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ORIGINAL ARTICLE

Adults who report difficulty hearing speech in noise: an exploration of experiences, impacts and coping strategies

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ABSTRACT

Objective: Listening difficulties in noise are common, even in those with clinically normal hearing. There is a suggestion that subjective assessment of hearing difficulties may be more closely associated with listening effort and fatigue rather than objective measures of hearing and/or speech perception. The aim of this study was to better understand these perceptual deficits and experiences of this population.
Design: An exploratory survey was distributed to participants with self-reported listening-in-noise difficulties. The primary aim of the survey was to gather information about challenging listening environments, its impact, and preferred rehabilitation strategies. Secondly, responses were compared to their performance on behavioural tasks.
Study sample: Fifty adults aged 33–55 (22 females, with normal or near-normal hearing thresholds), completed the survey, and 45 of these performed behavioural tasks.
Results: Background noise with conversational content was the most common source of hearing difficulties. Participants expended higher concentration and attention when communicating in noise, and correlations with previously published behavioural data was reported. Social impacts varied, few had sought treatment, and respondents preferred training over devices.
Conclusions: Insights gained may provide clinicians and researchers with an understanding of the situations, impacts and non-auditory factors associated with listening-in-noise difficulties, and preferred rehabilitation for these clients.

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KEYWORDS
Listening difficulties; hidden hearing loss; background noise; psychosocial impact; coping strategies

Introduction

For some time, audiologists and researchers have noted a phenomenon whereby people experience difficulties listening in noise to a greater extent than one would expect on the basis of their audiometric results. It is difficult to know exactly how widespread this problem is, but it is estimated that 5 to 15% of all otological referrals to specialist clinics are of this nature (Saunders and Haggard 1989; Kumar et al. 2007; Tremblay et al. 2015; Spankovich et al. 2018). Survey studies also suggest that a substantial proportion of the general population experience hearing difficulties in the absence of a diagnosed hearing loss. For example, a US study reported that 12% of 21-to 67-year-olds with clinically normal thresholds self-reported hearing difficulty (Tremblay et al. 2015), and a UK study found that 14.1% of 17- to 30-year-olds and 20% of 31- to 40-year-olds reported great difficulty hearing speech in noise, even though only 5.8% and 10.4% respectively had clinically abnormal thresholds (Davis 1989). In an Australian study of 1,196 adults aged 18- to 35-years, 37% reported difficulty following a conversation in background noise (Gilliver et al. 2015). An earlier study of 1,000 adults of the same age found that 39% reported ‘trouble hearing when there is background noise’ (Gilliver et al. 2013), even though prevalence of hearing loss in this population (defined as average 4-frequency average hearing loss $\geq$25 dB HL in the worse ear) is only around 5% (Access Economics 2006). Taken together, these results suggest that there is a substantial group of people who experience more difficulty in noise than one would expect on the basis of their hearing thresholds.

When first described some 60–70 years ago, it was noted that listening-in-noise problems seemed to arise from mechanisms separate to those that underlie hearing thresholds. For example, King–Kopetzky syndrome (KKS), named for the original proponents, King (1954) and Kopetzky (1948), was characterised as a loss of ability to discriminate sounds in the presence of background noise. It was thought to be a form of functional, psychogenic deafness, and no direct causal link was made to damage from noise exposure or any other cause. Subsequent research into KKS led Hinchcliffe (1992) to conclude that it was ‘primarily an auditory stress disorder’ (p.92). Zhao and Stephens (2000) later proposed seven subcategories of KKS, each associated with different underlying pathologies and/or aetologies: middle ear dysfunction; mild cochlear pathology; central/medial olivocochlear efferent system dysfunction; psychological problems; multiple auditory pathologies; combined auditory dysfunction and psychological problems; and unknown aetiology.

Several years prior to the work by Zhao and Stephens, Saunders and Haggard (1989) were also working on a description of these listening difficulties, which they termed Obscure Auditory Dysfunction (OAD): ‘self-reported auditory disability

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with no audiometric abnormality' (p.200). They conducted a case-control analysis of 50 adults with matched controls, which revealed OAD as a multifactorial condition, characterised by both auditory and psychological (or 'personality-related') factors. The OAD cases had deficits on speech-in noise, psychoacoustic, and cognitive tasks, and also differed from the controls on a 'personality-related' variable: those with OAD tended to underestimate their listening abilities – an important personality-related factor related to 'auditory confidence' (Saunders and Haggard 1992).

There is some debate about how accurately people can judge their own hearing difficulties. On the one hand, Middelweerd et al. (1990) reported that a group of adults with '(nearly) normal pure-tone audiograms' with self-reported listening difficulties had poorer speech reception thresholds in noise than a control group of normal hearers without speech-in-noise complaints. Ferman et al. (1993) studied a similar group of adults with self-reported difficulties in noise despite normal hearing acuity and found that in 95% of cases, speech reception thresholds were poorer than expected. In contrast, a study by Tremblay et al. (2015) showed population study of normal hearers found that those who self-reported hearing difficulty did *not* perform more poorly on word recognition tasks in quiet or in noise, and Füllgrabe et al. (2015) found that older listeners did not have poorer subjective ratings of hearing disability despite their poorer speech-in-noise perception (when compared to younger listeners). Similarly, Alicea and Doherty (2017) found that the speech-in-noise performance of normal hearers with self-reported difficulties was not significantly worse than the performance of normal hearers with no reported difficulties. The mismatch between self-report and behavioural measures of speech-in-noise could be because some people tend to under- or over-estimate their listening ability. However, it might also arise because lab-based tests of speech-in-noise do not truly reflect everyday listening-in-noise experiences. Increasingly, research evidence is suggesting that the subjective assessment of hearing difficulties may be more closely associated with levels of listening effort and fatigue rather than objective measures of hearing and/or speech perception (Hornsby and Kipp 2016; Wang et al. 2017, Alhanbali et al. 2017).

A significant development in our understanding of speech-in-noise difficulties came in 2006 with publication of animal research on noise-induced cochlear synaptopathy, which showed that animals exposed to single-dose, high-noise episodes sustained damage to inner hair cell synapses, particularly those that involve high-threshold auditory nerve fibres, even though their permanent hearing thresholds were unaffected (Kujawa and Liberman 2006; Kujawa and Liberman 2009). Kujawa and Liberman proposed that a similar process of cochlear synaptopathy was likely to occur in humans, and if so, people exposed to noise would also incur synaptic nerve damage, which would likely result in hearing difficulties in noise, prior to an audiometric hearing loss. This condition has come to be known as 'hidden hearing loss', so-called because the nerve damage and consequent hearing impairment are 'hidden' behind a normal audiogram (Schaette & McAlpine 2011). Thus for the first time, the possibility of identifying a physiological basis for listening in noise difficulties seemed within reach.

Accordingly we (and several other research groups) were spurred on to investigate whether noise-induced cochlear synaptopathy occurs in humans, and importantly whether it leads to hearing difficulties listening in noise (Bharadwaj et al. 2015; Prendergast et al. 2017; Fulbright et al. 2017). In each of these aforementioned studies, both noise-exposed and non-noise-exposed adults with normal or near-normal audiometric thresholds completed a range of auditory and speech-in-noise tasks. The results published to date suggest that the link between noise exposure, noise-induced damage, and consequent hearing difficulties listening in noise is not straightforward. For example, Prendergast et al. (2017), who tested 18- to 36-year-olds, and Fulbright et al. (2017), who tested 18- to 29-year-olds, found little evidence of noise-related cochlear synaptopathy in their respective samples using behavioural and objective measures. Bharadwaj et al. (2015), who tested adults in a similar age range (21–39 years) concluded that while noise exposure may be a contributory factor in speech-in-noise performance, other sources of individual variation in perceptual ability made a significant contribution to one's suprathreshold hearing performance.

In our earlier study of human cochlear synaptopathy, we recruited a cohort older than those in the above-mentioned studies (adults aged 30–57 years) in order to maximise the range of noise exposures across the sample (see Yeend et al. 2017). Yet we too observed no clear relationship between levels of noise exposure and impaired auditory perception indicative of synaptopathy. Rather we found that speech-in-noise difficulties were associated with various language and cognitive factors, extended high frequency thresholds and medial olivocochlear suppression strength (Yeend et al. 2017). Taken together, all these findings lend support to the conclusion reached by early KKS and OAD researchers that there is a complicated and multifactorial aetiology for speech-in-noise difficulties. Despite its elusive origins, the extent of speech-in-noise difficulties in the adult population means it is vital that we improve our understanding of the lived experience of people coping with this problem. Reconciling laboratory-based findings with real-life experiences has become an increasingly important aim of audiological research (Munro and Patel 1998; Best et al. 2016) and the current work shares this philosophy. Through understanding the personal experience of speech-in-noise difficulties and its impact on daily functioning and communication, we will be better equipped to identify and remediate them.

We know from previous survey-based research that groups of adults with diagnosed hearing impairment are more likely to experience emotional, social and communication dysfunction and poorer health-related quality of life (Mulrow et al. 1990; Scherer and Frisina 1998). A small number of studies have looked in detail at the lived experience of these individuals, and found that people with hearing loss experience anxiety and stress, negative impacts on their social lives, and feelings of isolation and negative self-image (Hétu et al. 1988; Hallberg and Carlsson 1991). More recently, Pryce's (2006) qualitative study outlined the various hearing difficulties and coping strategies of clients who had sought clinical help for KKS. In contrast, this study details the experience of people who have noticed some degree of listening difficulty, but have not necessarily sought help for the condition. Our aim was to contribute new insights to the limited research literature available on these individuals.For the current study, we drew on data from our larger laboratory-based research project, and surveyed those who self-reported difficulty hearing in noise. The study reported here primarily aimed to obtain an understanding of the situations in which communication difficulties arise, the impact of these on the individual, and strategies adopted to overcome these problems. Secondly, we aimed to determine whether there were associations between the participafnts' reported listening difficulties and behavioural data related to listening in noise that was collected in the preceding months as part of the larger study. Specifically we examined whether there was an association between four self-reported survey responses - noise tolerance, ability to ignore background noise, listening effort and level of concentration - with age, hearing thresholds, and performance on behavioural tasks of speech-in-noise, attention, working memory and noise suppression. Our third and final aim was to examine the extent to which 'under-estimation' of hearing abilities (as noted by Saunders and Haggard 1992) was present within our sample, and if so, whether this phenomenon was related to age; hearing thresholds; speech-in-noise performance; attention; working memory; noise suppression, or the self-report measures of noise tolerance, concentration and effort.

Materials and methods

All experimental protocols were approved by the Human Research Ethics committees of Australian Hearing and Macquarie University.

Recruitment

Participants were recruited from the larger study which targeted adults aged between 30 and 60 years with self-reported normal hearing, and with varying degrees of lifetime noise exposure (as assessed by an online noise exposure questionnaire; Yeend et al. 2017). The larger study involved a comprehensive test battery, including audiometry, tests of speech-in-noise perception, working memory, attention and noise suppression, and the short form of the Speech, Spatial and Qualities of Hearing Scale (SSQ12; Noble et al. 2013. We invited all those who indicated difficulty listening to speech to participate in the current study. That is, those who scored 6/10 or less on at least one of the five SSQ12 questions that related to speech perception in background noise; and/or those who scored 6/10 or less on the question: 'Do you have to concentrate very much when listening to someone or something?'.

Materials

Survey development

In preparation for developing a 'Hearing Experiences' survey, preliminary work was conducted to ensure the ecological and face validity of the survey. Fifteen individuals who met the inclusion criteria were interviewed briefly about their experience of communication difficulties in noisy listening environments. A content analysis of interview responses identified five recurring themes: The difficulties seem to be related to (i) concentration or focus; (ii) background noise, especially speech-based noise is problematic; (iii) meal times with large groups are difficult; (iv) respondents rely on lip reading and moving closer to minimise difficulties; (v) avoidance of difficult situations is common, which were used to guide construction of the 'Hearing Experiences' survey. Some additional questions (about social withdrawal and restrictions on participation) were taken from the questionnaire described by Gatehouse and Noble 2004).

The survey employed a variety of question and answer formats to maintain engagement, including open-ended, closed-set, and rank-order items. The inclusion of open-ended questions enabled deeper insights from participants than would have been possible from closed-set questions alone, which, by their nature, restrict the number and type of responses possible. A set of novel questions was also developed in which participants were asked to rate their ability to listen to a conversation by looking at images of various social scenarios, (e.g. a group at a restaurant), with matching audio excerpts representative of that social scenario.

'Hearing experiences' survey

The survey contained 14 items organised into three sections, with presentation of some items dependent on responses to previous items (see Supplementary Material). The first section of the survey (Q1–7) identified self-reported difficult listening situations. Participants were asked to nominate situations in which they have difficulties (Q1) and then rank (Q2) nine listening situations in order of difficulty. They were also asked to indicate when their difficulties first occurred (Q3ab); the nature of the difficulties they experienced (Q4–5); how often they participated in nine activities identified in the in-depth interviews as difficult for communication (Q6); and reasons for avoiding situations (Q7). The second section of the survey (Q8–10) asked about the reported impacts of hearing difficulties. These items probed the degree of social limitation and/or emotional distress experienced by participants (Q8); the level of effort and concentration required when listening (Q9) and participants' tolerance for noise (Q10). The third section of the survey (Q11–14) covered how participants responded to and managed their difficulties, with a focus on the strategies and remedial technologies that might alleviate their problems. Participants were asked about their help-seeking behaviours (Q11); strategies they use in difficult situations (Q12), and their willingness to use technological aids to improve their listening (Q13, 14).

A consistent scoring protocol was used throughout the survey with negative or lower numbers assigned to the left endpoint of each rating scale representing poorer performance or greater difficulty, while higher numbers were placed at the right endpoint of each scale, representing better performance or less difficulty.

Participants

A total of 50 participants completed the 'Hearing Experiences' survey. They were aged between 33 and 55 years (mean age 46.9 years, SD = 5.9) with 22 females and 28 males. Most participants (58%) had normal symmetrical hearing (defined as ≤20dB HL at 0.25–6kHz). Just over a quarter of the cohort (28%) had 'near-normal' thresholds as defined by Moore et al. 2012 (≤25dB HL up to 2 kHz; ≤30dB at 3 kHz, ≤35dB HL at 4 kHz; and ≤40dB HL at 6 kHz). Two participants (4%) had only one threshold in one ear that exceeded these criteria by a margin of only 2 dB, and therefore a decision was made to include them. The remaining five participants, although enrolled in the larger study, were unable to attend the lab, so they did not complete the behavioural tasks or have their hearing assessed, but they all self-reported normal hearing.

Procedure

A link to the 'Hearing Experiences' online survey was emailed to participants over a 2-month period, after which survey responses were downloaded. Responses for all open-ended questions were reviewed and coded into categories drawn from the text using the 'open coding' method (Strauss and Corbin 1990), and the data were collated in preparation for analysis.

Behavioural tasks

As stated earlier, 45 of the 50 participants had previously completed the larger study (Yeend et al. 2017). The time elapsed between completing the larger study and this study was up to 53 weeks (mean: 20 weeks). The six measures of interest from that study (described in full in Yeend et al. 2017) are outlined below. Participants' results on these behavioural tasks were extracted and collated with their 'Hearing Experiences' survey responses in a single database to enable statistical analysis.

Hearing thresholds. Thresholds were tested in 2 dB steps using an Interacoustics AC40 audiometer coupled with Etymotic EAR 3 A insert earphones in a sound-treated room using a modified Hughson–Westlake procedure (Le Prell et al. 2013). Average hearing threshold level was calculated for the test ear for low frequencies (HL-LF) 0.25–2 kHz; high frequencies (HL-HF) 3–6 kHz; and extended high frequencies (HL-EHF) 9–12.5 kHz.

Noise suppression (medial olivocochlear). The strength of the MOC response (in the 0.5–2.5 kHz band) was measured in the test ear using a computer-based research module (TE50_B2000_N60; Mimosa Acoustics 2014) following the method described in Marshall et al. (2014). Higher scores indicate a stronger response.

Listening in noise. The high-cue condition (different voices ± 90 degrees) of the Australian version (2.202) of the Listening in Spatialised Noise Sentences (LiSN-S) test was used to assess ability to understand speech-in-noise (Glyde et al. 2013) and results (in dB SNR) were recorded.

Comprehension in noise. A shortened version of the National Acoustic Laboratories Dynamic Conversations Test (NAL-DCT), was used to test real world 'on-the-go' speech comprehension in background noise (Best et al. 2016). Participants answered 50 comprehension questions and percentage correct was calculated.

Attention. Two subtests (3 and 5) taken from the Test of Everyday Attention (TEA Version A; Robertson et al. 1994) were used to assess selective attention and attention-switching respectively. The results of these tests were averaged to produce a single score out of 10.

Working memory. An Australian-English version of the Reading Span Test (RST; Daneman and Carpenter 1980) was used to assess working memory. Participants read aloud blocks of sentences, indicated whether each made sense and then recalled a word (first or last) from each sentence. The percentage of correct words recalled was noted for each participant.

Data analysis

Summary statistics were used to describe the responses to each of the survey items. Pearson's correlation coefficients were calculated to test for associations between survey items and behavioural measures from the earlier study. Before conducting group comparisons, the data were tested for normality using the Shapiro-Wilk test, and wherever there were non-normal distributions, Mann-Whitney tests were used. In all other cases, t-tests were conducted. The p-value was set at $p = 0.05$, and appropriate adjustments were made for multiple comparisons.

Results

First we addressed the primary aim of understanding the situations in which communication difficulties arise, the impacts of these difficulties and the strategies adopted by analysing the results from the 'Hearing Experiences' survey.

Self-reported difficult listening situations

The reported average age of onset of hearing difficulties was 32.1 years (SD = 9.8), and the number of years participants had been aware of their hearing difficulties ranged from 1 to 31 years (M = 10.2 years, SD = 8.6; Q3a,b).

Responses to Q1 yielded a total of 211 environments in which participants described experiencing listening difficulties. Most responses ($n = 209$) were coded by the researchers into two categories based on the primary source of the problem: either the participant indicated that background noise was the main problem, or there was difficulty hearing the signal itself. (Two responses which referred to attention-related issues, rather than particular situations, were not considered further). The majority of responses (73.9%) related to the presence of background noise. As shown in Figure 1, the most commonly cited type of problematic background noise was 'crowds' and 'conversational noise', with difficulty reported at bars, restaurants, cafes, and parties. Background music was also frequently nominated as a source of difficulty, in environments such as live concerts, dance clubs, and orchestral performances. The other main type of background-noise difficulty was trying to converse on transport or with machinery in the background. A small number of responses related to poor room acoustics, in which participants reported that reverberant environments (e.g. churches) and hard surfaces such as glass ceilings and tiled floors made conversation difficult.

The remaining responses (25.1%) related to the audibility of the signal. As shown in Figure 1(B), the most commonly reported issues were those associated with distance between speaker and listener. This included speakers with their backs turned towards listener, unavailability of visual cues/facial expressions, and the speaker being located in a different room. Other signal-related situations reported were telephone conversations; listening to speakers' with certain voice attributes (accented speech, soft voice, high-pitched voice, poor enunciation); and listening to television or film dialogues.

Q2 required participants to rank nine listening environments in order from 1 (least comfortable) to 9 (most comfortable). The mean score for each environment was calculated by averaging the rank-order scores from all respondents. Conversation at noisy parties (M = 1.9) and music venues (M = 2.7) were ranked the most difficult of the nine listening environments, followed by conversations in environments with suboptimal room acoustics (M = 3.1). The least troubling listening environments were conversations in quiet (M = 8.1), children's voices (M = 7.6) and phone conversations (M = 6.1).

When participants were asked to rank five statements in the order that most accurately described their own personal difficulties (Q4), the statement: 'I need to pay a lot of attention and concentrate on the speaker to follow conversations,' was rated first or second by 60% of respondents. The other four statements tended to appear lower on the list, with between 32%-40% of respondents selecting each one as their first or second most accurate description.

In response to Q5, the vast majority of respondents (70%) regarded their listening difficulties as a hearing issue ('If there

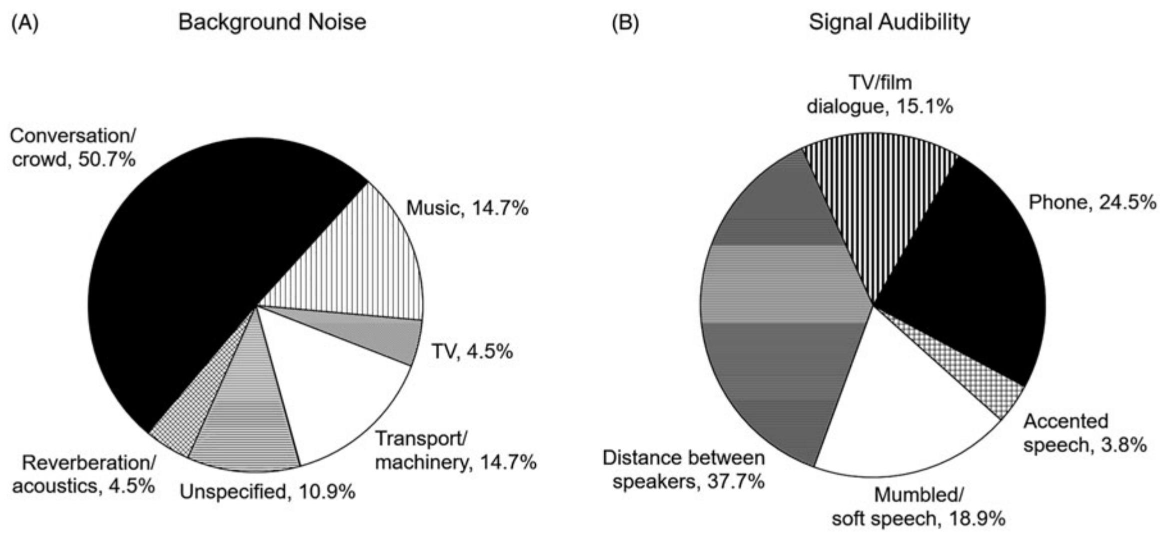

Figure 1. (A) Types of background noise causing listening difficulties; (B) Types of signal causing listening difficulties.

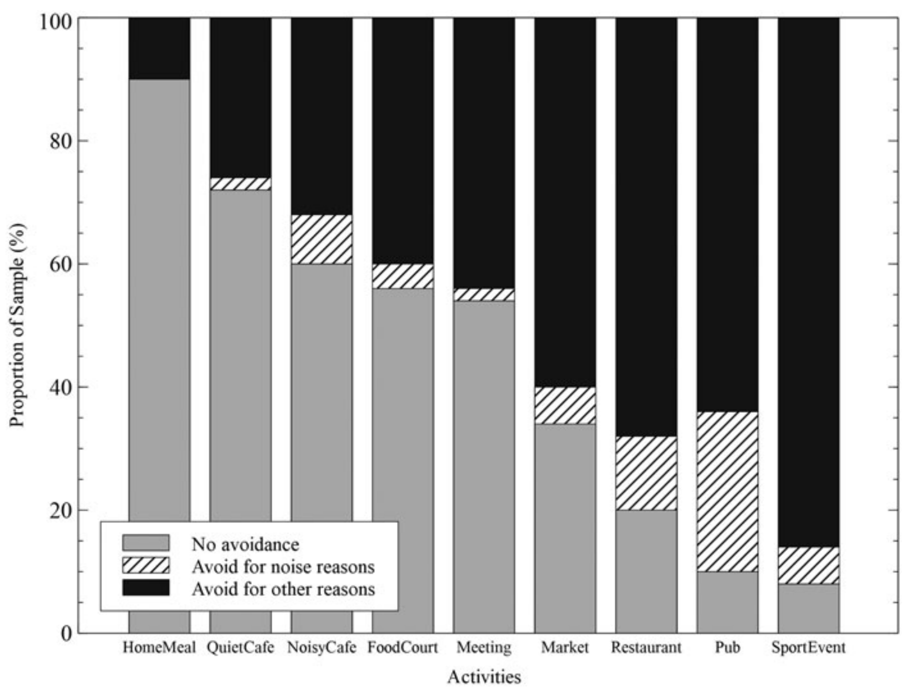

Figure 2. Attendance and avoidance at social activities for noise-related or other reasons.

are multiple background sounds it all appears to blend into a cacophony of noise'). Twenty-four percent considered that the problem was attentional or a combination of both hearing and attention ('Not being able to hear clearly initially leads to focussing on concentrating harder, but you can only concentrate so hard and it's hard to maintain this level of focus and attention'). Six percent were uncertain or nominated other issues that accounted for their hearing difficulties.

Participants' responses regarding their participation, and reasons for any non-attendance, at nine common scenarios (Q6) are shown in Figure 2. These nine scenarios differed from the nine listening environments listed in Q2. Of the nine activities, the two that were most commonly avoided for background noise-related reasons were: attending live music at a pub/club (26%) and a busy restaurant (12%). All other activities were avoided for noise-related reasons by very few people (≤8%).

Impacts of listening-in-noise difficulties

The extent to which adverse social or emotional consequences of hearing difficulties were experienced was calculated for each of the 13 statements in Q8, using the percentage of people who answered 'often' or 'almost always'. The most commonly experienced impacts were: feeling inclined to avoid social situations (18%); feeling tense and tired (16%); being inconvenienced (12%) and feeling self-conscious (10%). None of the other impacts were experienced often/always by more than 6% of people. The impacts that were experienced least often were: negative effects on work, social life, and self-image, all of which were reportedly experienced never or rarely by most participants (74%).

In response to Q10a, 20% of participants reported 'always' or 'often' avoiding events with high levels of background noise, and a further 20% stated that would 'sometimes' or 'occasionally' avoid such events (Q10b).

Participants' mean scores for questions regarding concentration and listening effort (Q9abc,10c) were all below the midpoint of their respective sliding scales, indicating greater difficulty or more effort listening when there is background noise. Four one-sample t-tests were conducted to compare the mean for each question to the midpoint of the scale and the p-value was adjusted accordingly ($p = 0.05/4 = 0.0125$). Responses to Q10c showed that, as a group, participants were intolerant of background noise, with a mean response of 3.2 (SD = 1.3) on a 1-7 scale, which differed significantly from the scale midpoint of 4, $t(49) = -4.6$, $p = 0.0001$. Ratings on the 0-10 scale used in Q9abc indicated a similar trend. Participants reported being unable to easily ignore other sounds when listening (Q9c; M = 3.9, SD = 2.2, $t(49) = -3.5$, $p = 0.001$). They also had to concentrate when listening to something (Q9a, M = 4.2, SD = 2.3, $t(49) = -2.4$, $p = 0.02$); and put in a lot of effort to hear during conversations (Q9b; M = 4.5, SD = 2.5, $t(49) = -1.4$, $p = 0.2$), but these results did not reach significance.

Help-seeking behaviours

Three participants (6% of respondents) had sought advice from a health professional regarding their hearing difficulties (Q11ab). Coding of responses to Q11c from the remaining 42 participants identified a number of potential motivators for seeking help or remediation, including: when the difficulties begin to impact on social choices and emotional well-being (31.6%), or when hearing deteriorated to the point that hearing difficulties increased (31.6%). Around one in 10 responses (10.5%) indicated that participants would seek help if hearing difficulties started to impact on work performance and 5.3% of responses indicated that participants did not know where to seek help for their hearing difficulties. Nearly one-fifth of participants' responses (21.1%) indicated a belief that the hearing difficulties could be self-managed or were not significant enough to warrant intervention.

Strategies

When prompted to list strategies used in difficult listening situations (Q12), 116 were provided, with most participants nominating more than one. The responses were coded into one of 14 categories. As shown in Table 1, respondents most commonly reported: relying on non-verbal cues such as lip reading, gestures, and facial expressions; moving closer or tilting one's ear to the speaker; moving to a quieter location; and concentrating/listening harder.

Table 1. Strategies used in noisy environments.

Strategy	No. of responses	%
Rely on lip reading, non-verbal cues	19	16.4
Move closer to/opposite speaker	18	15.5
Move to quieter location	13	11.2
Concentrate/listen hard	12	10.3
Reduce noise/turn down volume	10	8.6
Avoid noisy places	10	8.6
Request clarification	9	7.8
Tell the speaker 'I can't hear you'	6	5.2
Talk louder/ask speaker to talk louder	5	4.3
Nod, pretend to hear	4	3.4
Fill in missing words	4	3.4
Use ear cupping gesture	4	3.4
Use subtitles/captions	1	0.9
Wear earplugs	1	0.9

When asked to suggest potentially helpful remediation tools (Q13), the most common response indicated a lack of awareness of tools available for remediating hearing difficulties (43.4%). Other commonly reported options were: training courses to help focus attention or improve lip-reading skills (18.9%); and using a hearing aid or an assistive listening device, such as a 'remote wireless microphone systems' or 'noise-cancelling headsets' (13.2%). A small number of responses (5.7%) referred to earplugs, or a desire for improved listening environments ('I would love to see more acoustic damping in these environments'). The remaining responses (13.2%) indicated that no strategy was required to remediate their problem.

Of the nine strategies/technologies provided in Q14, participants were most receptive to communication training courses: 38% of participants indicated they were currently willing to undertake an online communication training course and a further 42% were willing to do so if their hearing deteriorated. There was a low-moderate correlation between those who were younger and had lower SSQ-12 scores and those willing to undertake training ($r = 0.31$ and $r = 0.27$ respectively). Willingness to consider using hearing aids varied substantially with only 6% of people prepared to consider usage now, increasing to 70% who would consider them if hearing deteriorated. Almost one in 10 participants (8%) indicated that they were unlikely to ever use any sort of device or training course (see Figure 3).

To address our second aim of determining the association between reported listening difficulties and previously collected demographic and behavioural data from the same participants, a series of Pearson's correlations were conducted. These examined whether responses regarding concentration and listening effort (Q9abc and Q10c) were related to age, audiometric thresholds, speech-in-noise performance, MOC strength, and performance on attention and working memory tasks, all of which were assessed in the earlier study by Yeend et al. (2017). As shown in Table 2, the self-reported measures were not associated with the results from Yeend et al. (2017) relating to hearing loss, MOC strength, or working memory. After adjusting the p-value to account for multiple comparisons ($p = 0.05/9 = 0.006$), only one correlation of moderate strength was found to be significant, i.e. scores on the TEA were associated with self-reported ability to ignore background noise ($r = 0.45$, $p = 0.002$). Weaker correlations were observed between TEA scores and tolerance for noise ($r = 0.30$, $p = 0.04$); and conversational effort ($r = 0.30$, $p = 0.04$) and between age and the need to concentrate during conversation ($r = 0.33$, $p = 0.02$), with older participants reporting a greater need to concentrate. These results suggest that those with better attention-switching and selective attention reported being better able to tolerate and ignore background noise, while expending less effort and less concentration.

Under-estimators

Finally, to address our third aim, we examined the mismatch between self-reported listening ability and performance on the speech-in-noise task that was conducted as part of the larger study by Yeend et al. (2017). For this, we identified those participants whose average scores across the five SSQ12 speech items were lower than average when compared to the full cohort described in Yeend et al. (2017; $n = 34$). We then examined their actual speech-in-noise performance on the LiSN-S. Participants

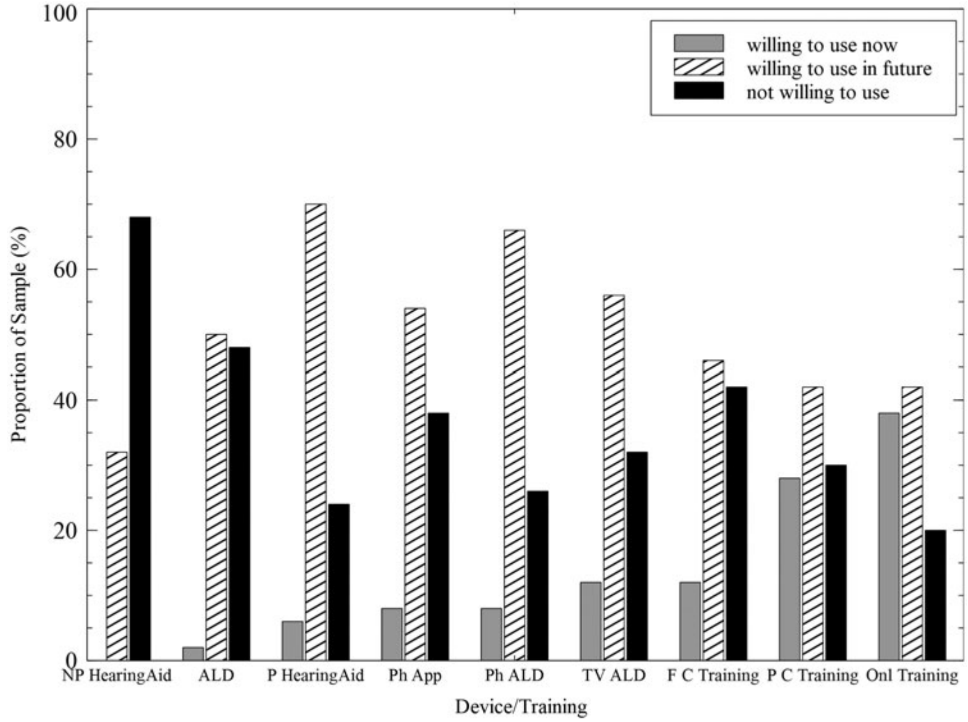

Figure 3. Participants' current and future willingness to use hearing devices and undertake communication training. ALD: Assistive Listening Device; F C Training: Family Communication Training Course; NP Hearing Aid: Non-personalised/Store-bought Hearing Aids; Onl Training: Online Communication Training Course; P C Training: Personal Communication Training Course; P Hearing Aid: Personalised Hearing Aids; Ph App: Smartphone App; Ph ALD: Telephone Listening Device; TV ALD: Television Listening Device.

Table 2. Correlations between self-reported survey measures and behavioural measures. Significant results are marked with an asterisk.

	Age	TEA	RST	LISN-s HC	DCT	MOC	HL-LF	HL-HF	HL-EHF
Concentrate (9a)	−.33*	.26	−.12	−.12	.14	.10	−.07	−.20	−.14
Effort (9b)	−.24	.30*	−.20	−.08	.10	−.14	.03	−.07	−.08
Ignore (9c)	−.17	.45*	.01	−.27	−.07	−.11	−.21	−.29	−.00
Noise tolerance (10c)	.04	.30*	−.08	−.08	.07	.10	−.06	−.19	−.00

TEA: Test of Everyday Attention; RST: Reading Span Test; LISN HC: Listening in Spatialised Noise: Sentences test (High Cue condition); DCT: Dynamic Conversations Test; HL-LF: Hearing Level: Low Frequencies; HL-HF: Hearing Level: High Frequencies; HL-EHF: Hearing Level: Extended High Frequencies.

were classified as 'under-estimators' if, despite their lower-than-average SSQ12 score, they had a higher-than-average LiSN-S score ($n = 15$). Those whose low self-reported difficulty matched their low behavioural LiSN-S score were classified as matched estimators ($n = 19$).

We conducted Mann-Whitney tests comparing the two groups on items Q9abc and Q10c, age, and the measures listed in Table 2. The groups did not differ significantly on any measures except self-reported ability to ignore background noise, $U = 70$, $p = 0.01$. That is, under-estimators were more likely to self-report better ability to ignore background noise than the matched estimators. There was also a trend for under-estimators to be younger, $U = 93.5$, $p = 0.08$ and have better scores on the RST, $U = 90.5$, $p = 0.07$.

Discussion

The main aim of this study was to obtain a deeper understanding of self-reported difficulties listening in noise, in particular, the situations in which communication difficulties arise, the impact of these on the individual, and the strategies or rehabilitative procedures which are relied upon to overcome these problems. We also aimed to compare participants' self-reported listening difficulties with previously collected behavioural data related to listening in noise.

Self-reported difficult listening situations

This study found that background noise involving conversation with other talkers was most frequently reported as the source of listening difficulty. This aligns with reports from those with KKS (Zhao and Stephens 1996) and is consistent with laboratory-based research showing speech-in-noise performance is poorer when the signal is masked by multi-talker speech compared to speech-shaped noise (Hall et al. 2002; Hornsby, Ricketts, and Johnson 2006; Desjardins and Doherty 2013). That is, performance suffers when the masking signal is both energetic (the distractor noise physically overlaps with the target signal) and informational (the distractor overlaps temporally and semantically with the target signal; Mattys et al. 2012).

In order to successfully separate a target signal from competing signals, the listener is required to selectively attend to the signal being masked, and the degree of listening effort increases as attentional resources are depleted (Shinn-Cunningham and Best 2008; Anderson Gosselin and Gagné 2011; Mattys et al. 2012). Consistent with this, many participants in the current study reported that their attentional resources were stretched, and intense concentration was needed when dealing with such situations. Sixty percent selected the statement: 'I need to pay a lot of attention and concentrate on the speaker to follow conversations,' as the first or second most accurate description of their listening difficulties, and just under a quarter of respondents felt that their difficulties were at least partly due to attentional problems. Notably, we found that participants who performed well on behavioural attention tasks reported less need for concentration, less effort expended, and better ability to ignore noise when listening in noise than those with poorer attention scores.

As expected, participants' self-reported listening difficulties on the SSQ12 and their actual performance on speech-in-noise tasks were not always consistent. Similar findings have been reported previously for those with OAD (Saunders and Haggard 1992) and in younger normal-hearing listeners whose SSQ12 scores were not significantly higher than older listeners despite significantly better performance on speech-in-noise tasks (Füllgrabe et al. 2015). Although the participants in this study had not been assessed for OAD or KKS, 15 of the 50 participants rated themselves poorly on the SSQ12 but performed quite well behaviourally. This result might reflect the fact that the LiSN-S does not accurately reflect real-life listening ability or it may be that this group had low auditory confidence. Perhaps they felt they *should* be able to hear well in noise, or perhaps they over-estimated how well others perform in similar circumstances. In any case, it seems that when they experience difficulty communicating in adverse listening conditions despite their best efforts, they conclude that their performance must be poor. One under-estimator explained: 'I am using a high level of attention and still have trouble hearing.' Interestingly, we found that there was a trend for 'under-estimators' to be younger and perform better on a task of working memory. Perhaps the relative youth of this group contributed to their expectations of how well they should be able to hear in noise, while their stronger cognitive skills helped them to achieve better-than-expected performance on the LiSN-S task. These findings underline the importance of discussing clients' self-reported difficulties, listening effort, attention, fatigue and performance expectations rather than relying solely on behavioural task results. This point has been made previously by researchers of KKS and OAD, who noted the significant influence that non-auditory factors can have on one's perception of hearing difficulties (King and Stephens 1992; Zhao and Stephens 1996; Pryce 2015).

Impacts of listening-in-noise difficulties

Another issue to consider is the perceived personal impact of listening difficulties. Although a small number of participants considered their difficulties significant enough to seek help and one in five respondents *always* or *often* considered background noise levels when deciding whether to attend an event, the majority reported fewer impacts and were less likely to consider background noise levels. Across the group, the most commonly experienced impacts were: feeling tense and tired; inconvenienced; and self-conscious. Few reported that listening difficulties impacted negatively on their work, social life, or self-image, and perhaps this is not surprising considering that most in this cohort had not yet sought help. Nevertheless it seems likely that, as is the case with hearing impairment, the social and emotional impacts of listening difficulties will vary widely between individuals (Hasson et al. 2011; Jerger 2011; Roup 2016), and that these impacts will not necessarily be predictable on the basis of objective measures such as thresholds or speech-in-noise testing (Gopinath et al. 2012; Roup, Post, and Lewis 2018; Spankovich et al. 2018).

Managing listening-in-noise difficulties

When participants were asked to nominate their preferred rehabilitation strategy, there was a preference for training over devices. For example, self-guided online communication training was a preferred option for 80% of participants, about half of whom were willing to undertake training immediately, and the remainder only if their hearing deteriorated. This suggests that participants had some degree of 'communication self-efficacy' or confidence that they could improve their ability to communicate by using their own cognitive resources (Laplante-Lévesque et al. 2012). Identifying clients with 'self-efficacy' is starting to emerge as a new direction in hearing health. As cost and time pressures mount, the need for new self-directed treatment methods is increasing. Self-efficacious clients are better able to self-manage their hearing health, use self-fitting devices and/or self-directed rehabilitation, and are ideal candidates for new patient-centred treatment models (Convery et al. 2016). If clients with listening difficulties display strong self-efficacy and a willingness to self-manage their condition, it makes sense for clinicians to encourage and facilitate this. In the long-term, if such clients go on to develop a diagnosed hearing loss, they will be well-placed to continue self-management of their hearing in the future.

Participants in the study showed some willingness to consider the use of assistive listening devices and phone app technology, which is likely to be welcome news for developers of personal sound amplification technologies (or 'hearables'). These devices, with their modern designs and mobile-phone compatibility, are more often compared to high-end headphones than stigma-laden hearing aids. As a result, they are likely to be more palatable to those who experience difficulties in background noise, but are not yet in the market for conventional hearing aids. Research on the use of these devices in normal hearers is starting to emerge (Shaw 2014; Viets 2015), but further research on the efficacy, utility and desirability of such devices for people with listening-in-noise difficulties is needed.

Limitations

Results from this study should be considered in the light of limitations relating to the survey and sample. Although this exploratory survey used here was specially developed using concepts derived from source interviews, it necessarily covered a restricted set of topics, and there may be other important issues relating to speech-in-noise difficulties that were not included. The response rate for the survey was 55%, and some people with evident speech-in-noise difficulties chose not to respond. This could mean that we have failed to capture the full range of insights or observations relating to listening difficulties. A further complication is that most of the respondents had recently completed a series of auditory tasks that may have increased the salience of their listening difficulties and therefore biased their responses in the survey. As a result, the findings here may not generalise to a more naïve sample drawn from the general population.

Conclusion

In this study, we presented self-report and behavioural data on a poorly understood client group, giving voice to the perspectives of those with listening-in-noise difficulties, and providing insights about this group's willingness to try different remediation strategies now and in future. The study showed that background noise in combination with high conversational content is the primary cause for hearing difficulties, and that the social impact of hearing-in-noise problems varies considerably between individuals. Although there was little appetite to use rehabilitative devices in the short-term, respondents were willing to consider self-directed communication training as a way of reducing their difficulties.

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