Associations between hearing health and well-being in unilateral hearing impairment

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ABSTRACT

Objectives: To determine population-based risks of adverse effects on hearing and well-being outcomes associated with unilateral hearing impairment.

Design: A group of 40-69-year-old adults (n = 861) who reported being able to hear only in one ear and having speech reception thresholds (SRTs) in noise indicating normal hearing in that ear ($SRT_{N/–}$) was selected from the UK Biobank cohort. The UK Biobank participants with SRTs indicating either normal ($SRT_{N/N}$, n = 95,514) or symmetrically impaired hearing in both ears ($SRT_{I/I}$, n = 17,429) were selected as comparison groups. Self-reported difficulty following conversations in noise, tinnitus presence, feelings depressed, lonely, unhappy, and being in poor health or dissatisfied with health were selected as hearing and well-being outcomes. Logistic regression models were used to evaluate the risks of reporting adverse outcomes associated with $SRT_{N/–}$ compared to $SRT_{N/N}$ and $SRT_{I/I}$ whilst controlling for numerous factors linked to hearing and general health.

Results: People with $SRT_{N/–}$ were significantly more likely to report difficulties following conversations in noise (Odds Ratio = 10.61, 95% Confidence Interval = 8.83 to 12.75), tinnitus (4.04, 3.51 to 4.66), poor health (1.35, 1.15 to 1.58), health dissatisfaction (1.22, 1.00 to 1.47), and loneliness (1.28, 1.08 to 1.51) compared to people with $SRT_{N/N}$. Well-being outcomes were similar in the $SRT_{N/–}$ and $SRT_{I/I}$ groups. However, difficulties following conversations in noise (5.35, 4.44 to 6.44) and tinnitus presence (2.66, 2.31 to 3.08) were significantly more likely with $SRT_{N/–}$ than with $SRT_{I/I}$. The $SRT_{N/–}$ was associated with increased risk of self-reported poor health by 18% (Relative Risk = 1.18, 95% Confidence Interval = 1.06 to 1.32) and loneliness by 24% (1.24, 1.07 to 1.43) compared with $SRT_{N/N}$. The risk of reporting difficulties following conversations in noise increased by 64% (1.64, 1.58 to 1.71) and tinnitus presence by 84% (1.84, 1.69 to 2.01) compared to $SRT_{I/I}$. The effect

of $SRT_{N/-}$ on reporting poor health was similar to that from having other health problems such as hypertension or high cholesterol.

Conclusions: The large increases in the risks of reporting adverse hearing-related outcomes associated with unilateral hearing impairment suggest its specific impact on hearing function in everyday situations. The increased risk of loneliness and poor health indicates that one normally functioning ear is also insufficient to protect against the adverse psychosocial impacts of unilateral hearing impairment. This impact was still significant after controlling for various health-related factors and can lead to perception of poor health comparable to that with having medical problems contributing to life-threatening conditions such as heart disease. The findings suggest the need for effective interventions to address the hearing-related problems and their impact on well-being in people with unilateral hearing impairment.

INTRODUCTION

Health satisfaction, happiness, mental health and social relationships are among things that matter most to people and their well-being (Balestra et al. 2017; Office for National Statistics 2019). Population-based studies suggest significant associations between hearing impairment and negative health, well-being and hearing-related outcomes (Agrawal et al. 2008; Davis 1989; Dawes et al. 2014b; Golub et al. 2018; Wilson et al. 1999). Hearing loss is associated with communication difficulties in noisy situations, listening effort and fatigue (Alhanbali et al. 2017; Gatehouse & Noble 2004), which can contribute to social isolation, anxiety, and depression (Arlinger 2003; Heffernan et al. 2016). A Lancet commission has also identified hearing loss as the mid-life factor associated with the highest population attributable risk for all-cause dementia (Livingston et al. 2017). Therefore, successful clinical management of hearing loss may improve both physical and mental health which are important predictors of adult well-being (Layard et al. 2014).

There is limited evidence from population-based studies about the impact of unilateral or single-sided deafness (SSD) characterised by audiometrically normal hearing in one ear and severe or profound deafness in the other ear (Baguley et al. 2006; Golub et al. 2018; Lin et al. 2011a). Findings from small-scale studies suggest difficulties following conversations in noise with unilateral hearing impairment even when the speech perception in the healthy ear is 'normal' which may be due to reduced ability to localise and separate talkers of interest from background noise (Bess et al. 1986b; Douglas et al. 2007; Firszt et al. 2017; Newton 1983; Rothpletz et al. 2012; Slattery & Middlebrooks 1994; Vannson et al. 2015; Vannson et al. 2017). These adverse hearing-related outcomes may in turn lead to social isolation and depressive symptoms (Giolas & Wark 1967; Lucas et al. 2018; Sano et al. 2013; Wie et al. 2010), and affect educational attainment and emotional well-being in children (Bess et al. 1986a; Bess & Tharpe 1986; Lieu 2004). Unilateral hearing impairment can lead to poor

quality of life (Arlinger 2003; Wie et al. 2010), which can be further adversely affected by a sudden and unexplained onset as in SSD (Baguley et al. 2006; Carlsson et al. 2011).

While current evidence suggests negative impact of unilateral hearing impairment on well-being, the risks associated with having access to normal speech perception in only one ear for hearing and well-being outcomes have not yet been evaluated in population-based studies. Moreover, available evidence does not allow an evaluation of the relative impact of unilateral hearing impairment with respect to other health-related problems such as cardiovascular disease that may be comorbid and associated with hearing loss (Cruickshanks et al. 1998; Dawes et al. 2014a). As these factors may also have an adverse effect on well-being their inclusion could provide wider context for the implications of unilateral hearing impairment and related clinical practice.

The aim of the present study was to evaluate the risks of adverse hearing and well-being outcomes in a group of 40-69 years old UK Biobank participants who reported being able to hear in only one ear indicative of unilateral deafness, and having speech reception thresholds (SRTs) in noise indicative of normal hearing in their better ear ($SRT_{N/-}$). The study compared the outcomes in the $SRT_{N/-}$ group with those from the UK Biobank participants whose speech perception was indicative of either normal ($SRT_{N/N}$) or impaired hearing ($SRT_{I/I}$) in both ears. The importance of having only one functionally normal ear was assessed in the context of different demographic, hearing and health-related factors.

MATERIALS AND METHODS

UK Biobank resource

UK Biobank is a resource of health data from >500,000 people aged 40–69 years (Allen et al. 2014). The UK Biobank participants were identified via the UK National Health Service (NHS) patient registries and invited to attend one of the 22 UK Biobank Assessment Centres in the proximity of the participant's place of residence. The baseline assessment conducted between 2007 and 2010, included a registration and consenting process, collection of health-related data using a touchscreen questionnaire and tests of hearing and cognitive function, as well as physical measures and biological samples (e.g. weight and blood samples). The consenting process and data collection were carried out by or under the supervision of trained clerical, nursing and healthcare technician staff (UK Biobank 2007). The present study included baseline data from 113,804 participants who completed a touchscreen questionnaire and a short test of speech perception in noise. The UK Biobank has ethical approval from the North West Multi-centre Research Ethics Committee (MREC). Associated research using the resource within the UK is monitored and licensed by the UK Biobank Ethics and Governance Council.

Outcomes

Seven outcome variables were selected from responses to the UK Biobank touchscreen questionnaire questions that corresponded to concerns reported by people with SSD (Giolas & Wark 1967; Lucas et al. 2018; Wie et al. 2010). Two questions from the 'hearing' category of the questionnaire described 'functional' domains of hearing loss: whether participants experienced difficulties following conversations in the presence of background noise or had tinnitus (see Supplemental Digital Content Table ST1). Five further questions from the 'psychosocial factors' and 'general health' categories of the questionnaire were selected as

relevant domains of well-being and included self-reports on depression, health rating, satisfaction with health, happiness and loneliness. These measures were framed in a general context without reference to hearing and were always asked before any questions about hearing. Responses were recoded as binary variables indicating the presence or absence of a negative outcome on well-being or hearing (Table 1).

*** PLEASE INSERT TABLE 1 HERE ***

Confounders

Data on participants' sex and age banded into 5-year age groups were extracted as demographic factors known to be associated with both general health and hearing (Dawes et al. 2014b). The national quintiles for the Townsend deprivation index score were used as a demographic measure quantifying an increase in material deprivation status of the population (Dawes et al. 2014b; Norman 2010). A subset of data from the questionnaire and physical measures conducted as part of the UK Biobank baseline assessments were also selected to determine 13 additional factors that may have influenced the outcomes due to their known associations with general health, well-being, or hearing (Dawes et al. 2014a). These data included self-reports about the participant's ethnic background, physical activity levels, illnesses or specific medication use as evidence of hypertension, high cholesterol, cardiovascular disease or diabetes, as well as information about tobacco and alcohol consumption, the use of ototoxic medication, and exposure to loud noise or music. The data also included physical measurements of body mass index (BMI), pulse wave arterial stiffness index (PWASI), and blood pressure as supporting evidence of hypertension (see Supplemental Digital Content Table ST1). The confounding factors were either recoded using

responses on the self-report measures or used as continuous variables for physical measures (BMI, PWASI) similar to our previous studies (Dawes et al. 2014a).

Speech in noise perception assessment

Participants who did not indicate being completely deaf or a cochlear implant user in the touchscreen questionnaire were asked to complete the Digit Triplets Test (DTT) – a short test of speech perception in noise (Dawes et al. 2014b; Smits et al. 2004; UK Biobank 2012). The DTT was completed at ten UK Biobank assessment centres by 164,770 UK Biobank participants (Dawes et al. 2014b). Participants who wore hearing aids were asked to remove them for the DTT. Each ear was assessed separately using circumaural headphones (Sennheiser D25). A participant's ear was not assessed if they selected "I can only hear on the right/left side" response option at the beginning of the test indicating potential unilateral deafness.

The stimuli were presented at a comfortable level set by the participant. The speech material comprised 15 monosyllabic digit triplets (e.g. 1-3-9). The triplets were presented in a spectrally shaped noise that was matched to the complete set of nine digits (0–9, excluding the disyllabic 7 and with '0' spoken as 'oh'). The noise level varied adaptively between the presentation trials but was limited such that the signal-to-noise ratios (SNRs) did not exceed the minimum of –12 dB and maximum of +8 dB. The mean SNR from the last eight triplets defined the speech reception threshold (SRT) in noise and was used as a measure of the participant's hearing function. The SRT scores indicate the SNR at which the participant can report all three successively presented digits accurately against a noise background on 50% of presentation trials. A more negative SRT score corresponds to an ability to identify digit triplets in higher levels of background noise, and thus to better hearing.

Several studies have shown that DTT SRTs correlate well with the average pure-tone thresholds and have high specificity and sensitivity (about 0.9) for distinguishing individuals with normal and impaired hearing (Jansen et al. 2013; Smits et al. 2004; Vlaming et al. 2014). The above characteristics of the DTT, better ecological validity due to the assessment of speech perception in noise as the most commonly reported complaint with hearing impairment (Action on Hearing Loss 2011; Smits et al. 2013) and ease of administration compared to pure-tone audiometry (Jansen et al. 2013), enabled a quantifiable assessment of hearing function in a large cohort of the UK Biobank participants. The high specificity and sensitivity of the DTT is typically achieved by an appropriate choice of cut-off values for differentiating between individuals with normal and impaired hearing based on the normative DTT SRT data obtained in these populations (Smits & Houtgast 2005; Vlaming et al. 2011). In a similar way, the normative data obtained from a sample of 20 young adults with clinically normal hearing (audiometric thresholds ≤25 dB HL from 0.25 to 8 kHz) who performed the UK Biobank DTT were used to assess the SRT variability and cut-offs to develop performance categories on the UK Biobank DTT (Dawes 2013; Dawes et al. 2014b). The normative data suggested a better ear mean SRT of −8 dB SNR (Standard Deviation, SD = 1.24) and categories 'normal' (SRT < −5.5 dB SNR), 'insufficient' (SRT ≥ −5.5 and ≤ −3.5 dB SNR) and 'poor' (SRT > −3.5 dB SNR), which can be used as indicators of hearing impairment in the UK Biobank participants (Dawes et al. 2014a; Dawes et al. 2015; Dawes et al. 2014b; Moore et al. 2014; Pierzycki et al. 2016; Rönnberg et al. 2014; Rudner et al. 2016).

Participant groups

The study group and two comparator groups were selected based on their hearing function and the performance categories developed for the UK Biobank DTT (Figure 1). To

avoid the inclusion of any cases where the DTT results could have been attributable to non-compliance or equipment failure, 849 participants with the poorest possible SRT score of +8 dB SNR in either ear were excluded (Pierzycki et al. 2016). The study group was selected from participants whose overall results suggested unilateral hearing impairment similar to SSD (self-reported ability to hear in only one ear and SRT in noise for that ear indicative of normal hearing; < −5.5 dB SNR). As the DTT was not performed in the contralateral ear, the group was referred to as $SRT_{N/-}$.

The outcomes reported in the $SRT_{N/-}$ group were compared to those reported in a group of participants with SRTs indicative of bilaterally normal hearing, $SRT_{N/N}$ (i.e. < −5.5 dB SNR in both ears). To further increase the specificity in the $SRT_{N/N}$ group, participants in that group who reported using hearing aids were excluded. A second comparison group, $SRT_{I/I}$, comprised people with SRTs indicative of bilaterally symmetric hearing impairment (i.e. ≥ −5.5 dB SNR in both ears). The $SRT_{I/I}$ group only included participants who had abnormal SRTs that differed by <4.6 dB SNR between the ears to avoid the inclusion of participants with potentially extreme forms of asymmetry in hearing function. An SRT difference ≥4.6 dB SNR was considered atypical as it fell more than two standard deviations away from the average SRT difference between the ears in the UK Biobank sample with SRTs indicating bilateral hearing impairment.

*** PLEASE INSERT FIGURE 1 HERE (STUDY GROUPS) ***

Data analysis

Participant characteristics were summarised using descriptive statistics. Prevalence estimates were standardised by age-band and sex to the whole UK biobank cohort (n = 500,097). Associations were analysed using logistic generalised linear models using statistical software

R version 3.5.0. Questionnaire responses 'Prefer not to answer' or 'Do not know' were treated as missing data. These responses could not be assumed missing completely at random due to the use of the 'Prefer not to answer' response option (see Supplemental Digital Content). Therefore, missing data in all outcome and predictor variables used in the models were accounted for by 100 multiple imputations by chained equations using the package 'mice' in R with predictive mean matching method and 5 iterations (Sterne et al. 2009; van Buuren & Groothuis-Oudshoorn 2011).

Separate binomial logistic models were used to calculate the odds of reporting of each outcome in the $SRT_{N/-}$ or $SRT_{I/I}$ groups compared to the $SRT_{N/N}$ group, and $SRT_{N/-}$ compared to the $SRT_{I/I}$ group (see Supplemental Digital Content for full model results). The models controlled for sex, age-band, interaction between sex and age-band, material deprivation score as demographic factors, and the 13 factors related to general health, well-being or hearing described above. Results were considered statistically significant if $p < 0.05$. Results were presented as odds ratios derived from regression models, which were subsequently converted to absolute and relative risks. The odds ratio is a measure of the effect size defined as the ratio between the odds of a specific outcome occurring in a diseased group compared to the odds of that outcome occurring in a comparator group (Grant 2014). By definition, the odds ratio >1 indicates a higher likelihood of the outcome occurring in the diseased group. The absolute risk describes the probability of developing a specific outcome in a given group, while the relative risk describes the ratio of the risk (probability) of the outcome in the diseased group and a comparator group. Therefore, a relative risk >1 would denote a greater risk (probability) of the outcome occurring in the diseased than in the comparator group.

A distribution of absolute risks across sex, age-bands, and material deprivation quintiles was derived for each of the hearing and well-being outcomes using the raw data (without imputations) to reflect the risks observed directly in the population. Point estimates

for absolute risks were obtained using marginal standardisation with corresponding 95% confidence intervals based on the distribution of standardised risks (Grant 2014; Muller & MacLehose 2014). Standardised relative risks with 'robust' 95% confidence intervals were calculated using marginal structural binomial regression modelling to avoid potential instability of estimation due to stratification by a large number of confounders included in the regression models (Richardson et al. 2015).

RESULTS

Participant characteristics

Table 2 shows the characteristics of participants. When considering the prevalence compared to the total UK Biobank sample standardised for age-band and sex, $SRT_{N/–}$, indicating unilateral hearing impairment, was found in 0.5% and $SRT_{I/I}$, indicating a symmetric bilateral hearing impairment, in 1.04% of the UK Biobank's participants. The mean SRT score in the $SRT_{N/N}$ group was −8.08 dB (SD = 0.96) for the better ear and −7.01 dB (SD = 0.81) for the worse ear. The mean SRT scores in the $SRT_{I/I}$ group were −4.61 dB (SD = 1.36) and −3.39 dB (SD = 1.81) in the better and worse ears, respectively. The mean SRT score for the only tested ear of participants in the $SRT_{N/–}$ group was −7.00 dB (SD = 0.90). There was a higher prevalence of older adults in the $SRT_{N/–}$ and $SRT_{I/I}$ groups with approximately double the proportion of 65–69-year-olds compared to the $SRT_{N/N}$ group. This difference may have led to lower SRT scores for the normally functioning ears in the $SRT_{N/–}$ compared to the $SRT_{N/N}$ group (Table 2). The distribution of material deprivation scores was similar across all groups and age-bands.

*** PLEASE INSERT TABLE 2 HERE ***

Associations with hearing and well-being outcomes

Table 3 shows the odds ratios with 95% confidence intervals for the self-reported outcomes in the $SRT_{N/–}$ and $SRT_{I/I}$ groups compared to the $SRT_{N/N}$ group, and for the $SRT_{N/–}$ compared to the $SRT_{I/I}$ group. Well-being outcomes showed a moderate effect of hearing impairment and participants in the $SRT_{N/–}$ group were significantly more likely to report being in poor health, dissatisfied with health and lonely compared to those in the $SRT_{N/N}$ group. The likelihood of reporting adverse well-being outcomes was similar in the $SRT_{N/–}$ and $SRT_{I/I}$

groups. However, adverse hearing-related outcomes were more likely to be reported in the $SRT_{N/-}$ compared to both the $SRT_{N/N}$ and $SRT_{I/I}$ groups. Difficulties following conversations in noise were almost 10 times more likely with the $SRT_{N/-}$ compared to $SRT_{N/N}$ and 5 times more likely compared to $SRT_{I/I}$. Participants with $SRT_{N/-}$ were also significantly more likely to report tinnitus than those in both $SRT_{N/N}$ and $SRT_{I/I}$ groups.

Figure 2 illustrates the relative effects (odds ratios and 95% confidence intervals) of $SRT_{N/-}$ and other demographic, health and lifestyle predictors of self-reported poor health (see model outputs in Supplemental Digital Content for other outcomes). Females, older age and white ethnic groups, current drinkers and those reporting moderate exercise levels were less likely to report being in poor health. Higher levels of material deprivation, and the presence of all other health and lifestyle factors were associated with higher likelihood of reporting poor health.

Table 4 shows estimated standardised relative risks associated with hearing impairment for the $SRT_{I/I}$ and $SRT_{N/-}$ groups. Compared to the absolute risk in those with $SRT_{N/N}$, there was a significant increase in the risk of self-reported loneliness and poor health in those with $SRT_{N/-}$. The risk of difficulties following conversations in noise associated with $SRT_{N/-}$ increased by about 161% and 64% compared to the absolute risk of this outcome occurring in the $SRT_{N/N}$ and $SRT_{I/I}$ groups, respectively. The risk of reporting tinnitus with $SRT_{N/-}$ increased even more compared to the $SRT_{N/N}$ (182%) and the $SRT_{I/I}$ group (84%).

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*** PLEASE INSERT FIGURE 2 HERE (IMPACT POOR HEALTH) ***

DISCUSSION

Key findings

The UK Biobank data suggests that hearing function indicative of unilateral hearing impairment is associated with significant increase in the likelihood of reporting adverse hearing-related outcomes. The large increase in the risk of difficulties following conversations in noise and tinnitus presence was observed when compared to both those with hearing function indicating normal or symmetrically impaired hearing in both ears. The risks of reporting adverse well-being outcomes were similar in those with unilateral and with bilateral symmetric hearing impairment. However, the risks of self-reported loneliness and poor health were somewhat larger with unilateral than bilateral hearing impairment when compared to absolute risks of those outcomes occurring with bilaterally normal hearing.

Hearing outcomes with unilateral hearing impairment

The significant increases in the likelihood of reporting difficulties following conversations in noise associated with unilateral hearing impairment were most likely connected with the loss of binaural hearing. Difficulty localising sound sources has been associated with asymmetric hearing loss (Noble & Gatehouse 2004), and could have contributed to these increases as their daily-life impact on a person's hearing ability can be disproportionate to the degree of hearing loss (Gatehouse & Noble 2004). Localisation difficulties could be particularly acute when hearing in one ear is lost completely as with SSD (Wie et al. 2010). However, there is also contrary evidence of good monoaural sound localisation in people with unilateral impairment (Agterberg et al. 2014; Firszt et al. 2015; Slattery & Middlebrooks 1994).

Therefore, another contributing factor could be associated with the difficulty to listen selectively when following conversations from multiple talkers in a noisy background as it

relies on comparing information from two ears (Colburn et al. 2006). Difficulties with the effective use of selective attention for segregating competing sounds into separate auditory objects could be negatively affected by the peripheral and central consequences of hearing impairment (Dai et al. 2018; Shinn-Cunningham & Best 2008). However, access to and comparison of auditory information from two ears, plausibly even with bilaterally impaired but symmetric hearing function, could give a binaural advantage for spatial separation of competing sounds that would not be available in monoaural listening conditions (Marrone et al. 2008). Selective listening with unilateral hearing impairment could also be predicted by head shadow effects which could negatively affect speech perception independently of individual localisation ability and be particularly acute when the target and masking sounds are collocated (Rothpletz et al. 2012). Therefore, experience of poor localisation and selective listening could have both influenced the large increases in the risk of self-reported difficulties following conversations in noise in the $SRT_{N/-}$ compared to both $SRT_{N/N}$ and $SRT_{I/I}$ groups.

The present findings could also be connected with the choice of measures used to evaluate hearing ability and define the study groups. A monoaural test of speech perception such as the UK Biobank DTT can be used to simulate the lack of auditory input in one ear in SSD (Williams et al. 2017), and suggests that UK Biobank participants had to rely mostly on monoaural cues to segregate the spoken digits from background noise. This scenario mimics the largest difficulty of separating the target from competing speech observed in monaural listening or when both signals are collocated (Marrone et al. 2008). This suggests that the DTT SRTs measured in noise were more relevant to the lived experience with unilateral hearing impairment and a better predictor of self-reported difficulty following conversations in noise in the $SRT_{N/-}$ group. Indeed, a significantly higher proportion of self-reported difficulties following conversations in noise was found in the $SRT_{N/-}$ group (83%) compared to the proportions reported by UK Biobank participants with large degrees of impairment in

hearing function on the DTT (55% on average; Supplemental Digital Content Fig. SF1). This significant increase suggests a categorical change in the perceived impact from high levels of hearing impairment or deafness in the worse ear in the $SRT_{N/-}$ group, and partly explains the significant increases in the risks of reporting difficulties following conversations in noise in the $SRT_{N/-}$ compared to the $SRT_{I/I}$ and $SRT_{N/N}$ groups.

Both the $SRT_{N/-}$ and $SRT_{I/I}$ were also associated with significantly greater risks of reporting tinnitus compared to $SRT_{N/N}$, consistent with hearing loss being one of the major risk factors for developing tinnitus (Gopinath et al. 2010; Shargorodsky et al. 2010), and consequences of SSD (Lucas et al. 2018). However, tinnitus appears to be more prevalent in those with acquired SSD (Lee et al. 2017), and better hearing thresholds in the contralateral ear have been suggested as a predictive factor of acute tinnitus onset in patients with sudden idiopathic sensori-neural hearing loss (Lee et al. 2015). The information about aetiology of deafness was not available for the present sample. However, given that sudden onset of deafness is one of the most common causes of acquired unilateral hearing loss (Baguley et al. 2006), having one normally functioning ear in the $SRT_{N/-}$ group could have contributed to their larger risks of reporting tinnitus compared with the $SRT_{I/I}$ group.

Impact of unilateral hearing impairment

The risks of loneliness and poor health were somewhat larger in the unilateral than bilateral hearing impairment when compared to the corresponding absolute risks with normal hearing function, but the increase in risks in both groups was generally consistent with a reduced sense of being able to cope with noisy situations and having a smaller social group with hearing loss (Kramer et al. 2002). The increased risk of reporting poor health was also compatible with the impaired health-related quality of life with SSD (Sano et al. 2013; Subramaniam et al. 2005) and bilateral hearing loss (Arlinger 2003).

A smaller number of adverse well-being outcomes and the lack of significant associations with self-reports of feeling depressed or unhappy in unilateral compared to bilateral hearing impairment could be related to a specific interaction between the severity of the symptoms and the aetiology or duration of deafness (Kurz et al. 2019). Psychosocial consequences of congenital deafness may be less severe as people adapt to their adverse hearing-related outcomes over time (Carlsson et al. 2015). The large risks associated with hearing-related outcomes found in the present study were compatible with an acute onset of SSD resulting from idiopathic sudden sensorineural hearing loss (Sano et al. 2013), or surgical removal of benign acoustic tumours (Kuhn et al. 2011). Both aetiologies can lead to distinct impacts on a patient's quality of life (Carlsson et al. 2011) and negative emotional responses such as the fear of losing hearing in the other ear (Sano et al. 2013). The information about participants' aetiology and duration of deafness or audiological interventions was not available. However, these factors may have contributed to hearing-related outcomes (Carlsson et al. 2015; Kurz et al. 2019; Slattery & Middlebrooks 1994), and be required for characterising the risks of adverse well-being outcomes and the impact on quality of life in unilateral hearing impairment (Carlsson et al. 2011; Kitterick et al. 2015; Subramaniam et al. 2005; Vannson et al. 2015).

The large-scale UK Biobank health data allowed controlling for numerous demographic, lifestyle, hearing, health and well-being characteristics (Dawes et al. 2014a; Dawes et al. 2014b; Lin et al. 2011b; Wilson et al. 1999), facilitating comparisons between the impact of unilateral hearing impairment and other significant confounding factors and health conditions (Fig. 2). For example, the demographic characteristics suggested a similar effect of material deprivation on poor health ratings to that of unilaterally impaired hearing, but females, those in older age and white ethnic groups were less likely to report poor health. These protective effects of age and ethnicity contrasted the higher likelihood of reporting

difficulties following conversations in noise in the present study (see Supplemental Digital Content), and higher levels of hearing disability found in other epidemiological studies (Cruickshanks et al. 1998; Davis 1989; Dawes et al. 2014a). These effects could have been associated with the 'healthy volunteer' bias in the UK Biobank sample (Fry et al. 2017), or the complex and comparative nature of self-health ratings observed when including multiple health indicators in multivariate models (Andersen et al. 2007; Jylhä et al. 2001).

Figure 2 also facilitates a comparison of the impact of unilateral hearing impairment with that of other significant health conditions. For example, the data from the UK Biobank sample suggest that the likelihood of reporting poor health with the $SRT_{N/-}$ can be similar to that associated with having hypertension or high cholesterol, and potentially higher than other factors associated with poor health such as high blood pressure and previous smoking. However, self-reports of poor health were less likely with unilateral hearing impairment than with being a current smoker or having medical conditions such as diabetes and cardiovascular disease which can be life-threatening (World Health Organization 2018). Therefore, the relatively higher impact of health conditions such as diabetes and cardiovascular disease may have been responsible for the moderate effects of unilateral hearing impairment on well-being.

Strengths and limitations

The major strength of the present study was the use of large-scale UK Biobank data. Previous studies of the impacts of SSD used relatively small sample sizes or participants with SSD as their own controls (Kitterick et al. 2015). The UK Biobank resource allowed for the first time to establish the relative risks of adverse hearing and well-being outcomes in people with hearing function indicative of SSD, and a comparison to normal and symmetrically

impaired hearing function in both ears. Another novel aspect was that the risks were evaluated whilst controlling for numerous factors associated with poor health and well-being.

However, the UK Biobank sample included only 40–69 year-old adults and previous studies suggested that it is not representative of the population due to bias towards recruitment of healthy participants (Fry et al. 2017). However, as the UK Biobank demographics may be associated with fewer hearing-related problems (Dawes et al. 2014b), the present findings would rather under- than over-estimate the risks of adverse outcomes associated with $SRT_{N/-}$. The prevalence of SSD in the general population is likely to be higher than that estimated from $SRT_{N/-}$ in the UK Biobank sample. Baguley and colleagues (2006) estimated about 7500 new cases of acquired unilateral sensori-neural hearing loss of different aetiologies per year, corresponding to about 0.016% of the UK population. However, unknown aetiology and history of deafness in the UK Biobank cohort does not allow estimation of and comparison with the incidence rates found in the previous study.

Direct comparisons with other studies are also difficult due to the use of different definitions of unilateral hearing loss or SSD. The prevalence of moderate-or-worse unilateral hearing loss; i.e. audiometric thresholds ≥41 dB HL in the worse ear, was found to be about 1.5% in the National Health and Nutritional Examination Surveys (NHANES) cohort (Golub et al. 2018; Lin et al. 2011a). However, about a third (31%) of participants with moderate-or-worse unilateral hearing loss have also reported having difficulty hearing, which was also reported by the majority of participants in the $SRT_{N/-}$ group (84%). Therefore, the prevalence of unilateral hearing impairment in the US population may be lower and closer to the 0.5% prevalence found in the UK Biobank cohort when one considers both the unilaterally impaired hearing function and self-reported difficulty hearing.

Due to the lack of audiometric thresholds and therefore clinical diagnoses of hearing loss in the UK Biobank, deafness in one ear was inferred using self-report and normal hearing

function in the better ear using cut-off criteria for SRT in noise similar to previous studies (Dawes 2013; Dawes et al. 2014b; Smits et al. 2004). While this is a limitation of the present study, characterisation of hearing using a speech in noise test such as the DTT increased the ecological validity of the findings compared to the use of pure-tone audiogram (Musiek et al. 2017), and related to the difficulty following conversations in noise as the most common complaint reported by patients with hearing loss (Action on Hearing Loss 2011; Assmann & Summerfield 2004; Heffernan et al. 2016). The ecological validity is further supported but the findings suggesting that difficulties understanding speech in noise may be an early symptom of dementia (Livingston et al. 2017; Moore et al. 2014).

Relevance to clinical practice and future studies

The findings suggest that one 'good' ear is not enough to protect against adverse outcomes related to well-being. The results support the notion that a holistic management strategy is warranted to address both the hearing difficulties and the negative impact on well-being in unilateral hearing impairment (Gordon et al. 2015; Lucas et al. 2018). Provision of appropriate support or psychological therapies for this population is in line with the current action plans for reducing the impact of disabling hearing loss put forward by hearing charities (Action on Hearing Loss 2011) and the Department of Health in the UK (NHS England and Department of Health 2015), and globally by the World Health Organisation (Curhan 2019; Olusanya et al. 2014). However, the large increases in risk of adverse hearing-related outcomes in the $SRT_{N/-}$ group suggest that current efforts should focus on the development and provision of effective hearing interventions for unilateral hearing impairment.

It was not possible to assess the type of hearing aid systems used by the UK Biobank participants, which may have included contralateral routing of signals (CROS) or bone-anchored hearing aids (BAHAs) as common interventions for SSD (Gordon et al. 2015;

Kitterick et al. 2016). However, a larger proportion of participants reported using 'hearing aids' in the $SRT_{N/-}$ (19%) than the $SRT_{I/I}$ group (8%, see Supplemental Digital Content). As the risks of self-reported difficulties following conversations in noise and tinnitus were also significantly higher in the $SRT_{N/-}$ group, it is plausible to assume that this group would be more likely to seek interventions for their communication problems. Indeed, despite not meeting typical eligibility criteria due to having one normally functioning ear, patients with SSD consider cochlear implantation towards restoring binaural hearing and alleviating tinnitus (Vermeire & Van de Heyning 2009).

There is an increasing body of evidence suggesting a benefit of cochlear implantation for the alleviation of tinnitus (Arts et al. 2015; Arts et al. 2016; Peter et al. 2019; Van de Heyning et al. 2008), as well as perception of speech in noise and binaural hearing (Dirks et al. 2019; Friedmann et al. 2016; Litovsky et al. 2019; Sladen et al. 2017; Távora-Vieira et al. 2013). However, the strength of conclusions about the evidence of the comparative effectiveness of cochlear implantation, CROS and BAHA systems made by previous reviews has been limited by inconsistencies in the use and reporting of treatment outcomes (Baguley et al. 2006; Blasco & Redleaf 2014; Cabral Junior et al. 2016; Kitterick et al. 2016; Peters et al. 2015). These inconsistencies have focussed recent efforts towards research identifying a core set of outcomes for use in clinical trials evaluating the effectiveness of interventions for SSD (Katiri et al. 2020; Van de Heyning et al. 2016). The significant risks of loneliness and perceptions of poor health found in the present study suggest their importance for patients and inclusion as outcomes in clinical trials of interventions for SSD in addition to those related to speech perception in noise and tinnitus.

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FIGURE CAPTIONS

Figure 1. Schematic of the study groups and the inclusion criteria based on the normative speech reception threshold (SRT) in noise cut-offs developed for the UK Biobank Digit Triplets Test (DTT). The SRT descriptors denote: N = 'normal', I = 'impaired', L/R = left/right ear.

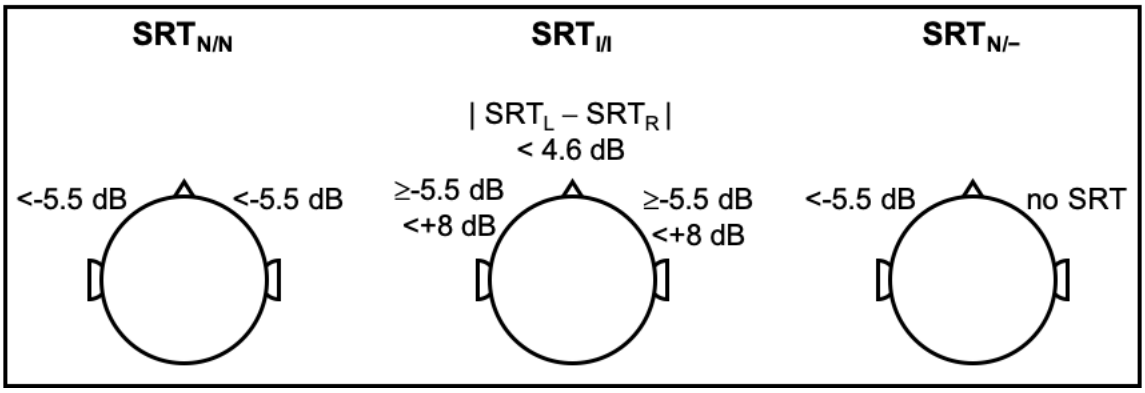

Figure 2. Odds ratios for $SRT_{N/-}$ and other predictors (reference levels in brackets) included in the regression model for the outcome 'In poor health' and comparison group $SRT_{N/N}$. Error bars show 95% confidence intervals for the estimates. The solid vertical line indicates the odds ratio of 1. Odds ratios >1 suggest greater odds of reporting poor health in the $SRT_{N/-}$ than the $SRT_{N/N}$ group.

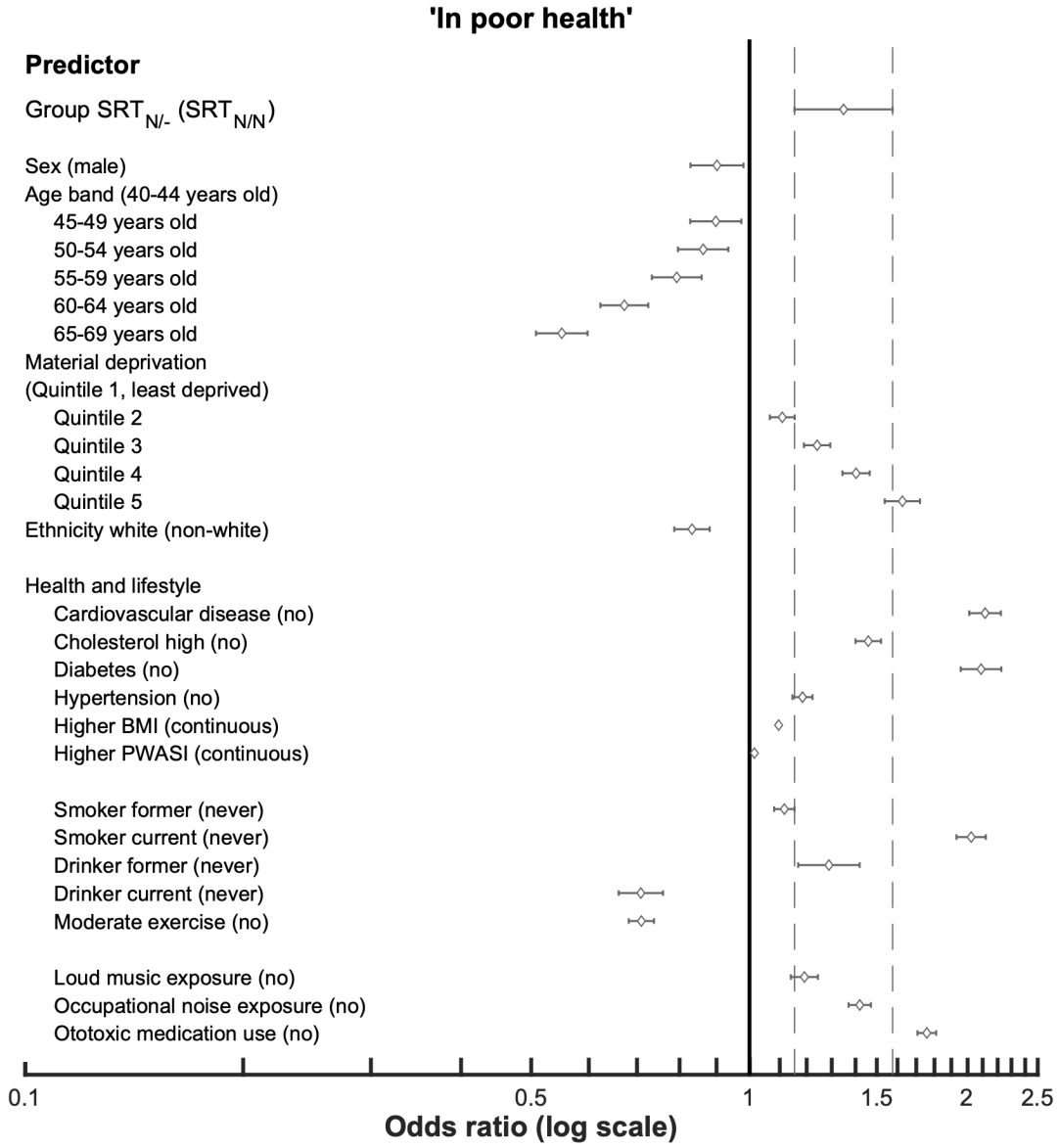

TABLE 1. Definitions of outcomes

Outcome	UK Biobank question
Well-being	
	Over the past two weeks, how often have you felt down,
Depressed	depressed or hopeless *
No	a) Not at all
No	b) Several days
Yes	c) More than half the days
Yes	d) Nearly every day
In poor health	In general how would you rate your overall health *
No	a) Excellent
No	b) Good
Yes	c) Fair
Yes	d) Poor
Dissatisfied with health	In general how satisfied are you with your health *
No	a) Extremely happy
No	b) Very happy
No	c) Moderately happy
Yes	d) Moderately unhappy
Yes	e) Very unhappy
Yes	f) Extremely unhappy
Lonely	Do you often feel lonely *
Yes	a) Yes
No	b) No
Unhappy	In general how happy are you *
As 'Dissatisfied with health'	Response options as in 'Dissatisfied with health'
Hearing	
Has difficulty following conversations in noise	Do you find it difficult to follow a conversation if there is background noise (such as TV, radio, children playing) *
As 'Lonely'	Response options as in 'Lonely'
	Do you get or have you had noises (such as ringing or buzzing) in your head or in one or both ears that lasts for
Has tinnitus	more than five minutes at a time *
Yes	a) Yes, now most or all of the time
Yes	b) Yes, now a lot of the time
Yes	c) Yes, now some of the time
No	d) Yes, but not now, but have in the past
No	e) No, never

* Included options "Do not know" and "Prefer not to answer" treated as missing data.

TABLE 2. Characteristics of participants

Characteristic	$SRT_{N/N}$		$SRT_{I/I}$		$SRT_{N/–}$	
	%	N	%	N	%	N
Total participants	84	(95,514)	15	(17,429)	1	(861)
Male sex	45	(43,315)	46	(7951)	43	(374)
Age band						
40-44	13	(12,141)	5	(872)	6	(53)
45-49	15	(14,514)	7	(1219)	8	(68)
50-54	17	(15,917)	10	(1707)	13	(113)
55-59	18	(17,377)	15	(2576)	17	(150)
60-64	23	(22,017)	30	(5190)	28	(240)
65-69	14	(13,548)	33	(5865)	28	(237)
Material deprivation						
Quintile 1	39	(36,897)	33	(5675)	33	(281)
Quintile 2	22	(21,473)	21	(3586)	21	(181)
Quintile 3	18	(16,878)	17	(3022)	18	(157)
Quintile 4	15	(13,971)	18	(3135)	18	(151)
Quintile 5	6	(6154)	11	(1981)	10	(89)
Missing	—	(141)	—	(30)	—	(2)
Better ear SRT in dB	Mean	SD	Mean	SD	Mean	SD
40-44	–8.28	(0.97)	–4.75	(1.31)	–7.14	(1.07)
45-49	–8.24	(0.95)	–4.75	(1.22)	–7.38	(1.02)
50-54	–8.18	(0.97)	–4.77	(1.17)	–7.13	(0.93)
55-59	–8.07	(0.95)	–4.68	(1.34)	–6.99	(0.84)
60-64	–7.97	(0.94)	–4.63	(1.33)	–7.01	(0.95)
65-69	–7.83	(0.93)	–4.47	(1.46)	–6.78	(0.73)
Worse ear SRT in dB *						
40-44	–7.17	(0.86)	–3.59	(1.73)	—	—
45-49	–7.14	(0.85)	–3.66	(1.66)	—	—
50-54	–7.09	(0.83)	–3.63	(1.61)	—	—
55–59	–7.01	(0.80)	–3.52	(1.78)	—	—
60–64	–6.91	(0.77)	–3.40	(1.79)	—	—
65–69	–6.81	(0.73)	–3.17	(1.91)		—

Data are percentages (counts) unless stated otherwise (% excluding missing data).
* Worse ear SRTs were not available if only one ear was tested ($SRT_{N/–}$ group).
'I', impaired; 'N', normal; SD, standard deviation; SRT, speech reception threshold.

TABLE 3. Odds ratios for the association between self-reported hearing and well-being outcomes

	$SRT_{I/I}$ vs $SRT_{N/N}$			$SRT_{N/–}$ vs $SRT_{N/N}$			$SRT_{N/–}$ vs $SRT_{I/I}$		
Outcome	OR	(95% CI)	*p*	OR	(95% CI)	*p*	OR	(95% CI)	*p*
Well-being									
Depressed	1.51	(1.41 to 1.63)	<0.001	1.19	(0.88 to 1.60)	0.258	0.79	(0.58 to 1.06)	0.116
In poor health	1.29	(1.24 to 1.34)	<0.001	1.35	(1.15 to 1.58)	<0.001	1.05	(0.89 to 1.23)	0.567
Dissatisfied with health	1.21	(1.15 to 1.27)	<0.001	1.22	(1.00 to 1.47)	0.048	1.00	(0.83 to 1.22)	0.960
Lonely	1.20	(1.15 to 1.25)	<0.001	1.28	(1.08 to 1.51)	0.004	1.06	(0.90 to 1.26)	0.476
Unhappy	1.19	(1.10 to 1.29)	<0.001	0.95	(0.68 to 1.34)	0.787	0.80	(0.57 to 1.13)	0.202
Hearing									
Has difficulty following conversations in noise	1.98	(1.91 to 2.06)	<0.001	10.61	(8.83 to 12.75)	<0.001	5.35	(4.44 to 6.44)	<0.001
Has tinnitus	1.52	(1.45 to 1.58)	<0.001	4.04	(3.51 to 4.66)	<0.001	2.66	(2.31 to 3.08)	<0.001

The models adjusted for all confounders used in the regression models.

CI, confidence interval; 'I', impaired; 'N', normal; OR, odds ratio; SRT, speech reception threshold.

TABLE 4. Absolute and standardised risks associated with normal and impaired hearing

	Absolute risk *	Relative risk with impaired hearing **		Absolute risk *	Relative risk **
Outcome	$SRT_{N/N}$ (95% CI)	$SRT_{I/I}$ (95% CI)	$SRT_{N/-}$ (95% CI)	$SRT_{I/I}$ (95% CI)	$SRT_{N/-}$ (95% CI)
Well-being					
Depressed	0.05 (0.05 to 0.05)	1.47 (1.36 to 1.58)	1.23 (0.90 to 1.68)	0.06 (0.06 to 0.06)	0.89 (0.65 to 1.22)
In poor health	0.02 (0.02 to 0.02)	1.16 (1.13 to 1.20)	1.18 (1.06 to 1.32)	0.03 (0.03 to 0.03)	1.06 (0.96 to 1.17)
Dissatisfied with health	0.01 (0.01 to 0.01)	1.17 (1.12 to 1.23)	1.13 (0.95 to 1.34)	0.01 (0.01 to 0.01)	1.06 (0.90 to 1.25)
Lonely	0.10 (0.10 to 0.10)	1.14 (1.09 to 1.18)	1.24 (1.07 to 1.43)	0.11 (0.11 to 0.11)	1.03 (0.89 to 1.18)
Unhappy	0.05 (0.05 to 0.05)	1.15 (1.05 to 1.25)	1.00 (0.69 to 1.44)	0.05 (0.05 to 0.05)	0.82 (0.58 to 1.16)
Hearing					
Has difficulty following conversations in noise	0.17 (0.17 to 0.17)	1.47 (1.44 to 1.51)	2.61 (2.52 to 2.71)	0.31 (0.31 to 0.31)	1.64 (1.58 to 1.71)
Has tinnitus	0.10 (0.10 to 0.10)	1.40 (1.35 to 1.46)	2.82 (2.58 to 3.09)	0.17 (0.16 to 0.17)	1.84 (1.69 to 2.01)

* Point estimates and 95% CIs for absolute risks adjusted for age and sex using UK Biobank population data.

** Relative risks and 'robust' 95% CIs adjusted for all confounders used in the regression models.

CI, confidence interval; 'I', impaired; 'N', normal; SRT, speech reception threshold.

Associations between hearing health and well-being in unilateral hearing impairment.

Supplemental Digital Content

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TABLE ST1. Definitions of confounding factors (Dawes et al. 2014a)

Factor	Levels	Definition
Sex	Male/Female	Self-reported
Age band	5-year bands in the 40–69 years old range	Calculated using self-reported age
Material deprivation status	Score 1 to 5 (from low to high material deprivation)	National quintiles for the Townsend deprivation index score calculated using the national census output areas for the participant's postcode immediately before joining the UK Biobank
Ethnicity	White/Non-White	Self-reported ethnic background
Moderate exercise	Yes/No	Self-reported moderate physical activity of >10 min on the day before assessment
Hypertension	Yes/No	Self-reported hypertension or measured systolic blood pressure >140 mm Hg and diastolic blood pressure >90 mm Hg
High cholesterol	Yes/No	Self-reported high cholesterol or taking medication for high cholesterol
Cardiovascular disease	Yes/No	Self-reported angina, heart attack, heart failure, stroke, transient ischemic attack, intermittent claudication, arterial embolism, or deep venous thrombosis
Diabetes	Yes/No	Self-reported diabetes type 1 or 2 or taking insulin for diabetes
Smoking status	Current/Former/Never	Self-reported tobacco consumption
Drinking status	Current/Former/Never	Self-reported alcohol consumption
Ototoxic medication use	Yes/No	Self-reported daily/weekly or monthly use of ototoxic medications (loop diuretics, aminoglycoside antibiotics, quinine derivatives, non-steroidal anti-inflammatories, and salicylates)
Occupational noise exposure	Yes/No	Self-reports of working in a noisy place where one had to shout to be heard
Loud music exposure	Yes/No	Self-reports of listening to music for >3 h/week at volumes where one needs to shout to be heard or to hear others
Body mass index (BMI)	Continuous	Weight in kilograms/(Height in metres)^2
Pulse Wave Arterial Stiffness Index (PWASI)	Continuous	Time between peaks on the infrared finger pulse measurement/Height

Validation of self-reported deafness in one ear

Participants in the $SRT_{N/-}$ group reported that they could hear only in their better ear which indicated deafness in the worse ear. Therefore, speech reception thresholds (SRTs) in noise on the UK Biobank Digit Triplets Test (DTT) were measured only for the better ear in that group. The better ear SRTs were indicative of normal hearing based on the cut-off criteria derived from the UK Biobank DTT normative data in young, normally hearing adults (Dawes 2013; Dawes et al. 2014b). To substantiate self-reports about the inability to hear in the worse ear, self-reported difficulties following conversations in noise in the $SRT_{N/-}$ group were compared to those reported by a group of participants with SRTs indicating high levels of hearing impairment in the worse ear. The comparator group, $SRT_{N/I}$, included participants who performed the DTT for both ears and had SRTs indicative of normal hearing in the better ear (< -5.5 dB SNR) and impaired hearing in the worse ear (≥ -5.5 dB SNR). Participants with the poorest possible SRT of +8 dB SNR in the worse ear, potentially attributable to non-compliance or equipment failure, were excluded (Pierzycki et al. 2016). Responses to the question "Do you find it difficult to follow a conversation if there is background noise (such as TV, radio, children playing)" in the UK Biobank questionnaire were used as the most relevant outcome for comparison of groups defined using a measure of speech perception in noise (i.e. DTT SRT). Table ST2 shows participant characteristics in the $SRT_{N/I}$ and $SRT_{N/-}$ groups. Table ST3 and Fig. SF1 show the proportions of difficulties following conversations in noise reported in both groups. The worse ear SRT in the $SRT_{N/I}$ group was presented in 2-dB-SNR bands for consistency with the normative DTT cut-off criteria (Dawes et al. 2014b), and to ensure the inclusion of sufficient number of participants across different levels of speech perception ability. Proportions of participants reporting difficulties following conversations in noise in the $SRT_{N/I}$ group increased with the increase of the SRT scores in the worse ear up to about –1.5 dB SNR indicating 'poor' hearing (Dawes et al. 2014b). The proportions reported for worse ear SRT scores larger than –1.5 dB SNR up to the poorest

SRT score of +7.75 dB SNR were similar (about 55% on average). About 83% of participants in the $SRT_{N/-}$ group reported having difficulty following conversations in noise. This proportion was significantly higher than the proportions found in the $SRT_{N/I}$ group, including those from participants with the highest SRT scores in their worse ear.

TABLE ST2. Characteristics of participants in the $SRT_{N/I}$ and $SRT_{N/-}$ groups.

Characteristic	$SRT_{N/I}$		$SRT_{N/-}$	
Total participants		(44,535)		(861)
Male sex	45	(20,154)	43	(374)
Age band				
40-44	8	(3,662)	6	(53)
45-49	10	(4,560)	8	(68)
50-54	13	(5,844)	13	(113)
55-59	17	(7,485)	17	(150)
60-64	28	(12,330)	28	(240)
65-69	24	(10,654)	28	(237)
Material deprivation				
Quintile 1	36	(16,008)	33	(281)
Quintile 2	22	(9,656)	21	(181)
Quintile 3	18	(7,806)	18	(157)
Quintile 4	16	(7,170)	18	(151)
Quintile 5	9	(3,817)	10	(89)
Missing (count)	—	(78)	—	(2)
Better ear SRT in dB	Mean	SD	Mean	SD
40-44	–7.31	(0.99)	–7.14	(1.07)
45-49	–7.25	(0.96)	–7.38	(1.02)
50-54	–7.23	(0.97)	–7.13	(0.93)
55-59	–7.16	(0.95)	–6.99	(0.84)
60-64	–7.08	(0.92)	–7.01	(0.95)
65-69	–7.02	(0.89)	–6.78	(0.73)
Worse ear SRT in dB *				
40-44	–4.75	(1.09)	—	—
45-49	–4.73	(1.15)	—	—
50-54	–4.65	(1.25)	—	—
55–59	–4.67	(1.20)	—	—
60–64	–4.57	(1.30)	—	—
65–69	–4.47	(1.35)	—	—

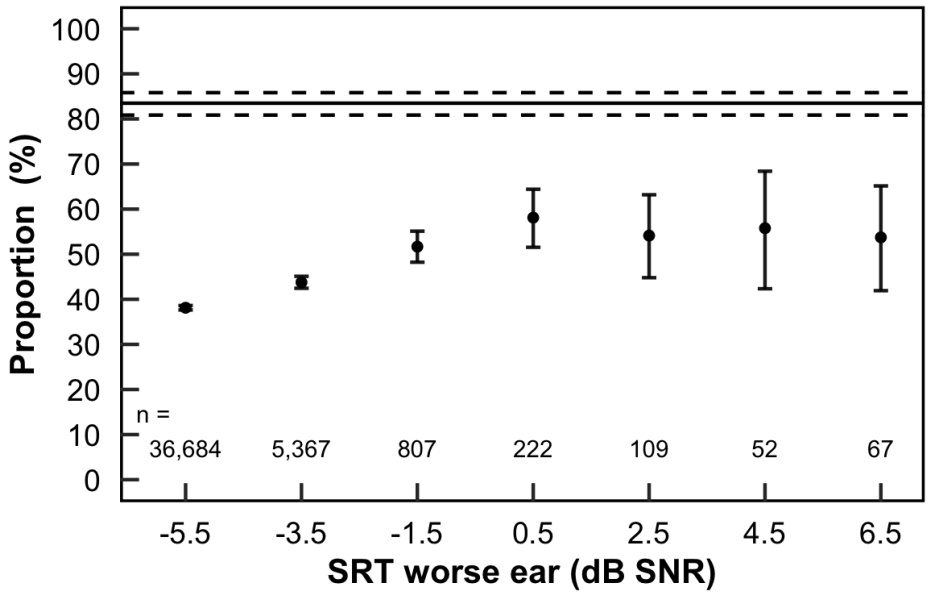
Data are percentages (counts) unless stated otherwise (% excluding missing data).
* Worse ear SRTs were not available if only one ear was tested ($SRT_{N/-}$ group).
I, impaired; N, normal SD, standard deviation; SRT, speech reception threshold.

TABLE ST3. Proportions of reported difficulty following conversations in noise.

Worse ear SRT band (dB SNR)	N	% (95% CI)
[–5.5, –3.5)	13,985	38 (38 to 39)
[–3.5, –1.5)	2,349	44 (42 to 45)
[–1.5, 0.5)	417	52 (48 to 55)
[0.5, 2.5)	129	58 (52 to 64)
[2.5, 4.5)	59	54 (45 to 63)
[4.5, 6.5)	29	56 (42 to 68)
[6.5, 8.0)	36	54 (42 to 65)

CI, confidence interval; SRT, speech reception threshold.

Figure SF1. Self-reported difficulties following conversations in noise in the $SRT_{N/I}$ group. Error bars show 95% confidence intervals for the proportions. The solid and dashed horizontal lines indicate the proportion and the 95% confidence interval reported in the $SRT_{N/-}$ group. The inset indicates the number of participants in each worse ear SRT band.



Missing data and complete case analysis

Table ST4 lists the proportions of missing data for the outcome and confounder variables used in the regression models. Complete case analyses for the group data suggested an effect of the loss of data in the variable 'moderate exercise' when comparing unilaterally impaired and normal hearing groups. However, removal of that variable from the complete case models did not change the findings compared to those from the imputed dataset, apart from the effect on 'dissatisfaction with health' which ceased to be statistically significant (cf. Table 3). The confounder 'moderate exercise' was included in the final models due to its known significant association with health, well-being and hearing impairment (Dawes et al. 2014a), and potential influence on data missingness in other variables included in the models.

TABLE ST4. Proportions of missing data in outcome and confounder variables.

Model variable	N	% *
Depressed	4637	4.07
In poor health	367	0.32
Dissatisfied with health	574	0.50
Lonely	1797	1.58
Unhappy	662	0.58
Has difficulty following conversations in noise	2802	2.46
Has tinnitus	2291	2.01
Age band	0	0.00
Sex	0	0.00
Material deprivation	173	0.15
Ethnicity	426	0.37
BMI	2513	2.21
PWASI	1885	1.66
Hypertension	0	0.00
Cholesterol	0	0.00
Cardiovascular disease	0	0.00
Moderate exercise	38806	34.10
Diabetes	0	0.00
Smoking status	353	0.31
Drinking status	73	0.06
Occupational noise exposure	1009	0.89
Loud music exposure	1662	1.46
Ototoxic medication use	0	0.00

* Percentage of the 113804 participants included in the study.
BMI, Body Mass Index; PWASI, Pulse Wave Arterial Stiffness Index.

Hearing aid use

All participants completing the UK Biobank touchscreen questionnaire were asked the question "Do you use a hearing aid most of the time?". Information on hearing aid use did not indicate which ear was aided or the type of hearing aid; e.g. whether participants used a specialised hearing aid system such as a contralateral routing of signals (CROS) hearing aid or a bone-anchored hearing aid (BAHA). However, self-reported hearing aid use was analysed and compared between the $SRT_{N/-}$ and $SRT_{I/I}$ groups to establish whether seeking help for hearing-related problems would be more likely with unilateral than with a bilateral, symmetric form of hearing impairment. About 19% of participants in the $SRT_{N/-}$ group reported using hearing aids compared to about 8% reported in the $SRT_{I/I}$ group. Logistic regression models controlling for age-band, sex, their interaction and the same health and lifestyle factors included in the main analyses (see Methods section) showed that participants in the $SRT_{N/-}$ group were significantly more likely to use hearing aids than those in the $SRT_{I/I}$ group (odds ratio 2.86, 95% confidence interval 2.37 to 3.45; $p < 0.001$). The risk associated with hearing aid use in the $SRT_{N/-}$ group was about 133% higher (relative risk 2.33, 95% confidence interval 1.99 to 2.71) compared to the absolute risk in the $SRT_{I/I}$ group (0.02, 95% confidence interval 0.02 to 0.02).

TABLE ST5. Model output: outcome 'Depressed', comparator $SRT_{N/N}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–3.035	0.117	–26.02	8837.94	<0.001
Group ($SRT_{N/N}$ *)					
$SRT_{I/I}$	0.413	0.037	11.19	20156.07	<0.001
$SRT_{N/–}$	0.172	0.152	1.13	32590.02	0.258
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	–0.085	0.073	–1.16	39719.76	0.245
Age band 3 (50–54)	–0.152	0.073	–2.08	42047.25	0.037
Age band 4 (55–59)	–0.399	0.075	–5.29	37134.07	<0.001
Age band 5 (60–64)	–0.818	0.077	–10.56	34001.59	<0.001
Age band 6 (65–69)	–1.160	0.091	–12.81	22164.43	<0.001
Sex (male)	0.182	0.072	2.54	38437.57	0.011
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.101	0.042	2.39	35686.22	0.017
Quintile 3	0.257	0.042	6.08	40801.57	<0.001
Quintile 4	0.460	0.042	11.07	32392.85	<0.001
Quintile 5 (most deprived)	0.638	0.049	13.14	25022.46	<0.001
Ethnicity white (non–white)	–0.711	0.042	–16.75	13323.67	<0.001
Higher BMI (continuous)	0.025	0.003	9.22	16976.48	<0.001
Higher PWASI (continuous)	0.002	0.003	0.56	36618.59	0.578
Hypertension (no)	–0.031	0.031	–1.01	35009.24	0.312
Cholesterol high (no)	0.147	0.042	3.48	23571.01	<0.001
Cardiovascular disease (no)	0.293	0.048	6.16	43171.64	<0.001
Moderate exercise (no)	–0.282	0.040	–7.08	404.69	<0.001
Diabetes (no)	0.163	0.059	2.75	16391.21	0.006
Smoking status (never smoker)					
Smoker former	–0.057	0.033	–1.72	30952.80	0.086
Smoker current	0.468	0.041	11.47	16082.11	<0.001
Drinking status (never drinker)					
Drinker former	0.185	0.078	2.38	19950.08	0.017
Drinker current	–0.325	0.057	–5.68	14668.67	<0.001
Occupational noise exposure (no)	0.356	0.034	10.45	16224.25	<0.001
Loud music exposure (no)	0.234	0.039	6.07	12583.91	<0.001
Ototoxic medication use (no)	0.467	0.029	15.94	24253.23	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	0.153	0.096	1.59	42231.82	0.113
Age band 3 x Female sex	0.201	0.095	2.12	38295.31	0.034
Age band 4 x Female sex	0.168	0.098	1.72	37293.85	0.086
Age band 5 x Female sex	0.228	0.099	2.31	32672.40	0.021
Age band 6 x Female sex	0.295	0.114	2.58	24205.18	0.010

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST6. Model output: outcome 'In poor health', comparator $SRT_{N/N}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–3.728	0.070	–53.30	47046.48	<0.001
Group ($SRT_{N/N}$ *)					
$SRT_{I/I}$	0.253	0.021	12.28	103878.98	<0.001
$SRT_{N/–}$	0.299	0.080	3.76	95832.22	<0.001
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	–0.107	0.041	–2.58	105229.38	0.010
Age band 3 (50–54)	–0.147	0.041	–3.60	105100.18	<0.001
Age band 4 (55–59)	–0.231	0.040	–5.74	107110.46	<0.001
Age band 5 (60–64)	–0.398	0.039	–10.24	101160.13	<0.001
Age band 6 (65–69)	–0.597	0.042	–14.25	104284.83	<0.001
Sex (male)	–0.103	0.043	–2.40	107202.10	0.016
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.104	0.020	5.17	106364.22	<0.001
Quintile 3	0.215	0.021	10.04	103263.00	<0.001
Quintile 4	0.339	0.022	15.30	106334.32	<0.001
Quintile 5 (most deprived)	0.486	0.029	16.96	99099.03	<0.001
Ethnicity white (non–white)	–0.183	0.029	–6.36	84075.46	<0.001
Higher BMI (continuous)	0.093	0.002	57.59	58748.12	<0.001
Higher PWASI (continuous)	0.016	0.002	6.64	63749.06	<0.001
Hypertension (no)	0.168	0.016	10.34	104187.90	<0.001
Cholesterol high (no)	0.377	0.021	18.23	106026.78	<0.001
Cardiovascular disease (no)	0.749	0.026	29.16	102320.76	<0.001
Moderate exercise (no)	–0.344	0.020	–16.77	560.86	<0.001
Diabetes (no)	0.736	0.033	22.34	98952.97	<0.001
Smoking status (never smoker)					
Smoker former	0.111	0.017	6.71	102761.07	<0.001
Smoker current	0.704	0.024	29.68	96202.81	<0.001
Drinking status (never drinker)					
Drinker former	0.252	0.050	5.06	94981.51	<0.001
Drinker current	–0.345	0.036	–9.62	91492.78	<0.001
Occupational noise exposure (no)	0.350	0.018	19.37	60304.65	<0.001
Loud music exposure (no)	0.174	0.022	7.94	59411.69	<0.001
Ototoxic medication use (no)	0.563	0.015	37.21	107517.18	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	0.146	0.058	2.53	107155.95	0.011
Age band 3 x Female sex	0.104	0.056	1.85	109371.29	0.064
Age band 4 x Female sex	0.104	0.055	1.90	109553.74	0.058
Age band 5 x Female sex	0.119	0.052	2.27	108409.08	0.023
Age band 6 x Female sex	0.261	0.056	4.69	108321.45	<0.001

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST7. Model output: outcome 'Dissatisfied with health', comparator $SRT_{N/N}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–4.531	0.083	–54.33	39860.62	<0.001
Group ($SRT_{N/N}$ *)					
$SRT_{I/I}$	0.190	0.026	7.38	82887.88	<0.001
$SRT_{N/–}$	0.195	0.099	1.98	70178.78	0.048
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	–0.110	0.051	–2.16	94361.55	0.031
Age band 3 (50–54)	–0.240	0.051	–4.74	99881.95	<0.001
Age band 4 (55–59)	–0.349	0.050	–6.97	102525.63	<0.001
Age band 5 (60–64)	–0.668	0.049	–13.55	102442.08	<0.001
Age band 6 (65–69)	–0.929	0.054	–17.12	101884.12	<0.001
Sex (male)	–0.025	0.052	–0.47	101137.28	0.637
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.036	0.026	1.40	95058.98	0.162
Quintile 3	0.118	0.027	4.32	96200.77	<0.001
Quintile 4	0.274	0.027	9.95	99292.05	<0.001
Quintile 5 (most deprived)	0.342	0.034	9.95	76592.44	<0.001
Ethnicity white (non–white)	–0.102	0.035	–2.95	59719.27	0.003
Higher BMI (continuous)	0.091	0.002	49.08	31784.85	<0.001
Higher PWASI (continuous)	0.008	0.003	2.97	47342.76	0.003
Hypertension (no)	0.102	0.021	4.92	99709.32	<0.001
Cholesterol high (no)	0.270	0.026	10.37	96066.63	<0.001
Cardiovascular disease (no)	0.640	0.029	21.74	91905.52	<0.001
Moderate exercise (no)	–0.358	0.025	–14.54	646.88	<0.001
Diabetes (no)	0.550	0.036	15.31	84062.13	<0.001
Smoking status (never smoker)					
Smoker former	0.092	0.021	4.37	92018.90	<0.001
Smoker current	0.459	0.029	15.84	87738.12	<0.001
Drinking status (never drinker)					
Drinker former	0.415	0.058	7.16	68403.69	<0.001
Drinker current	–0.206	0.044	–4.70	56040.32	<0.001
Occupational noise exposure (no)	0.190	0.023	8.40	75299.89	<0.001
Loud music exposure (no)	0.253	0.026	9.59	57439.02	<0.001
Ototoxic medication use (no)	0.611	0.019	31.68	98253.69	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	0.232	0.070	3.33	94887.50	<0.001
Age band 3 x Female sex	0.206	0.069	2.99	104390.06	0.003
Age band 4 x Female sex	0.225	0.068	3.32	102176.01	<0.001
Age band 5 x Female sex	0.262	0.065	4.00	105022.00	<0.001
Age band 6 x Female sex	0.403	0.071	5.68	101941.31	<0.001

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST8. Model output: outcome 'Lonely', comparator $SRT_{N/N}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–2.455	0.074	–33.21	29496.03	<0.001
Group ($SRT_{N/N}$ *)					
$SRT_{I/I}$	0.182	0.022	8.16	71708.40	<0.001
$SRT_{N/–}$	0.243	0.085	2.87	87762.99	0.004
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	–0.024	0.046	–0.52	85200.93	0.606
Age band 3 (50–54)	–0.061	0.046	–1.34	79393.11	0.179
Age band 4 (55–59)	–0.203	0.046	–4.43	71502.06	<0.001
Age band 5 (60–64)	–0.382	0.045	–8.58	82564.24	<0.001
Age band 6 (65–69)	–0.635	0.050	–12.76	73587.80	<0.001
Sex (male)	0.341	0.045	7.57	72779.85	<0.001
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.126	0.022	5.70	85452.24	<0.001
Quintile 3	0.253	0.023	10.91	67661.26	<0.001
Quintile 4	0.401	0.024	16.97	76928.64	<0.001
Quintile 5 (most deprived)	0.624	0.030	21.10	71842.44	<0.001
Ethnicity white (non–white)	–0.138	0.030	–4.59	69912.12	<0.001
Higher BMI (continuous)	0.024	0.002	14.70	39371.74	<0.001
Higher PWASI (continuous)	0.003	0.002	1.14	7247.40	0.256
Hypertension (no)	–0.080	0.017	–4.60	73208.60	<0.001
Cholesterol high (no)	–0.012	0.024	–0.49	82063.86	0.627
Cardiovascular disease (no)	0.213	0.029	7.34	85018.40	<0.001
Moderate exercise (no)	–0.164	0.022	–7.52	582.28	<0.001
Diabetes (no)	0.216	0.037	5.90	77447.90	<0.001
Smoking status (never smoker)					
Smoker former	–0.010	0.018	–0.57	78608.53	0.571
Smoker current	0.396	0.025	15.80	76211.84	<0.001
Drinking status (never drinker)					
Drinker former	0.290	0.053	5.49	57485.99	<0.001
Drinker current	–0.025	0.039	–0.63	59997.58	0.525
Occupational noise exposure (no)	0.254	0.020	12.66	52205.51	<0.001
Loud music exposure (no)	0.222	0.023	9.54	42316.77	<0.001
Ototoxic medication use (no)	0.302	0.016	18.37	92558.25	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	0.065	0.060	1.07	83196.99	0.282
Age band 3 x Female sex	0.099	0.059	1.67	83100.74	0.095
Age band 4 x Female sex	0.166	0.059	2.84	73120.59	0.005
Age band 5 x Female sex	0.219	0.056	3.90	82121.01	<0.001
Age band 6 x Female sex	0.389	0.062	6.30	75147.05	<0.001

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST9. Model output: outcome 'Unhappy', comparator SRTN/N.

Model variable	Estimate	SE	z value	df	p value
Intercept	–2.889	0.126	–22.95	51425.11	<0.001
Group ($SRT_{N/N}$ *)					
$SRT_{I/I}$	0.176	0.041	4.30	80023.35	<0.001
$SRT_{N/–}$	–0.046	0.171	–0.27	94825.85	0.787
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	0.102	0.068	1.49	98298.99	0.135
Age band 3 (50–54)	0.039	0.069	0.56	95301.96	0.575
Age band 4 (55–59)	–0.226	0.071	–3.16	97523.32	0.002
Age band 5 (60–64)	–0.615	0.073	–8.40	96547.21	<0.001
Age band 6 (65–69)	–1.103	0.090	–12.32	104571.39	<0.001
Sex (male)	–0.210	0.074	–2.84	95297.40	0.005
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.074	0.042	1.75	99676.27	0.080
Quintile 3	0.322	0.042	7.71	93093.15	<0.001
Quintile 4	0.481	0.042	11.48	84600.97	<0.001
Quintile 5 (most deprived)	0.556	0.051	10.86	83142.66	<0.001
Ethnicity white (non–white)	–0.015	0.051	–0.29	62793.84	0.771
Higher BMI (continuous)	0.006	0.003	2.06	35663.97	0.040
Higher PWASI (continuous)	–0.002	0.004	–0.42	63770.56	0.671
Hypertension (no)	–0.122	0.031	–3.91	86108.58	<0.001
Cholesterol high (no)	0.085	0.044	1.93	86633.62	0.054
Cardiovascular disease (no)	0.192	0.052	3.71	94985.99	<0.001
Moderate exercise (no)	–0.327	0.036	–9.15	905.14	<0.001
Diabetes (no)	0.239	0.063	3.80	83085.22	<0.001
Smoking status (never smoker)					
Smoker former	0.048	0.033	1.45	83730.51	0.146
Smoker current	0.412	0.042	9.88	84513.54	<0.001
Drinking status (never drinker)					
Drinker former	0.354	0.087	4.08	55994.48	<0.001
Drinker current	–0.205	0.068	–3.02	60371.91	0.003
Occupational noise exposure (no)	–0.006	0.035	–0.17	76420.57	0.867
Loud music exposure (no)	0.362	0.037	9.71	52563.82	<0.001
Ototoxic medication use (no)	0.295	0.030	9.97	98926.30	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	0.091	0.096	0.94	96815.56	0.348
Age band 3 x Female sex	0.061	0.096	0.64	97838.97	0.525
Age band 4 x Female sex	0.029	0.099	0.29	94903.63	0.770
Age band 5 x Female sex	0.090	0.100	0.90	96194.57	0.367
Age band 6 x Female sex	0.326	0.119	2.72	101178.74	0.006

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST10. Model output: outcome 'Has difficulty following conversations in noise', comparator $SRT_{N/N}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–2.089	0.067	–31.39	33753.81	<0.001
Group ($SRT_{N/N}$ *)					
$SRT_{I/I}$	0.685	0.018	37.70	77010.37	<0.001
$SRT_{N/–}$	2.362	0.094	25.20	98284.75	<0.001
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	0.324	0.041	7.99	66642.59	<0.001
Age band 3 (50–54)	0.494	0.039	12.50	77172.09	<0.001
Age band 4 (55–59)	0.686	0.039	17.75	67916.64	<0.001
Age band 5 (60–64)	0.830	0.037	22.39	74886.38	<0.001
Age band 6 (65–69)	1.012	0.039	25.81	72395.42	<0.001
Sex (male)	–0.011	0.043	–0.26	69261.72	0.795
Material deprivation (Quintile 1, least deprived)					
Quintile 2	–0.015	0.018	–0.87	76487.18	0.383
Quintile 3	–0.012	0.019	–0.65	76160.01	0.518
Quintile 4	–0.022	0.020	–1.07	78312.17	0.282
Quintile 5 (most deprived)	–0.006	0.027	–0.20	64733.28	0.838
Ethnicity white (non–white)	0.294	0.029	10.24	55848.09	<0.001
Higher BMI (continuous)	0.008	0.001	5.20	35893.94	<0.001
Higher PWASI (continuous)	0.005	0.002	2.66	23272.72	0.008
Hypertension (no)	–0.097	0.014	–6.71	74329.24	<0.001
Cholesterol high (no)	0.022	0.019	1.14	70065.65	0.254
Cardiovascular disease (no)	0.108	0.025	4.35	69892.82	<0.001
Moderate exercise (no)	–0.088	0.017	–5.11	989.23	<0.001
Diabetes (no)	0.000	0.032	0.00	78021.17	0.996
Smoking status (never smoker)					
Smoker former	0.109	0.015	7.53	70452.05	<0.001
Smoker current	0.012	0.023	0.52	58204.93	0.604
Drinking status (never drinker)					
Drinker former	0.179	0.048	3.71	58539.54	<0.001
Drinker current	0.097	0.035	2.77	49109.33	0.006
Occupational noise exposure (no)	0.527	0.016	32.39	54333.72	<0.001
Loud music exposure (no)	0.497	0.020	24.90	46004.08	<0.001
Ototoxic medication use (no)	0.153	0.014	10.94	63756.24	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	–0.106	0.056	–1.89	74170.59	0.058
Age band 3 x Female sex	–0.112	0.054	–2.08	71064.92	0.038
Age band 4 x Female sex	–0.253	0.053	–4.81	69784.80	<0.001
Age band 5 x Female sex	–0.280	0.050	–5.62	71891.74	<0.001
Age band 6 x Female sex	–0.418	0.052	–7.97	69867.59	<0.001

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST11. Model output: outcome 'Has tinnitus', comparator $SRT_{N/N}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–2.642	0.085	–31.26	33411.84	<0.001
Group ($SRT_{N/N}$ *)					
$SRT_{I/I}$	0.417	0.022	19.17	58849.67	<0.001
$SRT_{N/–}$	1.397	0.072	19.45	74373.72	<0.001
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	0.207	0.054	3.83	51468.65	<0.001
Age band 3 (50–54)	0.358	0.052	6.85	47591.77	<0.001
Age band 4 (55–59)	0.572	0.050	11.39	56098.19	<0.001
Age band 5 (60–64)	0.750	0.048	15.58	53191.66	<0.001
Age band 6 (65–69)	0.829	0.050	16.48	50334.21	<0.001
Sex (male)	–0.126	0.060	–2.11	47344.28	0.035
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.046	0.022	2.09	70551.53	0.037
Quintile 3	0.014	0.024	0.57	70179.40	0.566
Quintile 4	0.083	0.026	3.25	56423.54	0.001
Quintile 5 (most deprived)	0.159	0.033	4.80	63924.80	<0.001
Ethnicity white (non–white)	0.191	0.037	5.19	42703.08	<0.001
Higher BMI (continuous)	–0.002	0.002	–0.96	27229.19	0.336
Higher PWASI (continuous)	0.001	0.002	0.41	39965.83	0.685
Hypertension (no)	0.048	0.018	2.62	77743.80	0.009
Cholesterol high (no)	0.034	0.024	1.43	73676.78	0.153
Cardiovascular disease (no)	0.098	0.029	3.35	70018.36	<0.001
Moderate exercise (no)	0.019	0.022	0.88	1145.94	0.377
Diabetes (no)	–0.092	0.038	–2.40	68832.60	0.017
Smoking status (never smoker)					
Smoker former	0.007	0.018	0.39	63160.13	0.700
Smoker current	–0.128	0.030	–4.30	60796.86	<0.001
Drinking status (never drinker)					
Drinker former	0.190	0.058	3.28	60912.77	0.001
Drinker current	–0.051	0.043	–1.18	67591.51	0.238
Occupational noise exposure (no)	0.494	0.020	25.25	59801.18	<0.001
Loud music exposure (no)	0.492	0.024	20.57	47264.80	<0.001
Ototoxic medication use (no)	0.217	0.018	12.37	71740.08	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	–0.081	0.078	–1.04	49271.65	0.297
Age band 3 x Female sex	0.057	0.074	0.78	47151.92	0.438
Age band 4 x Female sex	0.018	0.071	0.25	54587.79	0.804
Age band 5 x Female sex	–0.073	0.067	–1.08	54341.38	0.279
Age band 6 x Female sex	–0.107	0.070	–1.55	49956.60	0.122

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST12. Model output: outcome 'Depressed', comparator $SRT_{I/I}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–2.621	0.118	–22.13	8828.65	<0.001
Group ($SRT_{I/I}$ *)					
$SRT_{N/–}$	–0.242	0.154	–1.57	36642.70	0.116
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	–0.085	0.073	–1.16	39719.76	0.245
Age band 3 (50–54)	–0.152	0.073	–2.08	42047.25	0.037
Age band 4 (55–59)	–0.399	0.075	–5.29	37134.07	<0.001
Age band 5 (60–64)	–0.818	0.077	–10.56	34001.59	<0.001
Age band 6 (65–69)	–1.160	0.091	–12.81	22164.43	<0.001
Sex (male)	0.182	0.072	2.54	38437.57	0.011
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.101	0.042	2.39	35686.22	0.017
Quintile 3	0.257	0.042	6.08	40801.57	<0.001
Quintile 4	0.460	0.042	11.07	32392.85	<0.001
Quintile 5 (most deprived)	0.638	0.049	13.14	25022.46	<0.001
Ethnicity white (non–white)	–0.711	0.042	–16.75	13323.67	<0.001
Higher BMI (continuous)	0.025	0.003	9.22	16976.48	<0.001
Higher PWASI (continuous)	0.002	0.003	0.56	36618.59	0.578
Hypertension (no)	–0.031	0.031	–1.01	35009.24	0.312
Cholesterol high (no)	0.147	0.042	3.48	23571.01	<0.001
Cardiovascular disease (no)	0.293	0.048	6.16	43171.64	<0.001
Moderate exercise (no)	–0.282	0.040	–7.08	404.69	<0.001
Diabetes (no)	0.163	0.059	2.75	16391.21	0.006
Smoking status (never smoker)					
Smoker former	–0.057	0.033	–1.72	30952.80	0.086
Smoker current	0.468	0.041	11.47	16082.11	<0.001
Drinking status (never drinker)					
Drinker former	0.185	0.078	2.38	19950.08	0.017
Drinker current	–0.325	0.057	–5.68	14668.67	<0.001
Occupational noise exposure (no)	0.356	0.034	10.45	16224.25	<0.001
Loud music exposure (no)	0.234	0.039	6.07	12583.91	<0.001
Ototoxic medication use (no)	0.467	0.029	15.94	24253.23	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	0.153	0.096	1.59	42231.82	0.113
Age band 3 x Female sex	0.201	0.095	2.12	38295.31	0.034
Age band 4 x Female sex	0.168	0.098	1.72	37293.85	0.086
Age band 5 x Female sex	0.228	0.099	2.31	32672.40	0.021
Age band 6 x Female sex	0.295	0.114	2.58	24205.18	0.010

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST13. Model output: outcome 'In poor health', comparator $SRT_{I/I}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–3.476	0.071	–48.99	47261.31	<0.001
Group ($SRT_{I/I}$ *)					
$SRT_{N/–}$	0.046	0.081	0.57	97093.89	0.567
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	–0.107	0.041	–2.58	105229.38	0.010
Age band 3 (50–54)	–0.147	0.041	–3.60	105100.18	<0.001
Age band 4 (55–59)	–0.231	0.040	–5.74	107110.46	<0.001
Age band 5 (60–64)	–0.398	0.039	–10.24	101160.13	<0.001
Age band 6 (65–69)	–0.597	0.042	–14.25	104284.83	<0.001
Sex (male)	–0.103	0.043	–2.40	107202.10	0.016
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.104	0.020	5.17	106364.22	<0.001
Quintile 3	0.215	0.021	10.04	103263.00	<0.001
Quintile 4	0.339	0.022	15.30	106334.32	<0.001
Quintile 5 (most deprived)	0.486	0.029	16.96	99099.03	<0.001
Ethnicity white (non–white)	–0.183	0.029	–6.36	84075.46	<0.001
Higher BMI (continuous)	0.093	0.002	57.59	58748.12	<0.001
Higher PWASI (continuous)	0.016	0.002	6.64	63749.06	<0.001
Hypertension (no)	0.168	0.016	10.34	104187.90	<0.001
Cholesterol high (no)	0.377	0.021	18.23	106026.78	<0.001
Cardiovascular disease (no)	0.749	0.026	29.16	102320.76	<0.001
Moderate exercise (no)	–0.344	0.020	–16.77	560.86	<0.001
Diabetes (no)	0.736	0.033	22.34	98952.97	<0.001
Smoking status (never smoker)					
Smoker former	0.111	0.017	6.71	102761.07	<0.001
Smoker current	0.704	0.024	29.68	96202.81	<0.001
Drinking status (never drinker)					
Drinker former	0.252	0.050	5.06	94981.51	<0.001
Drinker current	–0.345	0.036	–9.62	91492.78	<0.001
Occupational noise exposure (no)	0.350	0.018	19.37	60304.65	<0.001
Loud music exposure (no)	0.174	0.022	7.94	59411.69	<0.001
Ototoxic medication use (no)	0.563	0.015	37.21	107517.18	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	0.146	0.058	2.53	107155.95	0.011
Age band 3 x Female sex	0.104	0.056	1.85	109371.29	0.064
Age band 4 x Female sex	0.104	0.055	1.90	109553.74	0.058
Age band 5 x Female sex	0.119	0.052	2.27	108409.08	0.023
Age band 6 x Female sex	0.261	0.056	4.69	108321.45	<0.001

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST14. Model output: outcome 'Dissatisfied with health', comparator $SRT_{I/I}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–4.341	0.085	–51.20	39213.07	<0.001
Group ($SRT_{I/I}$ *)					
$SRT_{N/–}$	0.005	0.101	0.05	69367.14	0.960
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	–0.110	0.051	–2.16	94361.55	0.031
Age band 3 (50–54)	–0.240	0.051	–4.74	99881.95	<0.001
Age band 4 (55–59)	–0.349	0.050	–6.97	102525.63	<0.001
Age band 5 (60–64)	–0.668	0.049	–13.55	102442.08	<0.001
Age band 6 (65–69)	–0.929	0.054	–17.12	101884.12	<0.001
Sex (male)	–0.025	0.052	–0.47	101137.28	0.637
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.036	0.026	1.40	95058.98	0.162
Quintile 3	0.118	0.027	4.32	96200.77	<0.001
Quintile 4	0.274	0.027	9.95	99292.05	<0.001
Quintile 5 (most deprived)	0.342	0.034	9.95	76592.44	<0.001
Ethnicity white (non–white)	–0.102	0.035	–2.95	59719.27	0.003
Higher BMI (continuous)	0.091	0.002	49.08	31784.85	<0.001
Higher PWASI (continuous)	0.008	0.003	2.97	47342.76	0.003
Hypertension (no)	0.102	0.021	4.92	99709.32	<0.001
Cholesterol high (no)	0.270	0.026	10.37	96066.63	<0.001
Cardiovascular disease (no)	0.640	0.029	21.74	91905.52	<0.001
Moderate exercise (no)	–0.358	0.025	–14.54	646.88	<0.001
Diabetes (no)	0.550	0.036	15.31	84062.13	<0.001
Smoking status (never smoker)					
Smoker former	0.092	0.021	4.37	92018.90	<0.001
Smoker current	0.459	0.029	15.84	87738.12	<0.001
Drinking status (never drinker)					
Drinker former	0.415	0.058	7.16	68403.69	<0.001
Drinker current	–0.206	0.044	–4.70	56040.32	<0.001
Occupational noise exposure (no)	0.190	0.023	8.40	75299.89	<0.001
Loud music exposure (no)	0.253	0.026	9.59	57439.02	<0.001
Ototoxic medication use (no)	0.611	0.019	31.68	98253.69	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	0.232	0.070	3.33	94887.50	<0.001
Age band 3 x Female sex	0.206	0.069	2.99	104390.06	0.003
Age band 4 x Female sex	0.225	0.068	3.32	102176.01	<0.001
Age band 5 x Female sex	0.262	0.065	4.00	105022.00	<0.001
Age band 6 x Female sex	0.403	0.071	5.68	101941.31	<0.001

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST15. Model output: outcome 'Lonely', comparator $SRT_{I/I}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–2.273	0.075	–30.25	30186.13	<0.001
Group ($SRT_{I/I}$ *)					
$SRT_{N/–}$	0.062	0.086	0.71	89821.12	0.476
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	–0.024	0.046	–0.52	85200.93	0.606
Age band 3 (50–54)	–0.061	0.046	–1.34	79393.11	0.179
Age band 4 (55–59)	–0.203	0.046	–4.43	71502.06	<0.001
Age band 5 (60–64)	–0.382	0.045	–8.58	82564.24	<0.001
Age band 6 (65–69)	–0.635	0.050	–12.76	73587.80	<0.001
Sex (male)	0.341	0.045	7.57	72779.85	<0.001
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.126	0.022	5.70	85452.24	<0.001
Quintile 3	0.253	0.023	10.91	67661.26	<0.001
Quintile 4	0.401	0.024	16.97	76928.64	<0.001
Quintile 5 (most deprived)	0.624	0.030	21.10	71842.44	<0.001
Ethnicity white (non–white)	–0.138	0.030	–4.59	69912.12	<0.001
Higher BMI (continuous)	0.024	0.002	14.70	39371.74	<0.001
Higher PWASI (continuous)	0.003	0.002	1.14	7247.40	0.256
Hypertension (no)	–0.080	0.017	–4.60	73208.60	<0.001
Cholesterol high (no)	–0.012	0.024	–0.49	82063.86	0.627
Cardiovascular disease (no)	0.213	0.029	7.34	85018.40	<0.001
Moderate exercise (no)	–0.164	0.022	–7.52	582.28	<0.001
Diabetes (no)	0.216	0.037	5.90	77447.90	<0.001
Smoking status (never smoker)					
Smoker former	–0.010	0.018	–0.57	78608.53	0.571
Smoker current	0.396	0.025	15.80	76211.84	<0.001
Drinking status (never drinker)					
Drinker former	0.290	0.053	5.49	57485.99	<0.001
Drinker current	–0.025	0.039	–0.63	59997.58	0.525
Occupational noise exposure (no)	0.254	0.020	12.66	52205.51	<0.001
Loud music exposure (no)	0.222	0.023	9.54	42316.77	<0.001
Ototoxic medication use (no)	0.302	0.016	18.37	92558.25	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	0.065	0.060	1.07	83196.99	0.282
Age band 3 x Female sex	0.099	0.059	1.67	83100.74	0.095
Age band 4 x Female sex	0.166	0.059	2.84	73120.59	0.005
Age band 5 x Female sex	0.219	0.056	3.90	82121.01	<0.001
Age band 6 x Female sex	0.389	0.062	6.30	75147.05	<0.001

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST16. Model output: outcome 'Unhappy', comparator $SRT_{I/I}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–2.713	0.128	–21.15	50958.33	<0.001
Group ($SRT_{I/I}$ *)					
$SRT_{N/–}$	–0.222	0.174	–1.28	91233.17	0.202
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	0.102	0.068	1.49	98298.99	0.135
Age band 3 (50–54)	0.039	0.069	0.56	95301.96	0.575
Age band 4 (55–59)	–0.226	0.071	–3.16	97523.32	0.002
Age band 5 (60–64)	–0.615	0.073	–8.40	96547.21	<0.001
Age band 6 (65–69)	–1.103	0.090	–12.32	104571.39	<0.001
Sex (male)	–0.210	0.074	–2.84	95297.40	0.005
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.074	0.042	1.75	99676.27	0.080
Quintile 3	0.322	0.042	7.71	93093.15	<0.001
Quintile 4	0.481	0.042	11.48	84600.97	<0.001
Quintile 5 (most deprived)	0.556	0.051	10.86	83142.66	<0.001
Ethnicity white (non–white)	–0.015	0.051	–0.29	62793.84	0.771
Higher BMI (continuous)	0.006	0.003	2.06	35663.97	0.040
Higher PWASI (continuous)	–0.002	0.004	–0.42	63770.56	0.671
Hypertension (no)	–0.122	0.031	–3.91	86108.58	<0.001
Cholesterol high (no)	0.085	0.044	1.93	86633.62	0.054
Cardiovascular disease (no)	0.192	0.052	3.71	94985.99	<0.001
Moderate exercise (no)	–0.327	0.036	–9.15	905.14	<0.001
Diabetes (no)	0.239	0.063	3.80	83085.22	<0.001
Smoking status (never smoker)					
Smoker former	0.048	0.033	1.45	83730.51	0.146
Smoker current	0.412	0.042	9.88	84513.54	<0.001
Drinking status (never drinker)					
Drinker former	0.354	0.087	4.08	55994.48	<0.001
Drinker current	–0.205	0.068	–3.02	60371.91	0.003
Occupational noise exposure (no)	–0.006	0.035	–0.17	76420.57	0.867
Loud music exposure (no)	0.362	0.037	9.71	52563.82	<0.001
Ototoxic medication use (no)	0.295	0.030	9.97	98926.30	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	0.091	0.096	0.94	96815.56	0.348
Age band 3 x Female sex	0.061	0.096	0.64	97838.97	0.525
Age band 4 x Female sex	0.029	0.099	0.29	94903.63	0.770
Age band 5 x Female sex	0.090	0.100	0.90	96194.57	0.367
Age band 6 x Female sex	0.326	0.119	2.72	101178.74	0.006

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST17. Model output: outcome 'Has difficulty following conversations in noise', comparator $SRT_{I/I}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–1.404	0.067	–20.94	37773.93	<0.001
Group ($SRT_{I/I}$ *)					
$SRT_{N/–}$	1.676	0.095	17.69	97829.47	<0.001
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	0.324	0.041	7.99	66642.59	<0.001
Age band 3 (50–54)	0.494	0.039	12.50	77172.09	<0.001
Age band 4 (55–59)	0.686	0.039	17.75	67916.64	<0.001
Age band 5 (60–64)	0.830	0.037	22.39	74886.38	<0.001
Age band 6 (65–69)	1.012	0.039	25.81	72395.42	<0.001
Sex (male)	–0.011	0.043	–0.26	69261.72	0.795
Material deprivation (Quintile 1, least deprived)					
Quintile 2	–0.015	0.018	–0.87	76487.18	0.383
Quintile 3	–0.012	0.019	–0.65	76160.01	0.518
Quintile 4	–0.022	0.020	–1.07	78312.17	0.282
Quintile 5 (most deprived)	–0.006	0.027	–0.20	64733.28	0.838
Ethnicity white (non–white)	0.294	0.029	10.24	55848.09	<0.001
Higher BMI (continuous)	0.008	0.001	5.20	35893.94	<0.001
Higher PWASI (continuous)	0.005	0.002	2.66	23272.72	0.008
Hypertension (no)	–0.097	0.014	–6.71	74329.24	<0.001
Cholesterol high (no)	0.022	0.019	1.14	70065.65	0.254
Cardiovascular disease (no)	0.108	0.025	4.35	69892.82	<0.001
Moderate exercise (no)	–0.088	0.017	–5.11	989.23	<0.001
Diabetes (no)	0.000	0.032	0.00	78021.17	0.996
Smoking status (never smoker)					
Smoker former	0.109	0.015	7.53	70452.05	<0.001
Smoker current	0.012	0.023	0.52	58204.93	0.604
Drinking status (never drinker)					
Drinker former	0.179	0.048	3.71	58539.54	<0.001
Drinker current	0.097	0.035	2.77	49109.33	0.006
Occupational noise exposure (no)	0.527	0.016	32.39	54333.72	<0.001
Loud music exposure (no)	0.497	0.020	24.90	46004.08	<0.001
Ototoxic medication use (no)	0.153	0.014	10.94	63756.24	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	–0.106	0.056	–1.89	74170.59	0.058
Age band 3 x Female sex	–0.112	0.054	–2.08	71064.92	0.038
Age band 4 x Female sex	–0.253	0.053	–4.81	69784.80	<0.001
Age band 5 x Female sex	–0.280	0.050	–5.62	71891.74	<0.001
Age band 6 x Female sex	–0.418	0.052	–7.97	69867.59	<0.001

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST18. Model output: outcome 'Has tinnitus', comparator $SRT_{I/I}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–2.225	0.085	–26.06	33562.22	<0.001
Group ($SRT_{I/I}$ *)					
$SRT_{N/–}$	0.980	0.074	13.31	69142.46	<0.001
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	0.207	0.054	3.83	51468.65	<0.001
Age band 3 (50–54)	0.358	0.052	6.85	47591.77	<0.001
Age band 4 (55–59)	0.572	0.050	11.39	56098.19	<0.001
Age band 5 (60–64)	0.750	0.048	15.58	53191.66	<0.001
Age band 6 (65–69)	0.829	0.050	16.48	50334.21	<0.001
Sex (male)	–0.126	0.060	–2.11	47344.28	0.035
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.046	0.022	2.09	70551.53	0.037
Quintile 3	0.014	0.024	0.57	70179.40	0.566
Quintile 4	0.083	0.026	3.25	56423.54	0.001
Quintile 5 (most deprived)	0.159	0.033	4.80	63924.80	<0.001
Ethnicity white (non–white)	0.191	0.037	5.19	42703.08	<0.001
Higher BMI (continuous)	–0.002	0.002	–0.96	27229.19	0.336
Higher PWASI (continuous)	0.001	0.002	0.41	39965.83	0.685
Hypertension (no)	0.048	0.018	2.62	77743.80	0.009
Cholesterol high (no)	0.034	0.024	1.43	73676.78	0.153
Cardiovascular disease (no)	0.098	0.029	3.35	70018.36	<0.001
Moderate exercise (no)	0.019	0.022	0.88	1145.94	0.377
Diabetes (no)	–0.092	0.038	–2.40	68832.60	0.017
Smoking status (never smoker)					
Smoker former	0.007	0.018	0.39	63160.13	0.700
Smoker current	–0.128	0.030	–4.30	60796.86	<0.001
Drinking status (never drinker)					
Drinker former	0.190	0.058	3.28	60912.77	0.001
Drinker current	–0.051	0.043	–1.18	67591.51	0.238
Occupational noise exposure (no)	0.494	0.020	25.25	59801.18	<0.001
Loud music exposure (no)	0.492	0.024	20.57	47264.80	<0.001
Ototoxic medication use (no)	0.217	0.018	12.37	71740.08	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	–0.081	0.078	–1.04	49271.65	0.297
Age band 3 x Female sex	0.057	0.074	0.78	47151.92	0.438
Age band 4 x Female sex	0.018	0.071	0.25	54587.79	0.804
Age band 5 x Female sex	–0.073	0.067	–1.08	54341.38	0.279
Age band 6 x Female sex	–0.107	0.070	–1.55	49956.60	0.122

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

TABLE ST19. Model output: outcome 'Uses hearing aids', comparator $SRT_{I/I}$.

Model variable	Estimate	SE	z value	df	p value
Intercept	–5.053	0.413	–12.22	62742.03	<0.001
Group ($SRT_{I/I}$ *)					
$SRT_{N/–}$	1.051	0.095	11.05	109511.03	<0.001
Age (Age band 1, 40–44 years old)					
Age band 2 (45–49)	0.820	0.394	2.08	103673.23	0.038
Age band 3 (50–54)	0.821	0.379	2.17	101545.05	0.030
Age band 4 (55–59)	1.087	0.360	3.02	99996.10	0.003
Age band 5 (60–64)	1.425	0.348	4.10	98874.64	<0.001
Age band 6 (65–69)	1.790	0.346	5.17	98594.75	<0.001
Sex (male)	0.272	0.436	0.62	96502.10	0.532
Material deprivation (Quintile 1, least deprived)					
Quintile 2	0.026	0.073	0.35	108555.62	0.723
Quintile 3	0.035	0.081	0.44	109571.43	0.660
Quintile 4	–0.108	0.085	–1.28	110029.12	0.202
Quintile 5 (most deprived)	–0.138	0.107	–1.30	106717.18	0.195
Ethnicity white (non–white)	1.004	0.129	7.80	107069.71	<0.001
Higher BMI (continuous)	0.000	0.006	0.02	27133.82	0.985
Higher PWASI (continuous)	–0.006	0.008	–0.81	71910.53	0.415
Hypertension (no)	–0.114	0.062	–1.84	109815.43	0.065
Cholesterol high (no)	0.021	0.068	0.31	112652.41	0.757
Cardiovascular disease (no)	0.017	0.081	0.22	112051.10	0.830
Moderate exercise (no)	0.151	0.080	1.89	589.70	0.058
Diabetes (no)	0.148	0.098	1.51	109137.09	0.132
Smoking status (never smoker)					
Smoker former	0.095	0.060	1.59	104914.93	0.111
Smoker current	–0.283	0.103	–2.76	101532.32	0.006
Drinking status (never drinker)					
Drinker former	–0.061	0.178	–0.34	111125.79	0.730
Drinker current	0.028	0.128	0.22	110908.42	0.825
Occupational noise exposure (no)	0.581	0.062	9.39	92804.89	<0.001
Loud music exposure (no)	0.282	0.085	3.33	59712.36	<0.001
Ototoxic medication use (no)	0.299	0.058	5.14	112781.06	<0.001
Age band–sex interaction (Age band 1 x Male sex)					
Age band 2 x Female sex	–0.912	0.536	–1.70	99811.42	0.089
Age band 3 x Female sex	–0.224	0.487	–0.46	101418.87	0.646
Age band 4 x Female sex	–0.534	0.467	–1.15	99288.71	0.252
Age band 5 x Female sex	–0.389	0.446	–0.87	97126.84	0.384
Age band 6 x Female sex	–0.555	0.443	–1.25	97649.47	0.211

* Reference levels for the corresponding predictor variables are shown in brackets.
BMI, Body Mass Index; df, degrees of freedom; 'I', impaired; 'N', normal; PWASI, Pulse Wave Arterial Stiffness Index; SE, standard error; SRT, speech reception threshold.

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