The role of socio-economic and lifestyle factors in hearing function in middle-aged adults.

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Financial disclosures/ conflicts of interest: There are no conflicts of interest.

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Abstract

Objectives: This study aimed to investigate the associations between socioeconomic and lifestyle factors and measures of hearing ability to better understand potential risk factors for hearing loss. Insights from this research could help audiologists identify high-risk demographics, and ultimately contribute to addressing inequalities in hearing health.

Design: An online study design was used, where data were collected on participant demographics, lifestyle and socioeconomic status, including age, gender, ethnicity, region of residence, income, education, occupation, exercise frequency, height and weight, smoking status, and weekly alcohol consumption, which were used as model predictors. Participants also self-reported their hearing function using the Speech, Spatial and Qualities of Hearing Scale 12 (SSQ-12) and completed an online digits-in-noise (DiN) task to assess speech perception ability, which were used as outcome variables. A sample of 227 adults aged 45-65 (Mean age = 53.77, SD = 5.87) were recruited through Prolific (www.prolific.com) based on Office for National Statistics (ONS) income groups.

Results: Two multiple regression models were conducted with the outcome variables of speech perception ability (Digits-in-Noise: DiN) and self-reported hearing function (Speech and Spatial Qualities of Hearing Scale: SSQ-12). The analysis revealed that having a routine and manual occupation predicted worse self-reported hearing function, as did being a regular tobacco consumer. No significant predictors were significant for speech perception ability .

Conclusions: The findings suggest that socioeconomic and lifestyle factors, as measured in this study, are significantly associated with self-reported hearing function in mid-life, but not with speech in noise perception ability. These results partially align with previous research that has identified smoking and occupation factors as predictors of hearing sensitivity when measured

using pure tone audiometry. These data highlight the need for greater understanding as to how lifestyle and socioeconomic factors relate to different dimensions of hearing health.

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Introduction

Hearing loss is frequently accepted as an unavoidable consequence of ageing. However, not everyone experiences age-related hearing loss (ARHL); in fact, the validity of the concept of age-related hearing loss has been questioned [1]. Lifestyle-related hearing loss may be a more accurate conceptualisation; the accumulation of lifestyle factors over time may be the mechanism behind age-related declines. It may be the case that modifiable lifestyle factors and health inequalities lead to an increased likelihood of hearing loss in older age. Lifestyle factors may be modifiable factors such as diet, physical activity, noise exposure, or BMI; however, lifestyle may be strongly impacted by non-modifiable factors such as geographical location [2], cultural norms and socioeconomic position [1]. For example, living in an area where there is limited access to affordable healthy foods and recreational spaces will reduce the modifiability of lifestyle choices.

Hearing loss is not only a challenging sensory deficit; it impacts quality of life, and is related to reduced wellbeing [3], increased social isolation [4] and depression [5]. Previous data have indicated that the socioeconomic position of participants influenced the strength of the relationship between hearing loss and depression, and people with lower income had up to double the relative risk for depression compared to their counterparts with higher income [5]. Understanding the socioeconomic and lifestyle factors, possibly underlying ageing, which contribute to hearing difficulty in later life, will highlight avenues for intervention and reduce the burden of preventable hearing loss on both the individual and the health care system.

Previous research highlights that lower socioeconomic position (SEP; an umbrella term which often incorporates education, occupation, income and wealth factors), and lifestyle variables (including body mass index, physical inactivity, smoking and alcohol consumption) are associated with poorer hearing, as strongly as age and gender [1]. The link between SEP, lifestyle factors, and hearing loss is multifaceted [6]. SEP factors, contribute to social and health inequality [6]. Such factors increase the likelihood of high-noise exposure occupations [7]; financial barriers to audiological treatments [1]; financial stresses which may be associated with unhealthy eating, e.g. eating lower cost food that is less nutritionally rich, increased smoking, and alcohol consumption [6, 8]. Unhealthy eating could be predictive of hearing loss due to dietary behaviours that reduce vitamin B12 levels [9]. B12 plays an important role in cell metabolism, vascular function, and myelin synthesis; the impairment of these functions may increase the risk of hearing loss [10]. Similarly, the association between alcohol consumption and hearing loss may be due to alcohol induced B12 depletion [11]. The association between smoking and hearing loss may be due to oxidative stress, an imbalance of free radicals and antioxidants in the body [12]. Due to the high metabolic demands of the cochlea while responding to stimuli, the mitochondria of hair cells produce high levels of reactive oxygen species. This can result in cochlear degeneration when the antioxidants of hair cells are compromised by external factors, such as smoking, which may result in hearing loss [13-16]. All these factors increase the likelihood of poorer hearing. Critically, SEP disparities cultivate inequitable situations in which prioritising behaviours for hearing health is not an option for a proportion of the population; such as health-seeking behaviours like taking precautions to reduce noise exposure and accessing audiological services.

The present study investigates how SEP and lifestyle factors impact hearing ability and speech perception in middle-aged adults aged 45-65 years old. Previous research has focused on hearing sensitivity measured using pure tone audiometry [1], but communication in naturalistic settings requires understanding suprathreshold stimuli, such as speech in noise. Difficulties with speech perception in noisy environments are a common complaint, and such problems may be a precursor to clinical hearing loss [17]. This research aims to determine which, if any, SEP and lifestyle factors affect speech in noise perception ability and subjective hearing ability in middle age. Building on previous research that measured hearing function using one dimension, hearing sensitivity [1], this research measures two not yet explored dimensions of hearing function, speech perception ability and subjective hearing ability. Furthermore, this research targets a socioeconomically representative sample, recruited via income groups; previous research has utilised large-scale volunteer datasets such as The English Longitudinal Study of Ageing (ELSA) that have disproportionately high dropout rates for lower socioeconomic groups [18].Identifying the factors which may predict reduced hearing function in mid-life will allow for early implementation of lifestyle interventions to address risk factors, encourage uptake of hearing aids in at-risk populations, and reduce hearing health inequalities, as audiologists can target groups in most need.

Specifically, this study aimed to explore the role of socioeconomic position (incorporating level of education, occupation, and income), demographic information that relate to socioeconomic position and modify lifestyle choices (including region of residence, ethnicity, age, and gender), and health-related lifestyle factors (including body mass index, physical activity, smoking status, and alcohol consumption), in speech perception ability and self-reported hearing ability in middle-aged adults (45-65 years).

Methods

Ethical approval was obtained from Lancaster University's Faculty of Science and Technology Ethics Committee (FST-2022-0790-MA-1), and the research study was preregistered on the Open Science Framework (https://osf.io/xju76).

Participants

The participants included 227 adults (110 males and 117 females) aged between 45-65 (*M* = 53.78, *SD* = 5.87). The number of participants recruited was based on an a-priori power analyses using G*power [19], which suggested a minimum sample size of 124 participants. The minimum requirement was calculated by inputting 11 predictors, setting alpha at .05, power at .80, and Cohen's f^2 to .15 – representing a medium effect size. Further participants were recruited to ensure as much equal distribution across income bands as possible, this was facilitated by having multiple live studies on Prolific [20] each targeting a different income band, this was achieved by using Prolific's pre-screening function. All participants resided in the UK, did not have an ear infection at the time of the study, did not have a cochlear implant and self-reported having used headphones for the speech perception task. The participants were recruited based on Office for National Statistics (ONS) income distribution groups: £0-£12,999 (N=31), £13,000-£20,499 (N=37), £20,500-£26,799 (N=29), £26,800-£35,699 (N=37), £35,700-£53,999 (N=41), >£54,000 (N=52), to facilitate a wide distribution of SEP. Participants were recruited using the online portal Prolific [20] and were paid £5 on completion of the study.

Materials

Predictor Variables

Self-reported Demographic and Lifestyle factors

Gender

Gender was measured as a self-reported categorical variable (female, male, non-binary).

Age

Age was measured on a continuous scale; participants were given a drop-down box with ages 45-65 to select from.

Region of residence

Region of Residence in the UK was measured as a self-reported categorical variable. Participants could select from the options: Scotland, Northern Ireland, North-East, North-West, Yorkshire and the Humber, East Midlands, West Midlands, Wales, East of England, London, South-East, and South-West. The Region categories were based on the international territorial levels [21] and reflect the categories used by Tsimpida et al. [22].

Ethnicity

Ethnicity was recorded from participants' self-reported ethnic group; the categories were selected from the 13 categories provided in the UK Governmental Statistical Service (GSS) ethnicity harmonised standard [23].

Body Mass Index (BMI)

BMI was calculated from participants' self-reported height and weight according to the equation: BMI = kg/m2, where kg is the person's weight in kilograms and m2 is their height in meters squared. Being underweight was categorised as a BMI <18.5, healthy weight as 18.5-24.99, overweight as 25-29.99, and obese as >30.

Level of physical activity

Level of physical activity was measured by asking participants to rate on a four-point scale how often they complete moderate-to-high-intensity physical activity (e.g., activities like brisk walking, riding a bike, mowing the grass). Response options included (1) more than once a week, (2) once a week, (3) one to three times a month and (4) hardly ever or never. The categories reflect those used by [1].

Tobacco consumption

Tobacco consumption was measured by asking participants to disclose their consumption of Tobacco products. Response options included (1) regular, current smoker/consumer (2) occasional current smoker/consumer (3) former smoker/consumer (4) never smoked/consumed.

Levels of alcohol consumption

Levels of alcohol consumption were self-reported by participants. Participants were asked to disclose their alcohol intake in units over the last 7 days. To help participants respond accurately, they were provided with guidance on the number of alcohol units in a range of common alcoholic beverages.

Occupation

Occupation was measured as a self-reported categorical variable. Participants were asked to select the occupation they have spent the most years on. The 2020 UK Standard Occupational Classification major group structure [24] was used to create the ten response categories. Examples of jobs that fit in each major category were provided to support participants' accuracy.

The highest level of educational attainment

The highest level of educational attainment was self-reported by participants. Participants selected from the options: no qualifications, foreign or other, O level Certificate of Secondary Education or GCSE, A level (or level 3 equivalent), degree or higher education. The categories reflect those used by Tsimpida et al. [1, 22].

Net household income

Net household income was measured by asking participants to select their net household income from 6 categories. The categories were provided according to ONS income distribution, containing the average (median) annual household income by quintile from the year ending March 2019 [25]. The options were: above £54,000, between £35,700 and £54,000, between £26,800 and £35,699, between £20,500 and £26,799, between £13,000 and £20,499, or below £13,000.

Outcome variables

Speech, Spatial and Qualities of Hearing Scale-12

The SSQ-12 [26] is a questionnaire that enquires about an individual's perceptions of their hearing ability and hearing quality in different lifestyle situations. The questionnaire is used to measure subjective hearing function. Participants responded on a 10-point Likert scale where 0 indicated that they would be unable to hear or listen in the situation described, and 10 indicated that they would be perfectly able to hear or listen in the described situation. Therefore, scores ranged from 12 (perfect hearing) to 0 (poorest hearing). An example item is, 'You are talking with one other person, and there is a TV on in the same room. Without turning the TV down, can you follow what the person you're talking to says?'. The scores are averaged over all items to create a mean SSQ-12 score; lower mean scores indicate poorer self-reported hearing ability.

Remote Digits-in-Noise Task

The remote Digits-in-Noise (DiN) task measures speech perception accuracy [27]. It presents three numbers via an audio recording of a female voice with varying signal-to-noise ratios. During the DiN task, a participant hears three numbers and reports the numbers they heard using an onscreen keypad. An adaptive 1-up, 1-down psychophysical paradigm was implemented whereby a correct response resulted in the speech-to-noise ratio (SNR) being reduced and an incorrect one caused the SNR to increase, both the speech and noise were adapted. The starting SNR was 0 dB and the step sizes decreased from 5 to 2 dB after 3 reversals, which then reduced to 0.5 dB after 3 more reversals. There were no familiarization trials as to avoid participant fatigue, however there was a presentation of digits on a background of noise at the starting SNR that could be played as many times as the user needed to feel comfortable with hearing the sound. The run terminated after 10 reversals and the SNR at the last 5 reversals was averaged to calculate the DIN threshold (SNR-50) for each participant. A lower SNR-50 is related to better speech perception ability, whereas a higher SNR-50 indicates poor speech perception ability.

Procedure

Participants accessed the study through Prolific [20] using pre-screen filters for age, income, country of residence and cochlear implant use. They were redirected to an online

Qualtrics (https://www.qualtrics.com) questionnaire; they used their phones or computers and could complete the survey in their chosen location. All participants were provided with identical questionnaires. Before access was given to the questionnaire, participants provided their informed consent. They then had to enter their unique prolific ID for payment purposes. After this, they were directed to a set of screening questions; they were screened for age, hearing disorders and UK residency. If they did not meet the inclusion criteria, participants were redirected to the end of the survey and the debrief sheet. The participants who did meet the inclusion criteria were directed to the self-reported lifestyle factors survey, the SSQ-12 [26] and the DiN task. Prolific encourages the use of attention checks and allows for participant data to be rejected if they have failed two or more attention checks [28]. Within the survey there were three attention checks, two of which were instructional manipulation tasks. Participants were asked, “The test you are about to take part in is very simple; when asked for your favourite country, you must select ‘Thailand’. This is an attention check. Based on the text you read above, what country have you been asked to select?”. Participants could select from ‘India’, ‘Cambodia’, ‘Bangladesh’, ‘Thailand’ and ‘Vietnam’. The second attention check asked: “The Maths test you are about to take part in is very simple; when asked what is ‘2+2’, you must answer ‘5’. This is an attention check. Based on the text you read above, which answer have you been asked to select?”. The third attention check was a nonsensical item, the statement “The moon is made out of cheese” was paired with a Likert scale, to pass the check participants had to select “strongly disagree” or “disagree”. No participants failed the attention checks. Participants were required to wear headphones for the DiN task. To check this, participants were asked to self-report if they were wearing headphones and to indicate the type of headphones they were wearing, as well as the type of device they were using, i.e. mobile or laptop, no participants reported being hearing aid users. After completing the DiN task, participants were debriefed and redirected to Prolific for renumeration.

Statistical Analysis

Descriptive statistics for all planned analyses were reported. Data was analysed using multiple linear regression models. Two separate regression models were run to determine which variables best predict subjective hearing ability and speech perception performance. The outcome variables in the two multiple regression models were: 1) subjective hearing ability, as quantified by the mean score on the Speech and Spatial Qualities of Hearing Scale (SSQ-12 [26]); 2) speech perception performance, as quantified by the SNR-50 (the signal-to-noise ratio at which a participant achieves a 50% performance standard) obtained from an online Digits in Noise (DiN) task. The predictor variable region was grouped into three categories: north, midlands and south. Occupation was categorised into four categories: unemployed, routine and manual, intermediate, and professional and managerial occupations. The predictor, educational attainment, was dichotomised into those with a degree or higher education and those without a degree or higher education. The alcohol consumption predictor was dichotomised into those who consumed more than 14 units of alcohol and those who consumed less than 14 units of alcohol in the last 7 days. Table 1 displays the transformations of the collapsed variables. The transformations were made to simplify the models and increase their interpretability. Gender was dichotomised into male and female, as there were no non-binary participants. Age was maintained as a continuous variable.

Table 1

Table displaying the raw counts of and recoding of collapsed variables, Region, Occupation and Education level

Collapsed variables	Original categorisations
Region	
South (N=79)	South East (N=36), South West (N=19), London (N=24)
Midlands (N=77)	East Midlands (N=19), East of England (N=27), West Midlands (N=22), Wales (N=9)
North (N=71)	North West (N=23), North East (N=7), Yorkshire and the Humber (N=20), Scotland (N=17), Northern Ireland (N=4)
Occupation	
Managerial and professional (N=69)	Managers, directors and senior officials (N=24), Professional occupations (N=45)
Intermediate (N=105)	Associate professional and technical occupations (N=32), Administrative occupations (N=59), Skilled trades occupations (N=14)
Routine and manual (N=46)	Caring, leisure and other service occupations (N=13), Elementary occupations (N=6), Process, plant and machine operatives (N=5), Sales and customer service occupations (N=22)
Unemployed (N=7)	Unemployed (N=7)
Education level	
Degree or higher education (N=128)	Degree or higher education (N=128)

No degree (N=99)	A level (or level 3 equivalent) (N=44), O level Certificate of Secondary Education or GCSE (N=50), Foreign or other (N=3), No qualifications (N=2)

For both the SSQ-12 [26] and SNR-50 models the included predictors were: Alcohol consumption (Less than or more than 14 units per week), Age (years), BMI group (Healthy vs Overweight vs Obese vs Underweight), Gender (Male vs Female), Education (Degree or higher vs no degree) Income (£0-£12,999 vs £13,000-£20499 vs £20,500-£26,799 vs £26,800-£35,699 vs £35,700-£53,999 vs £54,000 <), Occupation (Routine and Manual vs Intermediate vs Managerial and Professional vs Unemployed), Exercise (Less than once a week vs Once a week vs Less than once a week), Region (North vs Midlands vs South), Tobacco consumption (Current smoker vs Former smoker vs Never smoked).

Deviations from Pre-registration

The ethnicity predictor was removed from the analyses due to a lack of variance in the sample (White: N = 216, All other ethnic groups combined: N = 11). The pre-registered analysis plan was changed to omit the use of stpwise model selection with the StepAIC() function from the r MASS package [29] due to concerns about the reliability of stepwise logistic regressions when attempting to determine risk factors for medical illnesses [30]. Austin and Tu conducted 1,000 runs of backward elimination on one data set produced 940 different “optimal” models, suggesting the instability of stepwise model selection [31]. Therefore, only the full models were reported. To address possible type I error inflation, Family-Wise Error Rate was controlled through Bonferroni correction. As such, the criterion for statistical inference was modified by dividing the alpha level of .05 by the number of tested hypotheses, $(0.05/9)$, which provided a new inference criteria of $p = .00\dot{5}$.

Results

Data Analysis

Data points were removed if they were more than three standard deviations away from the mean SSQ-12 or SNR-50 [32]. Two participants were excluded based on having an outlying SNR-50. Influential outliers were investigated using Cook's distance; data points > 4/n were classified as outliers and were removed from the models (n is the number of data points, i.e., the sample size). For the speech perception accuracy model, 13 influential data points were removed; for the subjective auditory function model, 18 influential data points were removed. The data distributions without influential data points for speech perception accuracy and subjective auditory function are displayed in Figure 1.

Fig 1

Violin plots displaying the data distributions for SNR-50 and SSQ-12 scores when influential data points are removed

Data pre-processing and analyses were conducted in R [33]. We utilised the packages tidyverse and dpylr [34-35], the car package [36], ggthemes and ggpubr [37-38] for data management and visualisation; effect sizes were computed using the rsq package [39].

Speech perception accuracy

The mean SNR-50 was -9.3 (*SD* = 4.37); a lower SNR-50 reflects better hearing. The model without influential data points removed is reported (Table 1). The model was non-significant overall, $R^2_{adjusted} = -.05$, $F(23, 184) = 0.61$, $p = .92$. The model with influential data points removed is reported (Table 2). The model was non-significant overall, $R^2_{adjusted} = 0.02$, $F(23, 171) = 1.14$, $p = .31$. The distributions of SNR-50 when stratified by socioeconomic status are reported in Figure 2.

Table 1

Linear multiple regression model predicting speech perception accuracy (SNR-50) before influential outlier removal

SNR-50 ~ Age + Alcohol consumption + BMI Group + Gender + Education level + Income + Occupation + Exercise frequency + Region of residence + Tobacco consumption

	β	SE	*t*	*p*	partial R²
Constant	-10.73	3.24	-3.24	.001	
Age	0.01	0.06	0.19	.848	.0002
Alcohol consumption					.003
Over 14 units (N=34)	0.69	0.91	0.75	.454	
Under 14 units (reference) (N=174)					
BMI group					.03
Overweight (N=65)	-1.02	0.77	-1.33	.184	
Obese (N=52)	0.71	0.84	0.81	.396	
Underweight (N=4)_	2.64	2.33	1.13	.260	
Healthy weight (reference) (N=87)					
Gender					.001
Male (N=106)	0.03	0.67	0.45	.652	
Female (reference) (N=102)					

Education level					.001
No degree (N=89)	-0.27	0.74	-0.37	.714	
Degree or higher education (reference) (N=119)					
Income					.03
<£13,000 (N=29)	1.30	1.14	1.14	.255	
£13,000-£20,499 (N=35)	1.52	1.09	1.40	.162	
£20,500-£26,799 (N=25)	0.01	1.21	0.01	.993	
£26,800-£53,699 (N=33)	0.56	1.07	0.52	.602	
£35,700-£53,999 (N=37)	1.87	1.02	1.83	.070	
£53,999< (reference) (N=49)					
Occupation					.01
Intermediate (N=98)	0.45	0.80	0.57	.571	
Routine and Manual (N=38)	1.07	1.11	0.97	.333	
Unemployed (N=6)	-0.53	2.02	-0.26	.794	
Managerial and Professional (reference) (N=66)					
Exercise frequency					.02
Hardly ever or never (N=23)	-1.28	1.12	-1.14	.254	
One to three times a month (N=9)	0.71	1.63	0.43	.665	
Once a week (N=44)	-1.23	0.84	-1.46	.146	
More than once a week (reference) (N=132)					
Region of residence					.0004
Midlands (N=71)	0.21	0.80	0.26	.792	
North (N=67)	0.18	0.82	0.23	.822	
South (reference) (N=70)					
Tobacco consumption					.01
Former smoker/consumer (N=54)	-0.73	0.81	-0.91	.366	
Occasional smoker/consumer (N=8)	0.48	1.74	0.28	.783	
Regular smoker/consumer (N=51)	-0.28	0.82	-0.34	.732	
Never smoked/consumed (reference) (N=95)					

Note. β = Regression coefficient, SE = Standard error

Table 2

Linear multiple regression model predicting speech perception accuracy (SNR-50) after influential outlier removal

SNR-50 ~ Age + Alcohol consumption + BMI Group + Gender + Education level + Income + Occupation + Exercise frequency + Region of residence + Tobacco consumption

	β	SE	*t*	*p*	partial R^2
Constant	-14.21	3.00	-4.73	**< .001**	
Age	0.09	0.05	1.60	.111	.02
Alcohol consumption					.01
Over 14 units (N=33)	0.91	0.85	1.07	.287	
Under 14 units (reference) (N=162)					
BMI group					.05
Overweight (N=59)	-1.34	0.71	-1.89	.061	
Obese (N=49)	0.78	0.76	1.03	.303	
Underweight (N=1)_	5.36	4.13	1.30	.196	
Healthy weight (reference) (N=86)					
Gender					.0004
Male (N=99)	-0.16	0.63	-0.25	.802	
Female (reference) (N=96)					
Education level					.004
No degree (N=84)	-0.57	0.71	-0.80	.426	
Degree or higher education (reference) (N=111)					
Income					.04
<£13,000 (N=27)	0.57	1.07	0.54	.591	
£13,000-£20,499 (N=34)	1.67	1.00	1.67	.097	
£20,500-£26,799 (N=21)	-0.94	1.17	-0.80	.424	
£26,800-£53,699 (N=33)	0.58	0.97	0.60	.552	
£35,700-£53,999 (N=34)	1.27	0.96	1.32	.190	
£53,999< (reference (N=46)					
Occupation					.02
Intermediate (N=95)	0.87	0.75	1.16	.249	
Routine and Manual (N=35)	1.58	1.04	1.52	.129	
Unemployed (N=4)	-0.40	2.18	-0.18	.857	
Managerial and Professional (reference) (N=61)					
Exercise frequency					.03

Hardly ever or never (N=22)	-1.84	1.03	-1.80	.074	
One to three times a month (N=8)	-0.82	1.55	-0.53	.597	
Once a week (N=42)	-1.11	0.76	-1.47	.014	
More than once a week (reference) (N=123)					
Region of residence					.001
Midlands (N=68)	0.27	0.73	0.37	.715	
North (N=62)	0.12	0.76	0.16	.872	
South (reference) (N=65)					
Tobacco consumption					.04
Former smoker/consumer (N=47)	-1.88	0.77	-2.46	**.015**	
Occasional smoker/consumer (N=6)	0.37	1.78	0.21	.837	
Regular smoker/consumer (N=51)	-0.39	0.75	-0.53	.598	
Never smoked/consumed (reference) (N=91)					

Note. β = Regression coefficient, SE = Standard error

Fig 2

Box plots showing the distributions of SNR-50 when stratified by socioeconomic factors

Note. The Larger black dots represent the mean SNR-50 for each group; the smaller black dots represent individual data points. MnP = managerial and professional occupation, INT = intermediate occupation, RnM = routine and manual occupation.

Subjective auditory function

The internal consistency of the SSQ-12 [26] was measured by calculating Cronbach's alpha, α =.89. And the Item-Rest Correlations for the 12 items ranged from r = .40 to .78. The mean SSQ-12 score was 7.47 (SD = 1.45), a higher SSQ-12 score reflects better-self-reported hearing: Scores can range from 0-10. The model without influential data points removed is reported (Table 3). The model was non-significant overall $R^2_{adjusted}$ = 0.01, $F(23, 203) = 1.07$, p = .379. The model with influential data points removed is reported (Table 4). The model was non-significant overall, $R^2_{adjusted}$ = 0.10, $F(23, 185) = 1.97$, p = .007. The model with influential data points removed found that being a regular tobacco consumer significantly predicted worse self-reported auditory function compared to those who had never smoked/consumed (β = -0.74, p <. 001) (Figure 3) and that having a routine and manual occupation compared to having a managerial and professional occupation significantly predicted worse self-reported auditory function (β = -1.01, p <. 001) (Figure 4). The distributions of SNR-50 when stratified by socioeconomic status are reported in Figure 5.

Table 3

Linear multiple regression model predicting subjective auditory function (SSQ-12 score) before influential outlier removal

SSQ-12 score ~ Age + Alcohol consumption + BMI Group + Gender + Education level + Income + Occupation + Exercise frequency + Region of residence + Tobacco consumption

	β	SE	*t*	*p*	partial R²
Constant	8.92	0.98	9.07	**< .001**	
Age	-0.02	0.02	-1.01	.315	.01
Alcohol consumption					.0002
Over 14 units (N=38)	0.05	0.28	0.19	.853	
Under 14 units (reference) (N=189)					
BMI group					.01
Overweight (N=70)	0.08	0.24	0.33	.741	
Obese (N=59)	-0.32	0.25	-1.27	.206	
Underweight (N=4)_	0.07	0.75	0.09	.931	
Healthy weight (reference) (N=94)					
Gender					.01

Male (N=110)	-0.32	0.21	-1.54	.124	
Female (reference) (N=117)					
Education level					.004
No degree (N=99)	0.20	0.23	0.85	.397	
Degree or higher education (reference) (N=128)					
Income					.01
<£13,000 (N=31)	0.15	0.35	0.43	.671	
£13,000-£20,499 (N=37)	-0.09	0.34	-0.25	.800	
£20,500-£26,799 (N=29)	-0.06	0.37	-0.17	.864	
£26,800-£53,699 (N=37)	0.18	0.33	0.55	.584	
£35,700-£53,999 (N=41)	-0.04	0.32	-0.13	.897	
£53,999< (reference (N=52)					
Occupation					.03
Intermediate (N=105)	-0.38	0.25	-1.55	.122	
Routine and Manual (N=46)	-0.89	0.34	-2.63	**.009**	
Unemployed (N=7)	-0.53	0.62	-0.87	.388	
Managerial and Professional (reference) (N=69)					
Exercise frequency					.01
Hardly ever or never (N=24)	-0.02	0.35	-0.07	.946	
One to three times a month (N=10)	-0.26	0.50	-0.52	.606	
Once a week (N=48)	-0.24	0.26	-0.92	.358	
More than once a week (reference) (N=145)					
Region of residence					.01
Midlands (N=77)	0.11	0.24	0.45	.651	
North (N=71)	0.37	0.25	1.46	.146	
South (reference) (N=79)					
Tobacco consumption					.03
Former smoker/consumer (N=60)	0.08	0.25	0.31	.759	
Occasional smoker/consumer (N=9)	-0.12	0.52	-0.23	.818	
Regular smoker/consumer (N=56)	-0.55	0.25	-2.18	**.031**	
Never smoked/consumed (reference) (N=102)					

Note. β = Regression coefficient, SE = Standard error

Table 4

Linear multiple regression model predicting subjective auditory function after influential outlier removal (SSQ-12 score).

SSQ-12 score ~ Age + Alcohol consumption + BMI Group + Gender + Education level + Income + Occupation + Exercise frequency + Region of residence + Tobacco consumption

	β	SE	*t*	*p*	partial R^2
Constant	9.72	0.85	11.50	**< .001**	
Age	-0.03	0.02	-1.84	.068	.02
Alcohol consumption					.00003
Over 14 units (N=35)	0.02	0.24	0.07	.946	
Under 14 units (reference) (N=174)					
BMI group					.03
Overweight (N=63)	0.01	0.21	0.04	.972	
Obese (N=55)	-0.49	0.22	-2.23	**.027**	
Underweight (N=3)_	-0.55	0.71	-0.77	.455	
Healthy weight (reference) (N=88)					
Gender					.02
Male (N=103)	-0.34	0.18	-1.89	.061	
Female (reference) (N=106)					
Education level					.02
No degree (N=90)	0.38	0.21	1.81	.072	
Degree or higher education (reference) (N=119)					
Income					.01
<£13,000 (N=28)	0.12	0.31	0.39	.700	
£13,000-£20,499 (N=33)	-0.10	0.30	-0.34	.734	
£20,500-£26,799 (N=25)	-0.13	0.32	-0.40	.689	
£26,800-£53,699 (N=35)	0.09	0.28	0.34	.733	
£35,700-£53,999 (N=39)	0.03	0.27	0.10	.919	
£53,999< (reference (N=49)					
Occupation					.06
Intermediate (N=95)	-0.59	0.21	-2.74	**.007**	
Routine and Manual (N=45)	-1.01	0.30	-3.39	**< .001**	
Unemployed (N=5)	-0.63	0.60	-1.05	.297	
Managerial and Professional (reference) (N=67)					
Exercise frequency					.01

Hardly ever or never (N=21)	0.09	0.30	0.30	.764	
One to three times a month (N=7)	-0.53	0.49	-1.08	.283	
Once a week (N=45)	-0.21	0.22	-0.95	.343	
More than once a week (reference) (N=136)					
Region of residence					.02
Midlands (N=70)	0.12	0.21	0.64	.525	
North (N=68)	0.37	0.21	1.76	.080	
South (reference) (N=71)					
Tobacco consumption					.07
Former smoker/consumer (N=57)	0.06	0.21	0.26	.792	
Occasional smoker/consumer (N=5)	0.19	0.57	0.34	.736	
Regular smoker/consumer (N=51)	-0.74	0.22	-3.37	**< .001**	
Never smoked/consumed (reference) (N=96)					

Note. β = Regression coefficient, SE = Standard error

Fig 3

Box plot displaying the effect of tobacco consumption on subjective auditory function after influential outlier removal

Note. The Larger black dots represent the mean SSQ-12 score for each group; the smaller black dots represent individual data points

Fig 4

Box plot displaying the effect of occupation on subjective auditory function after influential outlier removal

Note. The Larger black dots represent the mean SSQ-12 score for each group; the smaller black dots represent individual data points. MnP = managerial and professional occupation, INT = intermediate occupation, RnM = routine and manual occupation.

Fig 5

Box plots showing the distribution of SSQ-12 scores when stratified by socioeconomic factors

Note. The Larger black dots represent the mean SSQ-score for each group; the smaller black dots represent individual data points. MnP = managerial and professional occupation, INT = intermediate occupation, RnM = routine and manual occupation

Discussion

Potential socioeconomic and lifestyle predictors of midlife hearing function were investigated in this online study, with subjective hearing ability measured using the SSQ-12 [26] and speech perception measured with a remote DiN task. Participants recruited through Prolific were recruited based on ONS income group, so there were equal participant numbers between socioeconomic bands.

When controlling for Family-Wise Error Rate through Bonferroni correction (dividing alpha by the number of tested hypotheses and using $p < .005$), there were no significant relationships between lifestyle or socioeconomic factors and speech perception ability in both models (with and without influential data points removed). In the model with influential data points removed, the predictors that had the largest effect sizes were income group (partial R^2 = .04) and tobacco consumption (partial R^2 = .04); these effect sizes are small-medium (.01 indicates a small effect size and .06 a medium effect size [40]) and represent a narrow picture of what predicts speech perception ability. There were significant relationships between lifestyle and socioeconomic factors and self-reported hearing function. In the model with influential data points removed having a routine and manual occupation as compared to having a managerial and professional occupation was significantly associated with worse subjective auditory function (p <.001). Regular tobacco consumption as compared to non-consumption was significantly associated with worse subjective auditory function (p <.001). The model predictors with the largest effect sizes were occupation (partial R^2 = .06) and tobacco consumption (partial R^2 = .07). These represent medium effect sizes [40]. Thus, occupation and tobacco consumption have a moderate influence on subjective auditory function.

The observation that socioeconomic and lifestyle factors predict one dimension of hearing function in middle ag partially supports previous research [1, 41], although notably Scholes et al. only found there to be a significant effect of socio-economic status on hearing sensitivity for men and not women [41]. It is also important to consider that previous research has not applied Bonferroni correction to control for family-wise error rate, which may have resulted in an overestimation of reported effects [41]. Research has focused primarily on hearing sensitivity (as measured by pure tone audiometry) and not suprathreshold hearing including the perception of speech in noise, which is more reflective of the daily demands of listening [1, 41]. It may be the case that while socioeconomic and lifestyle factors impact hearing sensitivity and subjective hearing function, they do not impact speech perception.

However, the DiN task has been found to be less sensitive to hearing difficulty for those with mild hearing loss, where speech recognition remains intact [42]. The lack of an effect in the remote DiN task could be due to our sample being middle-aged, as a decline in speech in noise becomes the most exaggerated from age 75 [43]. Furthermore, within our sample, the mean SNR-50 was -9.3 (SD = 4.37) which is indicative of normal hearing when hearing is measured using the DiN task [44]. In our sample, SNR-50s ranged from -20.4 to 4, where a higher number represents worse performance. Armstrong et al. suggested that an appropriate cut-off level suggestive of insufficient performance would be > -5.55 to ≤ -3.80 dB and the optimal cut-off point for poor performance would be > -3.80 dB [44]. In our sample, 24 participants had insufficient performance, 30 participants had poor performance, and 154 had sufficient performance. A further complication of the DiN task is that using a closed set response such as numeric digits within a speech in noise task is that English digits 0-9 are distinct and would be easier to identify than more complex signals such as words/sentences, however using numeric digits is more reliable for an online study as participants are able to report the digits they heard using a simple mouse click interface. The DiN task also did not include any familiarisation trials, so possible learning effects were not stabilised [27]. These factors may explain the absence of significant predictors of speech perception performance, primarily individuals with more severe hearing impairment—who might exhibit stronger associations with socioeconomic and lifestyle factors—were underrepresented.

The SSQ-12 mean was 7.47 (*SD* = 1.45), and scores ranged from 3.13 to 10, where a lower number reflects worse performance. Cañete et al. suggest, that when comparing the Spanish SSQ-12 to pure tone audiometry, an SSQ-12 score of ≤8.5 points indicate insufficient hearing [45]. Within our sample the mean SSQ-12 score is 7.47 which is considered reflective of hearing impairment. However, Cañete et al. did find significant differences between the mean SSQ-12 of the Spanish version and the English version, with non-hearing-impaired English speaking young adults (range 18-29) from New Zealand having a mean SSQ-12 of 7.8 [45]. Due to scoring discrepancies between the Spanish and the English versions of the SSQ-12, it would not be prudent to categorise the hearing function of our sample based on SSQ-12 scores.

Tobacco consumption has been previously associated with hearing impairment when measured using pure tone audiometry to determine hearing sensitivity [12-16]. Similarly, occupation has been found to be associated with hearing sensitivity, with routine and manual occupations reported to have poorer hearing as measured by pure tone testing [1]. Digits in noise paradigms may be reflective of hearing sensitivity, as they have been found to be significantly correlate with PTA [46-47]. The discrepancy between the lack of effect of tobacco consumption and occupation on hearing sensitivity (as measured by the DIN task) but the significant effect of these factors on subjective hearing ability (as measured by the SSQ-12) observed in this study was, therefore, unexpected. However, in mid-life, changes in hearing sensitivity may be more difficult to detect using the online DIN task in the present study. Measures sensitive to extended high-frequency hearing [48] or employing the antiphasic DIN [47] may be more sensitive. In contrast, we observed that increased tobacco consumption and routine and manual occupations were related to poorer self-reported hearing ability. It may be the case that the self-report measure taps into difficulty listening in real-world scenarios, which involve spatial hearing, informational masking and listening effort. Such challenges are not adequately captured by measures of hearing sensitivity, such as the DIN or PTA [49-51].As such, the discrepancy between the results of the speech perception models and subjective hearing ability models is likely due to the DiN tasks lacking sensitivity for detecting more mild hearing losses.

Recruitment via Prolific may have limited how representative the sample is, although a strength of this research is the recruitment of participants based on an equal distribution of income groups; which without the availability of Prolific's filtered recruitment features, would have been difficult. However, Prolific requires consistent technological access, including access to a computer, Wi-Fi and online banking; these resources may not be available to everyone, particularly those in lower socioeconomic positions or people experiencing domestic or personal instability, such as living in temporary accommodation or having a disability. However Prolific also has further beneficial characteristics for diverse recruitment such as flexible scheduling and home-based collection, meaning people who might otherwise be unable to get time off work to come to a laboratory or have caring responsibilities are able to take part in research. Furthermore, participants over 60 recruited from Prolific are found to have speech perception in noise abilities that do not significantly differ from participants of the same age tested in the laboratory [52].

The online nature of the study introduces some measurement concerns, particularly around the listening environment. While participants were instructed to use headphones, it was not possible to control for the sound output of different devices or any potential Wi-Fi connectivity issues that might have affected the quality of the DiN task. This could have introduced noise into the data, potentially explaining the lack of effect on speech perception. Although previous research has found that online versions of the DiN tasks correlate with DiN tasks conducted in a lab environment [53] and that SSQ-12 [26] scores correlated with remote

DiN scores, this was not the case in our sample. We found no significant correlation between SNR-50 and mean SSQ-12, $r(206) = -0.10$, $p = .173$. It is important to note that Zadeh et al. conducted remote DiN tasks on a modest sample of participants (N=34) who had been instructed by the researchers in person, so the findings may not apply to larger-scale online research, where there is an inability to communicate with participants directly [53]. For example, online participants might be less likely to adequately follow written instructions such as the requirement to be in a quiet environment, which may result in an elevated SNR-50 that is not consistent with their self-reported auditory function.

The study helps identify the period in the ageing trajectory at which socioeconomic and lifestyle factors begin to impact hearing function. Mid-life hearing function within our sample appeared to be robust, with the majority of participants having an SNR-50 reflective of normal hearing. This was true among the diverse range of socioeconomic groups recruited (see Figures 2 and 5) which is a positive reflection on the maintenance of hearing in lower socioeconomic groups through mid-life, before a possible decline in later life.

Moving forward, it will be crucial to explore novel factors influencing speech perception ability, including diet, geographical location, and/or physical inactivity, which might better account for variability in hearing function. This study also lacks direct measurement of cardiovascular disease and health related factors, which may be direct physiological mechanisms underlying hearing function. The presence of cardiovascular risk factors, such as smoking, in those with hearing loss is well established [12-16], and our findings support this as tobacco consumption was a significant predictor of subjective auditory function in mid-life: smoking is a significant risk factor for cardiovascular disease [54] and cardiovascular disease is consistently associated with lower socioeconomic status [55]. It is important to identify factors predictive of poorer hearing function to establish preventive interventions and to encourage the uptake of hearing aids in at-risk populations, ultimately reducing hearing health inequalities as audiologists can target groups in most need. However, differences in individual characteristics, such as socioeconomic status, gender and ethnicity may not directly result in hearing loss but modify behaviour in a way that increases the risk of hearing loss. It may be the case that rather than targeting at-risk groups as to encourage audiological intervention, at risk groups in mid-life, for example smokers, should instead be provided with options to modify risky behaviour, such as harm reduction strategies like nicotine replacement therapy, or be given help to change the circumstances that led to dependency in the first place such as mental health distress. This layered approach acknowledging that people's choices are constrained might make way for meaningful interventions that makes taking care of hearing an option for everyone.

Conclusion

This study aimed to explore the potential associations between socioeconomic, lifestyle, and demographic factors with midlife hearing function, focusing on both subjective auditory function (measured with the SSQ-12) and speech perception in noise (assessed using the DiN task). While the results did not reveal significant predictors for speech perception ability in midlife, the results did show significant predictors of subjective auditory function. Having a routine and manual occupation as compared to a managerial and professional occupation predicted worse self-reported hearing function, as did being a regular tobacco consumer when compared to non-consumers. Medium effect sizes were also observed for the occupation and tobacco consumption variables. These findings suggest that while there is some influence of lifestyle factors and socioeconomic factors on hearing function, their overall impact appears limited, within the midlife cohort examined, to subjective auditory function.

The lack of strong associations between these factors and speech perception ability could be attributed to several factors, including the relatively healthy hearing status of our sample and potential limitations in the online study design, which may have affected the reliability of the speech perception task.

This study offers valuable insights into midlife hearing function and provides a foundation for further research into novel predictors of hearing ability. Future studies should investigate additional factors that could influence speech perception ability and subjective auditory function, as well as recruit larger, more diverse populations to strengthen the generalisability of findings. Ultimately, identifying risk factors for poorer hearing function early in the ageing process is essential for developing preventive interventions and reducing hearing health inequalities across different socioeconomic groups. As hearing loss has a significant impact on quality of life, enhancing the understanding of predictors of hearing ability can guide audiologists and healthcare providers in targeting at-risk populations, thereby improving early intervention and access to hearing aids.

Acknowledgments

The authors would like to thank all the participants who took part in the research, and we wish to thank researchers John Oyewole for providing proofreading, Matthew Ivory, Aafiyah Gani and Innes Bamford for coding and data support, and Cressida Greaves for supporting the management of this project.

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