics and related fields—and run online via PsychoPy's web platform, Pavlovia (https://pavlovia.org/). Participants were recruited through the Prolific platform (www.prolific.com), which also provided demographic information and directed participants to the online study.

Participants

Two groups of participants were recruited: self-reported normal hearing and hearing aid users. Participants were recruited online via Prolific using this platform's built-in profile pre-screening feature. At the profile level, Prolific includes a general self-

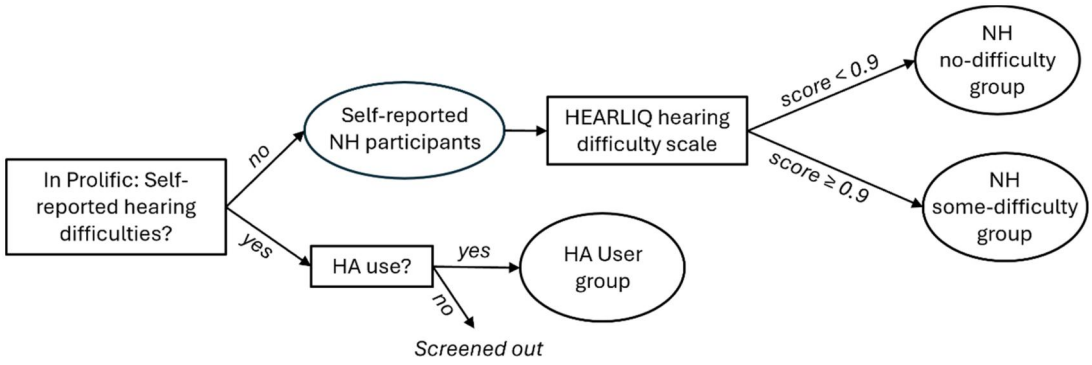

Figure 1. Recruitment and group assignment. Abbreviations: NH, normal hearing; HA, hearing aid; NH no-difficulty, self-reported normal-hearing participants with no (minimal) hearing difficulties according to their HEARLI-Q hearing difficulty score; NH some-difficulty, self-reported NH participants with hearing difficulties according to their HEARLI-Q hearing difficulty score.

report screening question about hearing difficulty; it does not include a field confirming hearing aid use. Hence, for the normal hearing recruitment stream, we recruited participants who, at the Prolific profile level, self-reported normal hearing (i.e., did not indicate hearing difficulties). Hearing aid users were recruited from the pool of participants who at the Prolific profile level self-reported hearing difficulties. Because Prolific does not maintain a verified hearing aid use screening criterion, we included a confirmation question "I am a hearing aid user" (yes/no) at the beginning of the PsychoPy script. Participants responding "no" were screened out and the online study terminated.

Other hearing-status constellations (e.g., individuals with diagnosed but unaided hearing loss, or individuals who use hearing aids despite perceiving their hearing as normal) were not captured within the recruitment framework and therefore may not be represented in our dataset. Eligibility criteria for both groups included being between 40 and 80 years of age and fluent in English, as restricting the sample to this age range helped ensure greater comparability between hearing aid users and participants with self-reported normal hearing by reducing the risk of age-related confounds that would arise from including younger adults, who are less likely to use hearing aids. Participants were excluded if they failed attention check questions or completed the study in under 25 minutes, as such behaviour could indicate inattentive responding. Details about the attention checks are presented in the *Questionnaires* section below.

One-hundred-forty-four participants with self-reported normal hearing and 65 hearing aid users were recruited. Thirty-two participants with self-reported normal hearing and 15 hearing aid users were excluded because they experienced technical issues with the platform which hindered them from successfully completing the study. Further 22 participants with self-reported normal hearing and 10 hearing aid users were excluded because they failed attention checks. A total of 90 participants with self-reported normal hearing (age: 54 ± 9; 54 females, 36 males) and 40 hearing aid users (age: 62 ± 8; 20 females, 20 males) successfully completed the study. The normal hearing group was further subdivided based on scores from the Hearing-Related Lifestyle Questionnaire (HEARLI-Q). Participants with a HEARLI-Q hearing difficulty score below 0.9 were classified as self-reported normal hearing participants with no (minimal) hearing difficulties (NH no-difficulty group; $N = 36$; mean age = 54 ± 7 years; 26 females, 10 males), while those with scores $\geq$ 0.9 were classified as self-reported normal hearing participants with some hearing difficulties (NH some-difficulty group; $N = 54$; mean age = 53.2 ± 9.4 years; 27 females, 27 males). These group labels are used throughout the manuscript. The recruitment and assignment of participants into three groups is schematised in Figure 1. A detailed description of the HEARLI-Q is provided below in the *Questionnaires* section.

The study flow

Participants were instructed to use headphones for the listening part of the study. They were also instructed that if they did not have headphones they could use earbuds, but headphones were preferred. Hearing aid users were further instructed to wear and turn on their hearing aids. The study flow is depicted in Figure 2 and described in detail in subsections below.

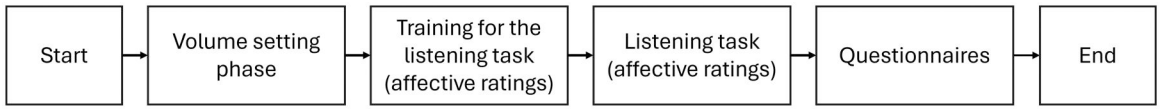

Figure 2. The study flow.

The listening task

Participants began by adjusting their computer volume for the listening test. To do this, a looped sequence of three sound tokens from the Marcell et al. (2000) database, spanning the full range of sound intensities used in the study, was played. Participants were instructed to set their volume to a level that felt comfortable for all three sounds.

Following this, participants received instructions for the main task. They were informed that they would be rating a series of sounds based on their emotional responses, specifically along two dimensions: valence (how pleasant or unpleasant the sound felt) and arousal (how calming or exciting the sound felt). To facilitate these ratings, the Self-Assessment Manikin (SAM) scale (Bradley and Lang 1994) was used. This scale features five pictorial figures per dimension, visually representing a range of emotional states. The valence scale appeared at the top (from very unhappy to very happy), and the arousal scale below (from very calm to very excited). Each dimension was rated on a 9-point Likert scale (1 = low, 9 = high), with endpoints aligned to the extreme figures. Higher scores indicated more positive valence or greater arousal. The concepts of valence and arousal were explained with examples. For valence, participants were told that, if a sound like birdsong was perceived as very pleasant, they should select the figure on the right; if a loud siren was perceived as very unpleasant, they should choose the figure on the left. For arousal, they were told that a gentle breeze might be rated as calming (left), whereas a loud explosion might be rated as highly exciting (right). It was emphasised that valence and arousal are independent dimensions—a sound could be both high in arousal and either pleasant (e.g., laughter, fast music) or unpleasant (e.g., a child crying, a gunshot).

The auditory stimuli were drawn from the Marcell et al. (2000) database, which includes 120 sounds varying in valence and arousal. These sounds range in duration from brief events (e.g., a cork popping, 137 ms) to longer recordings (e.g., a helicopter, 5.937 s), preserving their natural temporal characteristics. Before the main task, participants completed a brief familiarisation phase, rating three practice sounds (from an internal environmental sound database) on both emotional dimensions. They then proceeded to rate all 120 sounds, presented in random order without replacement. A one-minute break was provided after every 30 sounds. If a participant did not hear a sound, they could select the option "I did not hear the sound" to skip it.

Questionnaires

Following the listening task, participants completed the questionnaires described below. To ensure participants were paying attention and not clicking randomly through response alternatives, three attention check items were embedded within the questionnaires. The exact wording of these attention checks is presented in Supplemental Table 1. Participants who failed any of these checks were excluded from the final analyses.

- Positive and Negative Affect Schedule (PANAS) (Watson, Clark, and Tellegen 1988): 20 item questionnaire that consists of 10 items for positive affect and 10 items for negative affect. Respondents are asked to rate each item on a 5-point Likert scale (1 = very slightly or not at all, 5 = extremely), based on how they felt over the past week. The positive and negative affect scores are calculated by adding up the 10 items within each subscale. Each subscale ranges from 10 to 50 with higher scores indicating greater intensity of that affect. The scales are shown to be highly internally consistent, largely uncorrelated, and stable at appropriate levels over a 2-month time period (Watson, Clark, and Tellegen 1988).
- Emotional Communication in Hearing (EMO-CHeQ) (Singh et al. 2019): a questionnaire designed to assess experiences of hearing and handicap when listening to signals that contain vocal emotion information. The EMO-CHeQ consists of 16 items, each rated on a 5-point Likert scale from 'strongly disagree' to 'strongly agree.' The EMO-CHeQ total score is calculated by computing the mean score across all 16 items. The questionnaire has been shown to be a reliable and ecologically valid measure to assess experiences of hearing and handicap when listening to signals

that contain vocal emotion information (Singh et al. 2019).

- Hearing-Related Lifestyle Questionnaire (HEARLI-Q) (Lelic et al. 2022): This questionnaire evaluates hearing experiences across 23 everyday listening situations, with participants rating each on three 5-point Likert scales: frequency of occurrence (0 = never to 4 = daily), importance to hear well in the situation (0 = not important to 4 = extremely important), and hearing difficulty (0 = not difficult to 4 = extremely difficult). These ratings yield three composite scores: richness of hearing-related lifestyle and hearing demand (both ranging from 0 to 100), and hearing difficulty (ranging from 0 to 4). Richness of hearing-related lifestyle is calculated as (sum of occurrence scores/96) × 100; hearing demand is calculated as (sum of [occurrence × importance]/384) × 100; and hearing difficulty is calculated as the average of the difficulty scores across the 23 listening-situation items. Higher scores reflect a richer lifestyle, greater hearing demands, and increased difficulty. The questionnaire has demonstrated excellent short-term and good-to-excellent longer-term reliability (Lelic et al. 2022). For the present study, a fourth dimension, pleasantness, was added, with participants rating how pleasant each situation typically feels on a 9-point scale (1 = extremely unpleasant to 9 = extremely pleasant, with 5 as neutral); an overall pleasantness score was calculated as the average across all situations.
- The World Health Organisation-Five Well-Being Index (WHO-5)—a questionnaire designed to assess mental well-being. It includes five statements that reflect the respondent's experiences over the past two weeks. Each item is rated on a 6-point scale ranging from 0 to 5, where higher scores represent greater well-being. The total score, ranging from 0 to 25, is obtained by summing the scores of all five items.

Data analysis

Continuous and interval data are presented as mean ± standard deviation unless otherwise noted.

Valence and arousal categories were derived using normative emotional response data to Marcell sounds in older adults (Lelic and Marmel 2026). Sounds that received an average valence rating of 6 or higher (out of 9) were defined as positive-valence stimuli, and sounds that received an average rating of 4 or lower were defined as negative-valence stimuli. Similarly, high-arousal stimuli were the ones receiving an average arousal rating of 6 or above (out of 9), and low-arousal stimuli received an average of 4 or below.

To examine whether emotional responses to sound could predict well-being outcomes, five separate regression analyses were conducted - one for each of the following outcomes: positive affect and negative affect (PANAS), pleasantness of everyday listening situations (HEARLI-Q), emotional communication in hearing (EMO-CHeQ), and mental well-being (WHO-5). Each model initially included the following predictors: age, gender, hearing difficulty (HEARLI-Q), hearing aid use status (user vs. non-user), positive valence, negative valence, high arousal, and low arousal. A top-down model selection approach was applied, beginning with the removal of the least significant predictor ($p > .10$). After each removal, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values were compared between models. If the revised model showed improvement, the next least significant predictor ($p > .10$) was removed, and AIC/BIC comparisons were repeated. This iterative process continued until all remaining predictors had p-values $\leq .10$ or until AIC/BIC indicated no further model improvement. Final models are presented in the results section.

Group comparisons for age, HEARLI-Q, PANAS, EMO-CHeQ, WHO-5, valence, and arousal scores were conducted using analysis of variance (ANOVA) when data met assumptions of approximate normality. If normality was not met, the Kruskal-Wallis test was applied instead. The specific statistical test used is noted in the results section. Where significant main effects were observed, Bonferroni-corrected post-hoc pairwise comparisons were performed to account for multiple testing. For group comparisons of the gender ratio, the chi-squared (χ^2) test was used.

All analyses were done using Stata version 15 (StataCorp, College Station, TX, USA).

Results

Primary aim: emotional responses to sound as predictors of well-being

Results of the regression analyses examining whether emotional responses to sound predict various aspects of well-being are presented in Table 1. For positive affect, lower arousal ratings in response to low-arousal stimuli were significantly associated with greater positive affect, suggesting that individuals who exhibit less reactivity to calming auditory stimuli may experience enhanced positive mood. Neither age nor emotional responses to negative-valence stimuli significantly

Table 1. Results of regression analyses examining whether emotional responses to sound can predict well-being.

Outcome	Predictor	β	95% CI	*p*-value	R^2
Positive Affect (PANAS Scale)	Age	0.12	−0.02, 0.26	.100	0.09
	Negative Valence	1.34	−0.25, 2.94	.098	
	Low Arousal	−1.20	−2.16, −0.23	***.016****	
Negative Affect (PANAS Scale)	Age	−0.19	−0.31, −0.06	***.003****	0.14
	Negative Valence	−1.42	−3.14, 0.31	.106	
	High Arousal	0.89	−0.11, 1.89	.081	
Pleasantness (HEARLI-Q Scale)	Age	−0.01	−0.03, 0.00	.080	0.49
	Hearing Difficulty	−1.20	−1.50, −0.91	***<.001****	
	Negative Valence	0.20	0.02, 0.37	***.027****	
	Low Arousal	−0.08	−0.19, 0.03	.136	
Emotional Communication in Hearing (EMO-CHeQ Scale)	HA User	0.62	0.29, 0.95	***<.001****	0.32
	Hearing Difficulty	0.44	0.14, 0.74	***.004****	
	Positive Valence	0.17	0.05, 0.29	***.006****	
	Negative Valence	−0.22	−0.38, −0.06	***.007****	
	Low Arousal	0.08	−0.01, 0.18	.086	
Mental Well-Being (WHO-5 Scale)	Hearing Difficulty	−1.38	−3.60, 0.84	.221	0.12
	Negative Valence	1.59	0.27, 2.90	***.018****	
	High Arousal	−0.77	−1.48, −0.07	***.031****	

Significant differences are depicted in bold and italic in the "*p*-value" column.
Abbreviations: PANAS, Positive and Negative Affect Schedule; HEARLI-Q, Hearing-Related Lifestyle Questionnaire; EMO-CHeQ, Emotional Communication in Hearing Questionnaire; WHO-5 - World Health Organisation Well-Being Index.

predicted positive affect. In contrast, negative affect was significantly predicted by age, with older participants reporting lower levels of negative affect. Emotional responses to sounds—regardless of valence or arousal—did not significantly contribute to the prediction of negative affect.

Regarding pleasantness in everyday listening situations, higher valence ratings of negative-valence stimuli were associated with higher ratings of pleasantness. Greater hearing difficulty was linked to reduced perceived pleasantness.

For EMO-CHeQ, higher valence ratings of positive-valence stimuli and lower valence ratings of negative-valence stimuli were associated with higher reported handicap in emotional communication. Additionally, both hearing aid use status and hearing difficulty were positively associated with the EMO-CHeQ scores, which mirrors the findings of Singh et al. (2019) (their figure 1). These two results indicate that auditory and emotional factors jointly influence perceived challenges in emotional communication.

Finally, the WHO-5 scores were positively associated with emotional responses to negative-valence stimuli and negatively associated with responses to high-arousal stimuli. These findings suggest that individuals who respond more positively to negative auditory stimuli and less intensely to arousing sounds may report better overall mental well-being.

Secondary aim: group comparisons of well-being metrics and emotional responses

Group characteristics for all collected variables are presented in Table 2 and significant differences on the questionnaires are depicted in Figure 3. The three groups showed significant differences in Age, Hearing Difficulty, Pleasantness of Everyday Listening Situations, Emotional Communication in Hearing, and Mental Well-Being. Post-hoc comparisons indicated that the hearing aid user group was older than the two other groups (NH no-difficulty: contrast = 8.25 [95% CI: 3.34, 13.17], t = 4.07, p <.001; NH some-difficulty: contrast = 9.23 [95% CI: 4.77, 13.70], t = 5.02, p < .001). In terms of hearing difficulty, both the hearing aid user group (contrast = 0.97 [95% CI: 0.74, 1.20], t = 10.19, p < .001) and the NH some-difficulty group (contrast = 0.67 [95% CI: 0.45, 0.89], t = 7.52; p < .001) reported greater challenges than the NH no-difficulty group, with the hearing aid user group reporting even greater hearing difficulty than the NH some-difficulty group (contrast = 0.30 [95% CI: 0.09, 0.51], t = 3.47, p = .002). Regarding the pleasantness of everyday listening situations, both the hearing aid user group (contrast = −1.19 [95% CI: −1.73, −0.66], t = −5.43, p < .001) and the NH some-difficulty group (contrast = −0.69 [95% CI: −1.19, −0.19], t = −3.34, p = .003) rated these situations as less pleasant than the NH no-difficulty group, with the hearing aid user group reporting even lower levels of pleasantness than the NH some-difficulty group (contrast = −0.51 [95% CI: −0.99, −0.02], t = −2.54, p = .037). For emotional communication in hearing, both the hearing aid user group (contrast = 1.17 [95% CI: 0.74, 1.59], t = 6.61, p < .001) and the NH some-difficulty group (contrast = 0.55 [95% CI: 0.15, 0.95], t = 3.31, p = .004) experienced more limitations compared to the NH no-difficulty group, and the hearing aid user group reported greater

Table 2. Group data for all the collected variables.

Variable	NH no-difficulty group (N = 36)	NH some-difficulty group (N = 54)	Hearing aid user group (N = 40)	Statistic and *p*-value
Age[a]	54.22 ± 8.70	53.24 ± 9.45	62.48 ± 8.00	***$F_{2, 127} = 14.81$ $p < .0001$****
Gender (# of females)[b]	26	27	20	$\chi^2 = 5.22$ $p = .073$
Hearing-Related Lifestyle (HEARLI-Q Scale)[a]	53.71 ± 9.44	50.40 ± 12.42	52.69 ± 9.39	$F_{2, 127} = 1.13$ $p = .326$
Hearing Demands (HEARLI-Q Scale)[a]	37.74 ± 8.78	32.61 ± 10.66	34.39 ± 10.62	$F_{2, 127} = 2.76$ $p = .067$
Hearing Difficulty (HEARLI-Q Scale)[a]	0.69 ± 0.17	1.36 ± 0.36	1.66 ± 0.60	***$F_{2, 127} = 54.30$ $p < .0001$****
Pleasantness of Everyday Listening Situations (HEARLI-Q Scale)[a]	5.69 ± 0.68	5.00 ± 0.97	4.50 ± 1.14	***$F_{2, 127} = 14.81$ $p < .0001$****
Positive Affect (PANAS Scale)[a]	32.83 ± 7.82	30.20 ± 7.09	32.66 ± 8.02	$F_{2, 127} = 2.76$ $p = .177$
Negative Affect (PANAS Scale)[c]	17.92 ± 8.23	19.15 ± 7.54	16.51 ± 7.62	$\chi^2 = 4.88$ $p = .087$
EMO-CHeQ[a]	1.89 ± 0.66	2.43 ± 0.80	3.05 ± 0.81	***$F_{2, 127} = 12.98$ $p < .0001$****
Mental Well-Being (WHO-5 Scale)[a]	15.14 ± 5.00	11.67 ± 5.22	13.90 ± 6.47	***$F_{2, 127} = 4.50$ $p = .013$****
Positive Valence[a]	7.12 ± 0.84	6.72 ± 0.83	6.90 ± 1.19	$F_{2, 127} = 1.89$ $p = .155$
Negative Valence[a]	3.03 ± 0.72	3.04 ± 0.78	3.32 ± 1.05	$F_{2, 127} = 1.52$ $p = .222$
High Arousal[c]	6.66 ± 1.33	6.85 ± 1.02	6.13 ± 1.53	$\chi^2 = 5.45$ $p = .066$
Low Arousal[c]	3.17 ± 1.06	3.86 ± 1.42	3.89 ± 1.60	$\chi^2 = 5.39$ $p = .068$

Significant differences are depicted in bold and italic in the "Statistic and *p*-value" column.
[a]ANOVA test was conducted.
[b]Chi-squared test was conducted.
[c]Kruskall-Wallis test was conducted.
Abbreviations: HEARLI-Q, Hearing Related Lifestyle Questionnaire; PANAS, Positive and negative affect schedule; EMO-CHeQ, Emotional Communication in Hearing Questionnaire; WHO-5, World Health Organisation Well-Being Index; NH no-difficulty, self-reported normal hearing participants with no (minimal) hearing difficulties according to their HEARLI-Q score; NH some-difficulty, self-reported normal hearing participants with hearing difficulties according to their HEARLI-Q score.

limitations than the NH some-difficulty group (contrast = 0.62 [95% CI: 0.23, 1.01], t = 3.87, $p = .001$). Finally, the NH some-difficulty group had lower mental well-being scores than the NH no-difficulty group (contrast = −3.47 [95% CI: −6.38, −0.56], t = −2.89, $p = .013$), while no significant differences were observed between the hearing aid user group and either of the two other groups.

Discussion

This study aimed to investigate the association between individuals' emotional responses to environmental sounds and their overall well-being, while also conducting a group comparison of well-being aspects and emotional responses among participants with no (minimal) hearing difficulties, some hearing difficulties, and hearing aid users. Our findings reveal important insights into the multifaceted impact of hearing status on well-being and highlight the predictive power of emotional responses to sound.

Emotional responses to sound as predictors of well-being

Our results demonstrate that emotional responses to sound are significantly associated with several well-being outcomes. Notably, individuals who rated typically negative sounds more positively reported greater pleasantness in everyday listening situations and better mental well-being. This aligns with previous research suggesting that emotional resilience and adaptive emotional processing can buffer against stress and enhance psychological health (Feng and Wang 2025; Saskovets, Saponkova, and Liang 2025). The ability to reframe or reinterpret negative auditory stimuli may reflect a broader emotional flexibility that supports well-being. This notion of emotional flexibility is also relevant in the context of misophonia, a condition characterised by intense negative emotional reactions to specific everyday sounds. Research on misophonia has highlighted how heightened emotional reactivity to sound is related with reduced quality of life and difficulty with emotional regulation (Dibb and Golding 2022; Guetta et al. 2022, 2024;

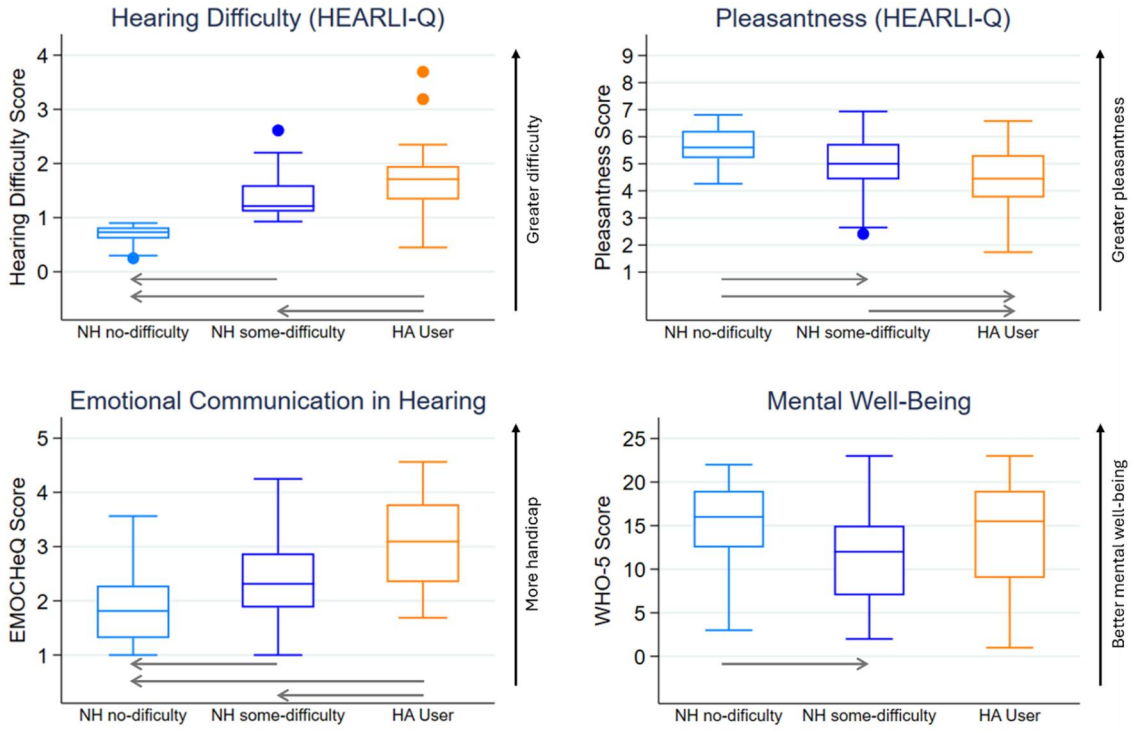

Figure 3. Group-level questionnaire results showing statistically significant effects. Arrows indicate significant differences between groups. The arrowhead points to the group with a lower score compared to the group from which the arrow originates. Abbreviations: HEARLI-Q, hearing-related lifestyle questionnaire; EMO-CHeQ, emotional communication in hearing questionnaire; WHO-5, World Health Organisation Well-Being Index; NH no-difficulty, self-reported normal hearing participants with no (minimal) hearing difficulties according to their HEARLI-Q score; NH some-difficulty, self-reported normal hearing participants with hearing difficulties according to their HEARLI-Q score; HA, hearing aid.

Kumar et al. 2017; Schröder, Vulink, and Denys 2013). These findings emphasise the importance of developing strategies to modulate emotional responses to auditory stimuli. In this light, our results may reflect a continuum of auditory emotional reactivity, with misophonia representing one extreme. Individuals who are able to reinterpret or downregulate negative sound experiences may possess a form of emotional resilience that protects against such maladaptive responses.

Conversely, heightened sensitivity to both positive and negative emotional sounds was associated with greater difficulty in emotional communication, as measured by the EMO-CHeQ. This finding suggests that individuals who are more emotionally reactive to sound may experience challenges in decoding or expressing emotional cues in auditory contexts. Misophonia research similarly points to disruptions in social and emotional functioning, likely due to the role that others play in triggering the individual with misophonia (Dibb and Golding 2022). These parallels suggest that emotional reactivity to sound may interfere with effective emotional communication.

Finally, lower arousal responses to low-arousal sounds were linked to higher positive affect on the PANAS scale, indicating that reduced reactivity to low-arousal auditory stimuli may be beneficial for mood regulation. This relationship may be partly explained by the negative association between valence and arousal to environmental sounds - calming sounds tend to be perceived as more pleasant (Hocking et al. 2013; Lelic and Marmel 2026). Supporting this, a recent review describes how low-arousal positive affect (LAPA), such as feelings of calm and relaxation, is distinctly linked to emotional well-being and psychological resilience (McManus, Nakamura, and Siegel 2024).

Although our regression analyses identify statistical predictors of well-being outcomes, these analyses do not establish causal direction. It is also important to acknowledge that mental well-being may not function solely as an outcome in these relationships but could also act as a potential confounder or moderator. Although the present data did not reveal group differences in emotional responses to sound, and hearing difficulty did not significantly predict WHO-5 scores in the regression model, it remains plausible that broader psychological factors influence how individuals appraise or cope with everyday listening situations. As such, mental well-being may shape, amplify, or

attenuate the association between hearing-related experiences and emotional responses to sound. The term "predictor" is used in the current work in the statistical sense, indicating variables that explain variance in the model. The relationships between emotional responses to sound and well-being are likely bidirectional. On one hand, emotional reactivity to sound may shape aspects of well-being. On the other hand, previous research indicates that psychological states and hearing-related factors can influence emotional processing of auditory stimuli. For example, individuals with unaided hearing loss report lower valence ratings of everyday sounds (Holman and Naylor 2025), exhibit a narrower range of valence responses to environmental sounds (Picou 2016), and appear less affected by emotional auditory cues than their peers with normal hearing (Husain, Carpenter-Thompson, and Schmidt 2014). Neuroimaging work further indicates that listeners with hearing loss engage more prefrontal and less amygdalar activity when processing emotional sounds, suggesting cognitive and behavioural consequences of hearing loss for emotional auditory processing (Husain, Carpenter-Thompson, and Schmidt 2014). Because the present dataset is cross-sectional, we cannot disentangle these potential pathways, and longitudinal or experimental research will be necessary to clarify the temporal and causal dynamics underlying these associations.

Irrespective of directionality, our findings highlight the potential value of incorporating emotional response training or sound-based emotional regulation strategies into hearing rehabilitation programs. Interventions that promote positive or flexible engagement with environmental sounds - such as sound therapy, auditory mindfulness, or techniques adapted from misophonia treatment - may enhance emotional communication, increase the enjoyment of everyday listening situations, and support overall mental well-being.

Group comparisons and hearing difficulty impact

The group comparisons demonstrated that individuals with self-reported normal hearing but some hearing difficulty in everyday listening situations, as well as hearing aid users, faced greater challenges in emotional communication and rated everyday listening situations as less pleasant. These findings align with previous research suggesting that hearing aids alone may not fully address the emotional and social aspects of hearing difficulties (Boothroyd 2007; Hickson et al. 2014; Singh et al. 2019). Our findings reinforce the importance of adopting a holistic approach to hearing care - one that extends beyond audiological measures and technological solutions. It is crucial for hearing care professionals to take an individualised approach that considers the social and emotional well-being of their clients in clinical settings (Timmer et al. 2024).

Interestingly, while the NH some-difficulty group showed lower mental well-being scores than the NH no-difficulty group, no significant difference in mental well-being was observed between hearing aid users and either self-reported normal hearing group. This suggests that although hearing aids may not fully resolve emotional communication issues or enhance the enjoyment of daily listening experiences, they could still contribute positively to mental health. This aligns with previous research linking hearing aid use to improved mental well-being (Choi et al. 2016; Joore et al. 2002; Mulrow et al. 1990; Zhang et al. 2024). Moreover, past studies have associated hearing loss with poorer psychological outcomes, such as increased depression and emotional distress (Scoresby et al. 2025; Singh, Gupta, and Rao 2023; Sun et al. 2025). What is particularly noteworthy in this study is that the HEARLI-Q revealed that many of the participants who self-reported having normal hearing still reported hearing difficulties when asked about their hearing experiences in everyday life situations, and these difficulties were associated with reduced mental well-being. This highlights the need for a broader evaluation of hearing challenges - one that does not rely solely on self-reported hearing loss or clinical thresholds. By identifying and addressing subtle hearing difficulties early, clinicians may be able to intervene sooner, potentially improving emotional outcomes and mitigating the risk of mental health decline.

No significant differences were observed between groups in their valence and arousal ratings of sounds, indicating that emotional responses to sound may remain intact regardless of hearing status. The unaffected arousal ratings are in line with previous work (Picou 2016; Picou et al. 2021; Tawdrous et al. 2022). The finding of unaffected valence ratings, however, contrasts with earlier studies, which reported that individuals with hearing loss tend to show a narrower range of valence ratings—typically rating pleasant sounds as less pleasant (Picou 2016; Picou et al. 2021)—and that hearing aids offer limited improvement in these affective evaluations (Picou et al. 2021; Tawdrous et al. 2022). One possible explanation for this discrepancy lies in the duration of the sound clips used. Previous studies employed very short, uniform

clips (1.5 seconds), whereas the current database includes sounds ranging from 137 milliseconds to 5.9 seconds (with average duration across the 120 sounds being 2.4 seconds), depending on the sound type. Supporting this argument, Marcell et al. (2000) found a positive correlation between sound length and pleasantness ratings, suggesting that longer sounds tend to be rated more positively. Another factor to consider is the study setting. While online studies using participants' own equipment may differ from controlled laboratory environments, we compared our online data with responses from 30 hearing aid users tested in our laboratory. The results showed no notable differences between the two settings (unpublished data; see Supplementary Figure 1). This suggests that conducting the study in a controlled setting would likely not have altered the conclusions. Based on the current findings, hearing status and hearing aid use do not appear to significantly influence affective responses to environmental sounds. However, this study does not address the potential effects of varying degrees of untreated hearing loss as determined by objective measures.

Study considerations

As mentioned earlier, the study relied on online testing, which may introduce variability in sound presentation. However, we do not view this as a significant limitation. Besides the affective ratings closely resembling those collected in our laboratory, previous research by Picou and Buono (2018) showed that emotional responses to environmental sounds were not significantly influenced by the type of transducer (headphones vs. loudspeakers) or by moderate variations in stimulus intensity (50–65 dBA). Based on this evidence, we believe that any differences in participants' listening setups likely had minimal, if any, impact on the overall findings.

Although we relied on self-reported normal hearing rather than objective audiometric assessments - an approach that may introduce some bias, particularly given the older age range of our sample - this method is not without precedent. For instance, the Australian Blue Mountains Hearing Study (Sindhusake et al. 2001) found that 82% of individuals who reported no hearing difficulties were confirmed to have normal hearing through standard audiometry. These findings suggest that, despite its limitations, self-report can serve as a reasonably reliable proxy for hearing status in studies where formal testing is not feasible. Furthermore, we divided the self-reported normal hearing group based on hearing difficulty status as measured by the HEARLI-Q. Here, we used the HEARLI-Q in a manner that has not yet been formally validated. We consider this approach justified based on the intended purpose of the questionnaire and on the following observations: (1) Lelic, Herrlin, et al. (2025) demonstrated that scores on the HEARLI-Q hearing difficulty scale decrease from moderate to slight in new hearing aid users after fitting; (2) studies of experienced hearing aid users show slight-to-moderate hearing difficulty scores (Lelic, Nielsen, et al. 2024; Lelic et al. 2024); and (3) unpublished HEARLI-Q data from 10 adults with confirmed clinically normal hearing show an average hearing-difficulty score of 0.4 ± 0.3 ($0 =$ no difficulty, $1 =$ slight difficulty). Together with the alignment between HEARLI-Q and EMO-CHeQ scores - where the latter have been shown to be sensitive to differences between listeners with normal and impaired hearing - these findings suggest that our division based on HEARLI-Q hearing-difficulty scores is reasonable for the purpose of the present study.

In addition, we did not collect information on tinnitus, hyperacusis, or misophonia. These conditions may influence emotional responses to sound as well as self-reported hearing difficulty, and the absence of these data represents a limitation that may have introduced unmeasured variability. Future work would benefit from screening for tinnitus, hyperacusis, and misophonia to better isolate hearing-difficulty-related effects from co-occurring auditory conditions.

Conclusions

This study demonstrates that hearing status is related to emotional communication, the perceived pleasantness of everyday listening environments, and mental well-being. Emotional reactions to sound seem to be associated with these outcomes. These results highlight the importance of considering emotional and psychological factors as part of auditory health. They also suggest that future hearing care strategies would benefit from a holistic approach, one incorporating sound therapy and counselling to address emotional responses to sound, which could lead to better outcomes for hearing aid users and individuals with subclinical hearing difficulties.

Disclosure statement

Both authors are employed by WSA.

Author contributions

CRediT: **Dina Lelic**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing; **Frederic Marmel**: Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing.

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