

# **The impact of age and psychosocial factors on cognitive and auditory outcomes during the COVID-19 pandemic**

Kate Slade<sup>a\*</sup>, Robert Davies<sup>a</sup>, Charlotte R Pennington<sup>b</sup>, Christopher J Plack<sup>a,c</sup>,  
Helen E Nuttall<sup>a\*</sup>

*<sup>a</sup>Department of Psychology, Faculty of Science and Technology, Lancaster University, Lancaster, UK; <sup>b</sup>School of Psychology, Aston University, Birmingham, UK; <sup>c</sup>Manchester Centre for Audiology and Deafness, School of Health Sciences, University of Manchester, Manchester, UK*

\*Correspondence: Kate Slade ([k.slade2@lancaster.ac.uk](mailto:k.slade2@lancaster.ac.uk)) and Helen E Nuttall ([h.nuttall1@lancaster.ac.uk](mailto:h.nuttall1@lancaster.ac.uk))

## Abstract

**Purpose:** In March 2020, the UK government announced that people should isolate to reduce the spread of the virus that causes COVID-19. Outside a pandemic, psychosocial factors, such as socialisation and mental health, may impact the relationship between hearing loss and increased dementia risk. We aim to report the impact of psychosocial factors, including social isolation, depression, and engagement in activities, on hearing and cognitive function in younger and older adults during the COVID-19 pandemic. **Method:** An online survey and experiment assessed self-reported psychosocial factors, self-reported hearing ability and speech-in-noise perception, and cognition. Data were collected between June 2020 and February 2021. Older ( $N = 112$ ,  $M_{AGE} = 70.08$ ) and younger ( $N = 121$ ,  $M_{AGE} = 20.52$ ) monolingual speakers of English, without any language or neurological disorders participated. Multiple linear regression models were employed to investigate hypothesised associations between psychosocial factors, and hearing and cognition, in older and younger adults. **Results:** Multiple regression analyses indicated that older adults displayed poorer speech-in-noise perception and poorer performance on one of four cognitive tasks, compared to younger adults; and increased depression was associated with poorer subjective hearing. Other psychosocial factors did not significantly predict hearing or cognitive function. **Conclusions:** Data suggest that self-reported hearing and depression are related. This conclusion is important for understanding the associations between hearing loss and cognitive decline in the long-term, as both hearing loss and depression are risk factors for dementia.

**Data availability statement:** Associated experimental scripts, stimuli, pre-registration, and research data are available on the Open Science Framework (OSF) at <https://osf.io/67rwh/>

**Authors' contribution statement: Slade:** Conceptualisation, Data Curation, Formal

Analysis, Investigation, Methodology, Visualisation, Writing – Original Draft Preparation;

**Davies:** Methodology, Writing – Review & Editing; **Pennington:** Methodology, Writing – Review & Editing; **Plack:** Conceptualisation, Methodology, Supervision, Writing – Review & Editing; **Nuttall:** Conceptualisation, Funding Acquisition, Methodology, Project Administration, Supervision, Writing – Review & Editing

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## **Introduction**

In March 2020, the UK government announced that people should avoid face-to-face social contact to reduce the spread of COVID-19 (GOV.UK, 2020). Unprecedented changes to communication occurred, including wearing face coverings and physical distancing (Bott & Saunders, 2021), and reliance on online technologies. These measures may have posed particular challenges for older adults, 70% of whom have hearing loss (Royal National Institute for Deaf People (RNID), 2020), due to poor online audio quality, or attenuation of sound due to barriers or distance (Batsis et al., 2021; Lebrasseur et al., 2021; Park, 2020). Outside of a pandemic, hearing loss is associated with loneliness and depression (Lawrence et al., 2020; Mick et al., 2014; Shukla et al., 2020), and is the largest potentially modifiable risk factor for dementia (Livingston et al., 2020).

Various hypotheses explaining the association between hearing loss and dementia have been proposed (see Griffiths et al., 2020; Slade et al., 2020 for reviews). For example, hearing loss may cause auditory deprivation that affects auditory and non-auditory brain regions (Fitzhugh et al., 2019; Lin et al., 2014; Panouillères & Möttönen, 2018), negatively impacting cognitive functioning. It is also hypothesised that psychosocial factors, including

increased loneliness or depression, exacerbate auditory deprivation and increase risk of cognitive decline. Research indicates that the association between self-rated hearing ability and episodic memory is mediated, in part, by loneliness and social isolation (Maharani et al., 2019). Older people may be particularly vulnerable to loneliness and depression due to the higher prevalence of living alone (Age UK, 2019), and hearing difficulty. For example, older adults with hearing loss may withdraw socially due to difficulties with communication, particularly in noisy environments. Despite speech perception being essential for communication and social participation, few studies have investigated the relationship between the perception of spoken sentences in a background of competing speech, psychosocial factors, and cognitive performance.

Understanding the associations between hearing ability, psychosocial factors, and cognition is essential, even outside of a pandemic. The first step requires examination of how psychosocial variables impact sensory and cognitive function across age ranges, and the social distancing implemented during COVID-19 provided a unique situation to do this. Such work is imperative for identifying intervention pathways targeting the association between hearing loss and cognitive decline. Considering that older adults may be at greater risk of loneliness and isolation, and that the majority experience some hearing loss, it is conceivable that this population may have been disproportionately affected during the pandemic. Indeed, in a previous study of older adults, poorer self-reported hearing ability exacerbated the impact of social distancing on depression, loneliness, and memory (Littlejohn et al., 2022).

The current study aims to understand the associations between age, psychosocial factors, speech perception, and cognition, and builds upon Littlejohn et al. (2022) by including younger adults and measures of speech-in-noise perception and cognitive function. We present novel insights firstly into the bidirectional associations between psychosocial

factors, age, self-reported hearing, speech perception and cognition and secondly into understanding these associations during an unprecedented time of social upheaval. We hypothesise that 1) speech-in-noise performance and self-reported hearing ability will be predicted by increased age, depression, social isolation, and by decreased engagement in lifestyle and auditory activities; and 2) poorer cognitive function will be predicted by increased age, depression, social isolation, decreased lifestyle and auditory engagement and by poorer self-reported hearing ability and speech-in-noise performance.

## **Materials and Methods**

Ethical approval was obtained from Lancaster University's Faculty of Science and Technology Ethics Committee (FST19175).

### ***Participants***

The sample included 112 adults (62 female) aged 60-82 ( $M = 70.08$ ,  $SD = 5.89$ ) with ( $N = 54$ ) and without ( $N = 58$ ) perceived age-related hearing loss, and 121 adults (85 female) aged 18-29 ( $M = 20.52$ ,  $SD = 2.63$ ) without hearing loss. Hearing loss was quantified using a single item question which asked whether participants had age-related hearing loss, no hearing loss, or any other hearing loss or disorder. Only younger participants who reported no hearing loss and older participants who reported age-related hearing loss or no hearing loss were able to participate. Power calculation (R Core Team, 2022) using *pwr.f2.test* from the *pwr* package (Champely et al., 2018) for multiple linear regression determined that a sample of 232 was required to detect small-medium effect sizes (Cohen's  $f^2 = .07$ ) at 80% power and .05 alpha. Participants reported via a pre-screening questionnaire that they were right-handed, monolingual English speakers, with normal or corrected-to-normal vision, no neurological,

language, or speech disorders, and typical cognitive status (<3.65 on the Self-Report Informant Questionnaire on Cognitive Decline (Jansen et al., 2008)). The sample was self-selected, and recruited primarily, but not exclusively, through advertisements on Lancaster University's Participation System and Centre for Ageing Research Participant Panel, as well as the University of the Third Age.

### ***Materials***

Data are part of a larger preregistered study (<https://osf.io/67rwh/>), and were collected online using Qualtrics (Qualtrics, Provo, UT) and PsychoPy3 hosted on Pavlovia (Bridges et al., 2020). Participants were advised to undergo testing in a quiet room, and were asked to remove hearing aids (if applicable) and wear earphones or headphones for the auditory task. All other materials, including the cognitive tasks, were conducted visually. Details of materials are provided in Supplementary Materials 1. Stimuli, stimuli creation scripts, and experimental scripts are provided in the OSF repository (<https://osf.io/67rwh/>).

### ***Model Predictors***

*Social Isolation.* A composite measure was obtained from the mean of z-standardised scores on the Lubben Social Network Scale (LSNS-6, Lubben et al., 2006) and the UCLA Loneliness Scale (UCLA-LS3, Russell, 1996). Higher scores indicate increased isolation.

*Depression.* Depression was measured using totalled scores from Beck Depression Inventory (BDI-I, Beck et al., 1961), higher scores indicated increased depressive symptoms.

*Auditory and Lifestyle Engagement.* A novel 10-item questionnaire measured engagement in auditory and lifestyle activities. The first seven items assessed auditory engagement, and the final three items assessed lifestyle engagement. Participants indicated how many hours (0-50) in an average week of the current month were spent engaging in

various activities, including in-person and online social activities, hobbies and sports.

Confirmatory factor analysis for the two-factor model suggested adequate construct validity of the questionnaire ( $\chi^2 = 123.52(34)$ ,  $p < .001$ , CFI = .70, root mean square error of approximation = .11 [90% CI = .09 - .13]). Higher scores indicate increased engagement.

### *Model Outcome Measures*

*Global Cognition.* A composite measure of cognition was obtained from the mean of z-standardised scores on four assessments across different cognitive domains: 1) forward digit span (e.g., Wechsler Adult Intelligence Scale: WAIS, Wechsler, 1997); 2) backwards digit span (e.g., WAIS, Wechsler, 1997); 3) Deary-Liewald choice reaction time task (Deary et al., 2011); and 4) Stroop colour-word test (Scarpina & Tagini, 2017; Stroop, 1935). Higher composite scores indicate better global cognitive function.

*Speech-in-noise perception.* A speech-in-noise test based on the Bamford-Kowal-Bench test (BKB-SIN: Etymotic Research) assessed auditory function. First, participants adjusted their volume to a loud but comfortable level by listening to sample stimuli. The stimuli consisted of target sentences from the IEEE corpus spoken by a British-English male in the presence of four-talker babble. The babble was created in MATLAB using the IEEE sentences, and combined with the target sentence in Praat (Boersma, 2002) at 10 signal-to-noise ratios (SNRs) ranging from -6 dB SNR to +21 dB SNR, in 3 dB steps. There were four trials in each of the 10 SNR blocks, which were ordered from easiest (+21 dB SNR) to hardest (-6 dB SNR). In a trial, participants saw a fixation cross (for 1s), then heard a sentence, then recalled the sentence by typing in a response window. In each sentence, there were five pre-determined target words, each scored a point if correctly recalled. Points were averaged across the trials within a SNR block. Scoring was based on the formula employed in the BKB-SIN procedure, derived from the Tillman-Olsen method (Tillman & Olsen, 1973),

and was adapted for this online task to estimate the SNR at which a person can identify 50% of words correctly (SNR-50). See Supplementary Materials 1 for the scoring formula.

*Self-Reported Auditory Function.* The Speech, Spatial and Qualities of Hearing scale (SSQ-12, Noble et al., 2013) assessed self-reported auditory function. Higher scores indicated poorer hearing.

### ***Statistical Analysis***

Data pre-processing and analysis were conducted in R (version 2022.07.1, R Core Team, 2022). Missing data were replaced through mean imputation, using the mean per age-group (see Supplementary Materials 2). Exploratory descriptive statistics and two-sample t-tests highlight age-group differences across variables. We ran three multiple linear regression models: 1) to test if age-group, gender, social isolation, depression, and auditory and lifestyle engagement predicted self-reported hearing ability (SSQ-12 scores); 2) to test if age-group, gender, social isolation, depression, and auditory and lifestyle engagement predicted speech-in-noise performance; 3) to test if age-group, gender, social isolation, depression, auditory and lifestyle engagement, self-reported hearing ability, and speech-in-noise performance predicted cognition. Please see Tables 1-3 for full details of the regression models. Reported *p*-values for individual regressions were Holm-Bonferroni corrected, but uncorrected for exploratory t-tests. Correction was applied across 7 comparisons for the first two regressions and 9 comparisons for the final regression, which accounts for the statistical test of the overall model and the tests for each predictor. Ordinal data from individual responses on self-report items were summed or averaged for each measure, creating a continuous-like variable which can be treated as such in the statistical analysis. Influential outliers were investigated using Cook's distance; datapoints  $>4/n$  were classified as outliers ( $n$  is the number of datapoints, i.e., the sample size).

## Results

### *Descriptive Statistics and Exploratory T-Tests*

Social isolation, measured by the UCLA LS-3, was worse in younger compared to older adults,  $t(231) = -2.65$ ,  $p = .009$ ,  $d = 0.35$ . However, there were no age-group differences in social isolation, measured by the LSNS-6 or overall social isolation composite ( $ps > .05$ ). Depressive symptoms were worse in younger compared to older adults,  $t(231) = -5.48$ ,  $p < .001$ ,  $d = 0.72$ . Engagement in lifestyle activities was higher for older compared to younger adults,  $t(231) = 5.47$ ,  $p < .001$ ,  $d = 0.72$ . However, there were no age-group differences in auditory engagement, or subjective hearing ability ( $ps > .05$ ). Global cognition was better in younger compared to older adults,  $t(231) = -7.08$ ,  $p < .001$ ,  $d = 0.93$ . However, younger adults only significantly outperformed older adults on one individual cognitive task, the Deary-Liewald reaction time task,  $t(231) = 19.93$ ,  $p < .001$ ,  $d = 2.61$ . Finally, speech-in-noise performance was better in younger compared to older adults,  $t(231) = 8.32$ ,  $p < .001$ ,  $d = 1.09$ . See Table A in Supplementary Materials. Variance inflation factors across all models were  $< 1.73$ , indicating no multicollinearity amongst predictors.

### *Multiple Linear Regressions*

#### *Self-Reported Hearing Ability and Speech-in-Noise Perception*

For the model predicting subjective auditory function, the outcome was the SSQ-12 score. The model was run before and after removal of outliers, and their exclusion affected the statistical inference. Before exclusion, the model was significant:  $F(6, 226) = 4.07$ , corrected  $p = .001$ , adjusted  $R^2 = .07$ , yet no individual predictors significantly contributed to SSQ-12

scores (corrected  $ps > .10$ ). After exclusion of 8 outliers, for the remaining 119 younger (84 female,  $M = 20.55$ ), and 106 older adults (58 female,  $M = 70.02$ ), the model remained significant:  $F(6, 218) = 4.88$ , corrected  $p = .001$ , adjusted  $R^2 = .09$ . Of the individual predictors, depression significantly predicted SSQ-12 scores (unstandardised  $B = -.05$ , corrected  $p = .01$ ), wherein increased depression was associated with poorer subjective hearing. See Table and Figure 1.

Table 1. Linear multiple regression predicting subjective auditory function (SSQ-12 scores).

**SSQ-12 Score** ~ Age Group + Assigned Sex + Depression + Social Isolation + Auditory Engagement + Lifestyle Engagement

Predictors	$\beta$	$t$	$p$ Corrected	Cohen's $f$
Age-group	0.37	1.93	.22	0.10
Sex	-0.40	-2.23	.13	0.15
Depression	-0.05	-3.07	<b>.01</b>	0.29
Social Isolation	-0.15	-1.31	.57	0.11
Auditory Engagement	0.01	0.89	.75	0.04
Lifestyle Engagement	-0.005	-0.74	.75	0.05

*Notes:  $\beta$  = unstandardized; SSQ-12 = Speech and Spatial Qualities of Hearing Scale.*

**Partial Regression Plot: Self-Reported Hearing predicted by Depression**

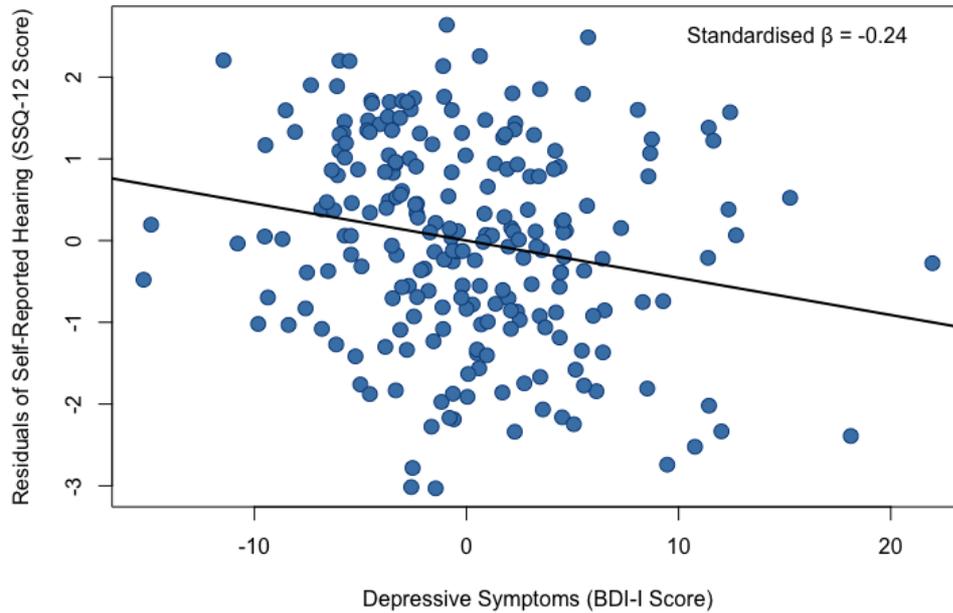


Figure 1. Partial regression plot for the association between subjective hearing and depression, whilst holding other predictors constant.

For the model predicting speech-in-noise perception, the outcome measure was the speech-in-noise task score. The model was run before and after removal of outliers, and exclusion did not affect the statistical inference. After removal of 11 outliers, for the remaining 120 younger (85 female,  $M = 20.49$ ), and 102 older adults (55 female,  $M = 69.86$ ), the model was significant:  $F(6, 215) = 18.17$ , corrected  $p < .001$ , adjusted  $R^2 = .32$ . Of the individual predictors, only age-group significantly predicted speech-in-noise task scores ( $B = -3.35$ , corrected  $p < .001$ ), wherein older adults had poorer hearing ability. See Table 2.

Table 2. Linear multiple regression predicting speech-in-noise task scores.

**Speech-in-Noise Task Score** ~ Age Group + Assigned Sex + Depression + Social Isolation + Auditory Engagement + Lifestyle Engagement

Predictors	$\beta$	$t$	$p$ Corrected	Cohen's $f$
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Age-group	-3.35	-9.47	< .001	0.68
Sex	0.37	1.11	.80	0.07
Depression	0.04	1.66	.40	0.13
Social Isolation	0.08	0.39	.92	0.01
Auditory Engagement	0.04	1.81	.36	0.11
Lifestyle Engagement	-0.01	-0.74	.92	0.05

*Notes:  $\beta$  = unstandardized; SSQ-12 = Speech and Spatial Qualities of Hearing Scale.*

### *Association Between Hearing and Cognition*

A multiple linear regression investigated if self-reported hearing ability and speech-in-noise perception significantly predicted cognitive performance, whilst accounting for the other predictors. The exclusion of outliers affected the statistical inference. Before exclusion, the model was significant:  $F(8, 224) = 9.13$ , corrected  $p < .001$ , adjusted  $R^2 = .22$ . Of the predictors, age group ( $B = .30$ , corrected  $p = .01$ ) and speech-in-noise performance ( $B = -.03$ , corrected  $p = .03$ ) significantly predicted global cognition. After exclusion of 11 outliers, for the remaining 120 younger (84 female,  $M = 20.54$ ), and 84 older adults (55 female,  $M = 69.93$ ), the regression model remained significant:  $F(8, 213) = 8.64$ , corrected  $p < .001$ , adjusted  $R^2 = .22$ . However, only age-group remained significant ( $B = .33$ , corrected  $p < .001$ ), and not speech-in-noise perception ( $B = -.02$ , corrected  $p = .41$ ). See Table 3.

Table 3. Linear multiple regression predicting global cognition

**Global Cognition** ~ Age Group + Assigned Sex + Depression + Social Isolation + SSQ-12 Score + Speech-in-Noise Task Score + Auditory Engagement + Lifestyle Engagement

Predictors	$\beta$	$t$	$p$ Corrected	Cohen's $f$
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Age-group	0.33	4.17	<.001	0.52
Sex	0.02	0.38	>.99	0.02
Depression	0.001	0.14	>.99	0.02
Social Isolation	0.03	0.77	>.99	0.03
Auditory Engagement	-0.003	-0.59	>.99	0.11
Lifestyle Engagement	-0.005	-1.90	.41	0.13
SSQ-12 Score	0.02	1.08	>.99	0.11
Speech-in-Noise Score	-0.02	-1.833	.41	0.13

*Notes:  $\beta$  = unstandardized; SSQ-12 = Speech and Spatial Qualities of Hearing Scale.*

## Discussion

This study examined if: 1) speech-in-noise performance and self-reported hearing ability and 2) cognitive ability were predicted by age and psychosocial factors during the COVID-19 pandemic, and 3) whether hearing was associated with cognition. These data partially supported our hypotheses. Older age was associated with poorer speech-in-noise perception and cognition. Increased depression was associated with poorer self-perceived hearing ability.

Previous research finds associations between depression and hearing, specifically in older adults (Lawrence et al., 2020), which are exacerbated by social distancing (Littlejohn et al., 2022). However, we found such associations only for the model predicting self-rated hearing ability, not speech-in-noise perception. Indeed, conflicting findings across self-report and speech-in-noise measures of hearing ability are not uncommon (Cox et al., 1991). Discrepancies may be due to poor awareness or denial of hearing difficulty (Rawool & Keihl, 2008), or because measures assess separate dimensions of hearing (Alhanbali et al., 2019).

We suggest that, unlike speech perception scores, self-rated hearing ability may reflect self-efficacy; a construct related to depression (Maciejewski et al., 2000; Tak et al., 2017).

Knowing how co-morbid low hearing self-efficacy and increased depression contributes to socialisation and, subsequently, auditory deprivation and cognitive decline is essential.

In this cross-sectional analysis, neither speech-in-noise perception nor self-reported hearing ability, nor psychosocial factors were associated with cognitive performance. This contradicts previous research which has found such associations (Shukla et al., 2020; Lin, 2011). However, this may be a consequence of heterogeneity in cognitive or hearing assessment which vary across studies or due to sample characteristics in the present study. Older (vs. younger) adults reported lower depression and higher engagement in lifestyle activities, despite stricter pandemic-related guidance (GOV.UK, 2020). Whilst younger adults may have experienced more mental health consequences of the pandemic (Leach et al., 2021; Office for National Statistics, 2020), our results may be biased by a self-selected sample of potentially active, and socially-engaged older adults. Computer-literacy or socioeconomic position may mitigate feelings of loneliness, or even cognitive decline (Cotten et al., 2013; Fakoya et al., 2020). Future research should account for these factors, as socioeconomic inequalities play a critical role in hearing health (Tsimpida et al., 2019).

This study highlights the feasibility of online auditory research across age ranges, providing new insights into associations between behavioural measures and psychosocial factors. Further, as the cognitive tasks were presented visually, cognitive performance was not confounded by hearing ability as the assessments did not load on audition (Füllgrabe, 2020). However, study limitations include the potential for a biased self-selected sample and lack of control over the study environment in online research. Importantly, this study reports on cross-sectional associations only; longitudinal data is necessary to infer causal relations.

Understanding the impact of long-term social isolation on the association between depressive symptoms and perceived hearing ability is an essential next step.

Overall, these data suggest that increased depression is associated with poorer self-reported hearing. However, psychosocial factors were not found to contribute to speech-in-noise perception, nor cognitive ability. Future research should ascertain if associations between depression and self-reported hearing, which may reflect self-efficacy, contribute to increases in auditory deprivation or social withdrawal, and impact on cognition.

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**Supplementary materials description:** The associated file provides additional methodological and statistical information.