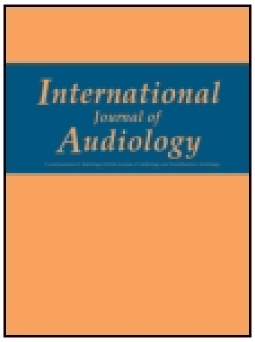

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Original Article

Prospective effects of hearing status on loneliness and depression in older persons: Identification of subgroups

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Abstract

Objective: To determine the possible longitudinal relationships between hearing status and depression, and hearing status and loneliness in the older population. *Design:* Multiple linear regression analyses were used to assess the associations between baseline hearing and 4-year follow-up of depression, social loneliness, and emotional loneliness. Hearing was measured both by self-report and a speech-in-noise test. Each model was corrected for age, gender, hearing aid use, baseline wellbeing, and relevant confounders. Subgroup effects were tested using interaction terms. *Study sample:* We used data from two waves of the Longitudinal Aging Study Amsterdam (2001–02 and 2005–06, ages 63–93). Sample sizes were 996 (self-report (SR) analyses) and 830 (speech-in-noise test (SNT) analyses). *Results:* Both hearing measures showed significant adverse associations with both loneliness measures ($p < 0.05$). However, stratified analyses showed that these effects were restricted to specific subgroups. For instance, effects were significant only for non-hearing aid users (SR-social loneliness model) and men (SR and SNT-emotional loneliness model). No significant effects appeared for depression. *Conclusions:* We found significant adverse effects of poor hearing on emotional and social loneliness for specific subgroups of older persons. Future research should confirm the subgroup effects and may contribute to the development of tailored prevention and intervention programs.

Sumario

Objetivo: Determinar las posibles relaciones longitudinales entre la condición auditiva y la depresión, y la condición auditiva y la soledad, en adultos mayores. *Diseño:* Se usaron múltiples análisis de regresión lineal para evaluar las asociaciones entre la audición basal y el seguimiento a 4 años con la depresión, la soledad social y la soledad emocional. La audición se midió tanto por auto-reporte como por la prueba de audición en ruido. Cada modelo fue corregido por edad, género, uso del auxiliar auditivo, bienestar basal y elementos relevantes de confusión. El efecto de subgrupo fue evaluado usando términos de interacción. *Muestra del Estudio:* Usamos datos de dos etapas del Estudio Longitudinal de Envejecimiento e Amsterdam (2001-02 y 2005-06, edades 63-93). El tamaño de las muestras fue 996 (análisis de auto-reporte (SR) y 830 (análisis de la prueba de audición en ruido). *Resultados:* Ambas mediciones auditivas mostraron asociaciones adversas significativas con ambas medidas de soledad ($p < 0.05$). Sin embargo, los análisis estratificados mostraron que estos efectos eran restringidos a subgrupos específicos. Por ejemplo, los efectos fueron significativos solo para quienes no usaban auxiliar auditivo (modelo SR – soledad social) y para hombres (SR y SNT – modelo de soledad emocional). No hubo efecto significativo para la depresión.*Conclusiones:* Encontramos efectos adversos significativos de un audición pobre sobre la soledad emocional y social para subgrupos específicos de personas mayores. Investigaciones futuras deberán confirmar el efecto de subgrupo y podrán contribuir al desarrollo de programas de prevención e intervención a la medida.

Key Words: Hearing status; depression; loneliness, older persons; longitudinal

Hearing impairment is one of the most prevalent chronic conditions in older persons (Adams & Benson, 1991) mainly due to progressive sensorineural age-related hearing loss (Davis, 1997). There is ample evidence showing that older people can suffer considerably from hearing loss, both socially and emotionally (Kramer, 2005). The latter may involve mood changes and feelings of frustration, anger, anxiety, loss of control, low self-worth, and embarrassment (Heine & Browning, 2002). Social problems may comprise disruption of personal relations and inability to satisfactorily fulfill desired social roles, both of which are critical to older persons' wellbeing. Two important conditions often mentioned in this respect are depression and loneliness. (Minor) depression is one of the most common psychiatric disturbances in late life and can have devastating consequences on quality of life and functioning (Blazer, 2003) and has been associated with mortality (Schoevers et al, 2000). Also loneliness is frequently reported in older persons and is associated

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Abbreviations

CES-D	Center for Epidemiologic Studies Depression Scale
CVC	Cardiovascular condition
LASA	Longitudinal Aging Study Amsterdam
MMSE	Mini-Mental State Examination
OECD	Organization for Economic Cooperation and Development
SD	Standard deviation
SES	Socio-economic status
SNR	Signal-to-noise ratio
SNT	Speech-in-noise test
SR	Self-report
$SRTT_n$	Speech-reception-threshold in noise by telephone

with decreased wellbeing (Dykstra, 2009). It must be noted that the effect of hearing impairment on loneliness has frequently been investigated, but these studies often concentrated on specific (patient) samples limiting extrapolation to the general older population.

Several studies investigated the association between hearing and loneliness or depression in population-based older samples. However, these show conflicting evidence. Most studies on depression found a significant association with poor hearing (Gilhome Herbst & Humphrey, 1980; Carabellese et al, 1993; Ives et al, 1995; Wallhagen et al, 1996; Cacciatore et al, 1999; Strawbridge et al, 2000; Kramer et al, 2002; Capella-McDonnall, 2005; Ishine, 2007; Lee et al, 2010; Saito et al, 2010). However, some did not (Jones et al, 1984; Chou, 2008; Nachtegaal et al, 2009; Lee et al, 2010). This was similar for studies investigating the relationship between hearing and loneliness. Whereas some reported significant associations (Wallhagen et al, 1996; Strawbridge et al, 2000; Kramer et al, 2002; Hawthorne, 2008), others did not (Kivett, 1979; Berg et al, 1981; Nachtegaal et al, 2009).

There may be various factors causing differences in study outcomes. Examples are the study design, adjustment for confounding variables, examination of subgroup effects, and the instrument to measure hearing status.

With regard to the study design, the vast majority of the existing studies used a cross-sectional design. Although cross-sectional analyses are highly valuable to elucidate associations between variables, strictly, conclusions about causality cannot be drawn. Causality implies a chronological order between cause and effect and thus a change in outcome over time. Hence, at least two measurements are needed. Additionally, longitudinal designs allow adjustment for potential 'reporting bias' in self-report data, i.e. people who report a depressed mood also rate their hearing more negatively because of that (e.g. Tambs, 2004). By correcting for baseline wellbeing, such a bias could be adjusted for.

To date, only four studies used a longitudinal design (Wallhagen et al, 1996; Strawbridge et al, 2000; Chou, 2008; Saito et al, 2010). The two studies investigating loneliness found significant adverse effects of poorer hearing (Wallhagen et al, 1996; Strawbridge et al, 2000). Of those addressing depression, Wallhagen et al (1996), Strawbridge et al (2000), and Saito (2010) reported significant adverse effects, but Chou (2008) found none. Although most longitudinal studies reported significant relationships, the treatment of the factors potentially influencing the outcomes (i.e. confounding factors, subgroup effects, hearing status instruments) may have been suboptimal. This will be discussed in the following paragraphs.

Previous research showed that age, gender, socio-economic status (SES), partner status, vision status, comorbidity, cognitive status, and hearing-aid use can be associated with wellbeing and hearing and should thus be considered as confounding variables (Stephens, 1996; Strawbridge et al, 2000; Bazargan et al, 2001; Kramer et al, 2002; Gates & Mills, 2005; Chia et al, 2007). Only a number of the cross-sectional studies performed so far adjusted for age and gender only or did *not* test or adjust at all (Berg et al, 1981; Jones et al, 1984; Ives et al, 1995; Cacciatore et al, 1999; Ishine, 2007). A few adjusted for some of the other confounders (Kivett, 1979; Gilhome Herbst & Humphrey, 1980; Carabellese et al, 1993; Kramer et al, 2002; Capella-McDonnall, 2005; Hawthorne, 2008; Nachtegaal et al, 2009; Lee et al, 2010). Of the last group, only Nachtegaal et al (2009) and Lee et al (2010) failed to find significant effects on depression and loneliness. All four longitudinal studies adjusted for age, gender, and some of the additional confounders. Only Chou (2008) failed to find a significant effect (on depression).

In addition to confounding factors, interaction effects (or: effect modifications) may be present, indicating that the magnitude or direction of an effect may be different at one level of a variable than at another. For instance, it is known that there are age, gender, and socio-economic differences in problem awareness and use of communication strategies (Erdman & Demorest 1998a,b; Garstecki & Erler, 1999) which may modify the effect of hearing on psychosocial health. Only a few studies explored such subgroup differences. These mainly considered testing effect modification by age and/or gender in cross-sectional depression models. Tambs (2004) and Nachtegaal et al (2009) found significant effect modification by age, such that effects of poorer hearing on depression were found for relatively younger age groups only and remained absent for older groups (i.e. >49 years). Ives et al (1995) and Chen (1994) found a gender difference in the appearance of adverse effects, unlike Nachtegaal et al (2009) and Saito et al (2010) who found none. The former reported significant effects on depression (Ives et al, 1995) and loneliness (Chen, 1994) in women only.

Finally, contradictory outcomes may have been caused by different hearing status measures. Most studies, including all longitudinal studies, used self-report scales. Some administered single-item generic questions such as: 'Do you have trouble hearing?' (Kivett, 1979; Wallhagen et al, 1996; Capella-McDonnall, 2005; Chou, 2008). Others used (multi-item) scales relating to hearing in specific situations or associated emotions (Jones et al, 1984; Ives et al, 1995; Cacciatore et al, 1999; Kramer et al, 2002; Strawbridge et al, 2006; Ishine, 2007; Hawthorne, 2008; Saito et al, 2010). The studies using self-report instruments had inconclusive findings; there was no agreement on the effects of hearing impairment on depression or loneliness.

It is sometimes suggested that self-report measures are better predictors of wellbeing than objective hearing tests (Tambs, 2004; Hallberg et al, 2007; Saito et al, 2010). Some dismiss this as mainly being the result of reporting bias (e.g. Tambs, 2004). Others argue that self-report better taps the actual impact on daily life and subsequently, wellbeing (e.g. Hickson, 2008). Strawbridge et al (2000) concluded that it would be helpful to compare clinical assessments with self-report to understand how much of an overlap there is and to better understand the trade-offs when only one assessment type is available. To our knowledge, only the cross-sectional studies by Lee et al (2010) and Tambs (2004) compared a self-report and an objective measure (i.e. averaged pure-tone thresholds) in a population-based sample. Both studies considered the association with depression. Whereas Tambs (2004) found a better predictive power for the self-report measure, Lee et al (2010) found a significant effect for the objective measure only.

Using a speech-in-noise test to asses hearing status is becoming increasingly common both in screening and in the clinic (e.g. Smits et al, 2006). Such a measure is assumed to have greater face validity as everyday communication usually occurs in the presence of background sounds (music, voices, traffic). Also, difficulty recognizing speech in noise is a central feature of presbyacusis and the most frequently reported disability in people with hearing impairment (Kramer et al, 1998). Nonetheless, studies reporting the relationship between speech-in-noise measures and wellbeing outcomes are largely lacking. To our knowledge, only Nachtegaal et al (2009) used a speech-in-noise test. They reported no significant effects on depression and loneliness in older persons. However, they used a cross-sectional study design and their sample comprised a relatively 'young' group of elderly people, i.e. aged 60–70 years.

In summary, evidence on the relationships between hearing status and depression and loneliness is still not definitive. Existing studies rarely used longitudinal designs and careful explorations of subgroup effects are largely lacking. Moreover, studies comparing the predictive abilities of a self-report measure and a speech-in-noise test are absent. The objective of the present study is to address these research gaps in a longitudinal four-year follow-up study using a large older population-based sample.

Methods

Sample and procedures

The sample for this study originates from the Longitudinal Aging Study Amsterdam (LASA) (Deeg et al,1993). LASA is an ongoing cohort study on predictors and consequences of changes in autonomy and wellbeing in an aging population. For the first LASA measurement (1992/1993), a random sample of 3107 older persons (aged 55–85 years), stratified for age and gender, was drawn from the Dutch population. Follow-up measurements were conducted every three to four years. From the 2001/2002 measurement, hearing status was measured both by a self-report (SR) measure and a speech-in-noise test (SNT) by telephone (details of this test are described under 'Measures'). Data from this and the subsequent four year follow-up measurement were used for the present study (referred to as T_1/baseline and T_2, respectively). All measurements were performed in the respondent's home by trained and supervised interviewers. Informed consent was obtained from all respondents. The study was approved by the Medical Ethics Committee of the VU University Medical Center.

Two samples were created. The first is referred to as self-report (SR) and the second as speech-in-noise test (SNT). The SR samples comprised 996, 995, and 992 respondents for the social loneliness, emotional loneliness, and depression analyses, respectively. The SNT samples included 830, 829, and 829 respondents, respectively. The latter were smaller as not all respondents participated in a second interview in which the SNT was administered. The reasons for the non-participation and other attrition are described under 'Attrition', in the Results section.

Measures

Hearing status: Self-report

SR hearing status was measured using three questions originating from the Organization for Economic Cooperation and Development (OECD) long-term disability indicator (McWhinnie, 1979): (1) Without a hearing aid, can you follow a conversation in a group of three or four people? (2) Without a hearing aid, can you follow a conversation with one person? (3) Can you use a normal telephone? Answers could be given on a scale from 1 (without difficulty) to 4 (no, I cannot). The scores of the three questions were summed (range 3–12, a higher score indicating poorer self-reported hearing). Note that we asked about the unaided situation (question 1 and 2) so as to allow valid comparison with the unaided SNT.

The OECD long-term disability indicator questions are used in several large public health surveys (e.g. Ormel et al, 1997). In our sample, the internal consistency of the three-item scale was satisfactory (Cronbach's alpha = 0.65; mean inter-item correlation = 0.47).

Hearing status: Speech-in-noise test

The SNT was originally developed as a functional self-test screen by telephone (Smits et al, 2004; Smits & Houtgast, 2005). The test determines the speech-reception-threshold in noise by telephone ($SRTT_n$), defined as the signal-to-noise ratio (SNR) in dB corresponding to 50% intelligibility. In the LASA study, portable testing equipment was brought by the interviewer consisting of a telephone, an amplifier, and headphones. Hearing aids had to be removed during the assessment. Before the test started, the respondent could adjust the level of the speech to clearly understand the triplets. Subsequently, twenty-three different monosyllabic digit triplets were presented at this level against varying levels of stationary background noise according to an adaptive up-down procedure. The signal-to-noise ratio decreased by 2 dB if the respondent had correctly repeated the triplets, and increased by 2 dB after an incorrect response. Baseline scores ranged from −9.2 to 5.1 dB SNR.

A high correlation with the standard Dutch sentences SNT (Plomp & Mimpen, 1976) was found ($r = 0.87$) indicating good validity (Smits et al, 2004). Furthermore, test-retest reliability appeared satisfactory in an older sub-sample from Nachtegaal et al (2009) (Intraclass correlation coefficient, two-way random effects model = 0.67, n = 54, 63–82 years).

Depression

Depression was measured using the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977). It consists of 20 statements each with a four-point response scale (0–3) yielding a total score of 0–60. A higher score indicated a higher level of depression. In case of one or two missing items, the score was imputed with the average of the remaining items. This occurred for 11 respondents on T_1, and 21 on T_2.

The CES-D has been widely used in older samples and has good psychometric properties (Beekman et al, 1997). In the SR sample (n = 996) a Cronbach's alpha of 0.85 was found, indicating good internal consistency.

Social and emotional loneliness

Loneliness was measured using the social (five-item) and emotional (six-item) loneliness subscale of the De Jong Gierveld scale (De Jong Gierveld & Kamphuis, 1985; De Jong Gierveld & Van Tilburg 1999a). Social loneliness relates to deficits in social integration and embeddedness. Emotional loneliness is linked to the absence of an intimate attachment figure such as a partner or a best friend (Weiss, 1973). Each item represented a statement with a three-point response scale (no; more or less; yes). The answers were dichotomized with 'more or less' and 'yes' merged into one category referring to loneliness (score 1) and 'no' referring to no loneliness (score 0). All item scores were summed ranging from 0–5 (social loneliness) and 0–6 (emotional loneliness). A higher score indicated a higher level of loneliness.

The subscales have proven to be valid and reliable (Dykstra & De Jong Gierveld, 2004; De Jong Gierveld & Van Tilburg 1999b). In our study sample, satisfactory Cronbach's alphas ($\alpha = 0.85$ and 0.79) and mean inter-item correlations ($r = 0.53$ and 0.44) were found for the social and emotional loneliness scales, respectively.

Potential confounders and effect modifiers

We tested the confounding and suppressing effects of a number of variables described below. These variables were also checked for their modifying effect (see under 'Statistical analyses').

Age was included as a continuous variable. Education and income were used to indicate socio-economic status (SES). Education was dichotomized into low (uncompleted elementary, elementary, lower vocational) and medium or high (general intermediate, intermediate vocational, general secondary, higher vocational, college and university). Income was also dichotomized into low (net income <€841 per month) and medium or high (net income ≥€841 per month). Partner status was defined as living with a partner in the household vs. not. For vision, the scores of two OECD long term disability indicator-items (McWhinnie, 1979) were summed (range 2–8, higher scores indicated poorer vision). Information on chronic diseases was derived from self-report. The total number of diseases was included as a continuous variable. A dichotomous variable (yes/no) was used to indicate whether respondents had one or more of the following cardiovascular conditions (henceforth: CVCs): stroke, myocardial infarction, hypertension, claudication or diabetes mellitus. The Mini-Mental State Examination (MMSE) (Folstein et al, 1975) was used to measure cognition (range 0–30, higher scores indicated better cognition). Hearing-aid use was included as a dichotomous variable ('Do you usually wear a hearing aid? 'yes; no').

Statistical analyses

Attrition

To test for selectivity in attrition, characteristics of those lost to follow-up and the study sample were compared. This was determined for two time intervals: (1) time between the LASA measurement prior to T_1 (i.e. 'T_0') and T_1; (2) time between T_1 and T_2. As the SR and the SNT samples differ, separate attrition analyses were performed. Loss to follow-up due to death was not regarded as potentially selective and was therefore not considered. Group differences were tested using independent samples t-tests (continuous measures) and Chi square tests (dichotomous measures). In addition, reasons for attrition were investigated.

Baseline characteristics

We tested whether baseline hearing status (SR and SNT) scores differed between various participant groups. Independent samples t-tests and one-way ANOVAs were used to compare two and three or more groups, respectively.

Effects of hearing status on loneliness and depression

Multiple linear regression analyses were used to investigate the longitudinal effect of hearing status on the wellbeing measures. T_1 hearing status was entered as central determinant and T_2 wellbeing as dependent variable. T_1 wellbeing was entered as covariate to correct for the cross-sectional association. All hearing and wellbeing variables were entered as continuous variables. As the distributions of all wellbeing variables were skewed to the right, they were log-transformed (log[score +1]) to normalize the data. As the resulting regression coefficients relate to the logarithmic scale, additional calculations were performed to interpret the actual effect sizes (see under 'Interpretation of regression coefficients', in the Results section). Because the LASA sample was pre-stratified for age and gender, these variables were entered as covariates in all regression models. In addition, all models were adjusted for hearing-aid use. For direct effects, a p-value of <0.05 was considered statistically significant.

To determine significant confounding or suppressing effects of variables, three criteria had to be met: (1) the variable was associated with the wellbeing measure ($p < 0.20$), (2) the variable was associated with the hearing status measure ($p < 0.20$), and (3) the regression coefficient of the hearing status measure changed with ≥10% after adding the variable to the model. The variables were also tested for their modifying effect. If the interaction term (potential effect modifier × hearing status variable) was statistically significant ($p < 0.05$) in the adjusted model, subgroup effects were calculated using the method introduced by Figueiras et al (1998).

Respondents with missing data on certain confounders/suppressors/effect modifiers were omitted from the statistical models in which these variables were included. The number of cases with a missing value equalled 0 or 1 for almost all variables, but was somewhat higher for the income and CVC variables. The highest number of missing values for these variables was 79 (income) and 28 (CVC).

Statistical software

All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS), version 14.0.

Results

Attrition

Attrition appeared selective for a number of characteristics (see Table 1). In general, those lost to follow-up were older, had lower SES and had poorer health. Reasons for attrition for the SR sample (517 in total) included: not interested in participating any more (17%), not able due to physical/cognitive problems (9%), and could not be reached (2%). However, most attrition (72%) could be attributed to respondents who were interviewed via a shortened telephone interview which did not include hearing status assessment. For the attrition of the SNT sample (805 in total), these reasons were partly similar: not interested (14%), physical/cognitive problems (8%), could not be reached (2%), and interviewed by telephone (37%). The reason for the remaining attrition (n = 210; 26%) was that the SNT could not be administered. A randomly selected sample (n = 36) from these 210 revealed that in most cases (i.e. 86%), this was caused by technical problems such as an inaccessible or absent telephone socket which was required to connect the SNT equipment. For 11%, the reason was unknown, and 3% had physical/cognitive problems.

Baseline description and comparison

The SR sample comprised 426 men (43%) and 570 women (57%). For the SNT sample, this concerned 362 men (44%) and 468 women (56%). Mean ages were 76.4 (SD = 8.0) and 73.4 (SD = 6.5) years for the SR and SNT sample, respectively. Table 2 shows the baseline characteristics of the study sample by SR and SNT hearing status.

Older age groups and hearing-aid users clearly had a much poorer baseline hearing status than their counterpart groups (both hearing measures, $p < 0.001$). In addition, those with lower education, lower

Table 1. Selective attrition between measurement T_0–T_1 and T_1–T_2. Variables differing significantly ($p < 0.05$) between those lost to follow-up and those remaining in the self-report or speech-in-noise test sample are indicated by 'X'. The number of participants lost to follow-up is indicated by 'n'.

	T_0–T_1		T_1–T_2	
Variable	*SR (n = 313)*	*SNT (n = 681)*	*SR (n = 204)*	*SNT (n = 123)*
Age (older)	X	X	X	X
Gender (female)		X		
Education (lower)	X	X	X	
Income (lower)	X	X		
Partner status (no partner in hh)		X	X	
Number of chronic diseases (more)		X		
Number of CVCs (more)		X		
Hearing aid use (yes)		X		
Self-reported vision (worse)	X	X	X	X
Self-reported hearing (worse)	X	X		
Depression (more)	X	X	X	X
Social loneliness (more)			X	X
Emotional loneliness (more)		X	X	X

SR: Self-report sample; SNT: Speech-in-noise test sample; hh: household; CVCs: Cardiovascular conditions (stroke, myocardial infarction, hypertension, diabetes mellitus, claudication)

income, poorer cognition, and poorer vision had a somewhat but statistically significant poorer hearing. No significant differences in hearing status appeared when the scores were stratified for partner status, chronic conditions, or CVCs. Further, a gender difference appeared: men had poorer baseline hearing than women. However, this was only significant for the SNT (men: −4.84; women: −5.46 dB SNR) but not for the SR measure ($p = 0.154$). Finally, poorer hearing was associated with poorer baseline depression, social, and emotional loneliness scores. This was only significant for the SR measure.

Effects of hearing status on loneliness and depression

Table 3 shows the results of the longitudinal multiple regression analyses. Both the effects of the SR (left column) and SNT hearing measure (right column) are presented, resulting in six main analyses. In both loneliness models, significant effect modifiers were found. The results of the stratified analyses are presented only for those analyses in which statistically significant subgroup effects appeared. The results are described below.

Social loneliness

For neither hearing measure was the overall effect on social loneliness statistically significant (borderline significant for SR hearing, $p = 0.050$). After adjusting for the confounding effect of self-reported vision and the suppressing effect of education, the effect remained borderline significant ($p = 0.058$). However, income, partner status, and hearing-aid use appeared to be significant effect modifiers. Stratified analyses showed that the main effect could be attributed to three significant subgroup effects. For those (1) with medium/high income, (2) living with a partner in the household, and (3) not using a hearing aid, poorer SR hearing resulted in higher (worse) social loneliness scores. The effects of their counter groups remained non-significant ($p > 0.597$).

In the SNT model, education appeared as a significant effect modifier. Stratified analyses showed a significant adverse effect of poorer SNT hearing on social loneliness only for those with medium/high education ($p = 0.022$).

Emotional loneliness

Regarding emotional loneliness, no significant overall effect was observed for SR hearing ($B_{log} = 0.006$, $p = 0.376$). However, stratified analyses showed significant adverse effects for the following subgroups: men, persons without CVCs, those living with a partner in the household, and non-hearing aid users. These effects were rather similar in strength ($B_{log} = 0.017$– 0.019). However, the effect for non-hearing-aid users was borderline significant after adjusting for chronic diseases ($p = 0.065$). In addition, we explored whether there was a three-way interaction between SR hearing, partner status, and gender. This was indeed the case: the adverse significant effect could only be ascribed to men living with a partner in the household ($B_{log} = 0.019$, $p = 0.031$).

For the SNT model, again, the significant overall effect ($B_{log} = 0.010$, $p = 0.013$) could be ascribed to subgroups. The first subgroup comprised men ($B_{log} = 0.018$, $p = 0.001$), as was the case in the SR model. The second group was those with medium/high education ($B_{log} = 0.023$, $p < 0.001$). The third group comprised those with one or more chronic diseases ($B_{log} = 0.010$, $p = 0.025$). This effect was stronger but non-significant for those without any diseases ($B_{log} = 0.013$, $p = 0.165$).

Interpretation of regression coefficients

As log-transformed scales were used for the loneliness measures, the regression coefficients cannot be interpreted directly. Therefore, we illustrated this magnitude for four subgroups in Table 4. The values in the right columns show the change in loneliness when varying the hearing status score (keeping other covariates constant).

For men, subsequent increases (i.e. worsening) in SR hearing of one standard deviation (SD), resulted in modest increases of subsequently 0.07, 0.07, and 0.08 in emotional loneliness (possible range: 0–6). The increase in emotional loneliness was somewhat larger for poorer SNT scores (i.e. 0.16, 0.18, and 0.19 points in loneliness per SD step worsening of the SNT). The largest effect was observed for those with medium/high education (increases of 0.19, 0.22, and 0.24 points). Regarding social loneliness, a modest effect was observed for non-hearing-aid users (increases of 0.09 or 0.10).

Depression

No significant effects for depression appeared (total sample, SR model: $p = 0.576$; SNT model: $p = 0.179$).

Discussion

The study aim was to determine the relationships between hearing status and depression, and hearing status and loneliness in a population-based older sample and to explore differences in subgroup effects. The findings show that both self-report of hearing status and speech-in-noise test scores predict adverse effects on social and emotional loneliness. However, the adverse effects did not apply to the total population-based sample, but were restricted to specific subgroups. This is a novel finding. No effects on depression were observed.

As outlined in the introduction, several studies investigated the effects of hearing on loneliness in population-based samples of which two used longitudinal designs (i.e. Strawbridge et al, 2000;

Table 2. Baseline characteristics (categorized) of the study samples by self-reported (n = 996) and speech-in-noise test hearing status (n = 830).

		T_1 SR Hearing status* (3–12)				T_1 SNT Hearing status * (− 9.20 to 5.10 dB SNR)			
		Test statistics				*Test statistics*			
	n (%) (SR; SNT sample)	*Mean*	*SD*	*t /F*	*p*	*Mean*	*SD*	*t /F*	*p*
Age									
63–74 years	571 (57); 493 (59)	3.53	1.10	37.80	< **0.001**	− 5.92	1.93	74.18	< **0.001**
74–83 years	332 (33); 270 (33)	4.09	1.63			− 4.45	2.64		
84–93 years	93 (10); 67 (8)	4.74	2.14			− 2.84	3.04		
Gender									
men	426 (43); 362 (44)	3.91	1.49	1.43	0.154	− 4.84	2.51	3.61	< **0.001**
women	570 (57); 468 (56)	3.77	1.45			− 5.46	2.42		
Education									
low	551 (55); 459 (55)	3.97	1.62	3.60	< **0.001**	− 4.92	2.56	3.59	< **0.001**
med-high	445 (45); 371 (45)	3.65	1.23			− 5.53	2.32		
Income									
low	168 (18); 114 (19)	4.25	1.95	3.23	**0.001**	− 4.40	3.14	3.45	**0.001**
med-high	750 (81); 630 (81)	3.74	1.33			− 5.36	2.30		
Partner status									
partner in hh	599 (60); 524 (63)	3.76	1.35	-1.78	0.076	− 5.27	2.45	− 1.20	0.230
no partner in hh	397 (40); 306 (37)	3.93	1.63			− 5.06	2.52		
Chronic diseases									
0	141 (14); 121 (15)	3.68	1.42	-1.30	0.195	− 5.44	2.37	− 1.20	0.232
≥ 1	855 (86); 709 (85)	3.85	1.48			− 5.15	2.49		
CVCs									
0	551 (57); 467 (58)	3.75	1.31	-1.87	0.061	− 5.23	2.41	− 0.42	0.679
≥ 1	417 (43); 343 (42)	3.93	3.93			− 5.16	2.56		
Cognitive status (MMSE)									
≥ 26	871 (87); 737 (89)	3.76	1.37	− 3.23	**0.002**	− 5.37	2.36	− 5.13	< **0.001**
< 26	125 (13); 93 (11)	4.34	1.97			− 3.76	2.91		
Self-reported vision (2–8)									
2	827 (83); 694 (84)	3.73	1.35	− 4.02	< **0.001**	− 5.29	2.38	− 2.40	**0.017**
3-8	168 (17); 135 (16)	4.34	1.88			− 4.66	2.87		
Hearing aid use									
no	886 (89); 747 (90)	3.49	0.88	-14.33	< **0.001**	− 5.59	2.13	− 13.88	< **0.001**
yes	110 (11); 83 (10)	6.55	2.22			− 1.60	2.52		
Social loneliness (0–5)									
0	561 (56); 479 (58)	3.73	1.35	3.40	**0.034**	− 5.34	2.47	2.18	0.113
1-2	306 (31); 244 (29)	3.92	1.63			− 5.02	2.43		
3-5	129 (13); 107 (13)	4.05	1.52			− 4.90	2.57		
Emotional loneliness (0–6)									
0	560 (56); 464 (56)	3.72	1.29	6.56	**0.001**	− 5.35	2.38	2.18	0.113
1–2	268 (27); 232 (28)	3.84	1.42			− 5.03	2.50		
3–6	168 (17); 134 (16)	4.18	1.97			− 4.92	2.74		
Depression (0–60)									
0–15	863 (87); 732 (88)	3.75	1.38	− 3.22	**0.002**	− 5.26	2.40	− 1.88	0.063
16–60	132 (13); 98 (12)	4.30	1.86			− 4.67	2.98		

*SR: Self-reported hearing status, a higher score indicates poorer hearing; SNT: Speech-in-noise test hearing status in dB signal-to-noise ratio (SNR), a higher score indicates poorer hearing. med: medium; hh: household; CVCs: Cardiovascular conditions (stroke, myocardial infarction, hypertension, diabetes mellitus, claudication); SD: Standard deviation; MMSE: Mini-Mental State Examination. Summed sample sizes may vary due to missing values.

Wallhagen et al, 1996). Similar to our study, these longitudinal studies adjusted for relevant confounders and assessed hearing status by self-report, which may explain similarities in findings. However, neither Strawbridge et al (2000) nor Wallhagen et al (1996) examined interaction effects.

We found significant effect modification by gender such that an adverse effect on emotional loneliness was observed only in men. Only one previous study also found a gender difference in the occurrence of an adverse loneliness effect (Chen, 1994), but instead, they found it for women only. Our results may be supported by other findings, though. For instance, it is reported that men use fewer non-verbal communication strategies and report less problem awareness and more denial than women (Erdman & Demorest 1998a,b; Garstecki & Erler, 1999). These coping mechanisms may explain the adverse effect on men's emotional loneliness. However, based on men's lower level of problem awareness and more denial, one would not expect to find effects for the SR hearing measure. Apparently, these did not play a decisive role in our sample.

Table 3. Longitudinal associations (logarithm-transformed regression coefficients) between self-reported and speech-in-noise test hearing status and social loneliness, emotional loneliness, and depression. For the total sample and for subgroups.

		SR Hearing status*				SNT Hearing status*			
		B_{log} ◊ *(SE)*	*95%CI*		*p*	B_{log} ◊ *(SE)*	*95%CI*		*p*
Social loneliness									
Total sample (n = 996|830)	†	0.012 (0.006)			**0.050**	0.004 (0.004)	−0.003	0.012	0.240
		0.012 (0.006)			0.058				
Subgroups:									
Income									
low (n = 168)	†	− 0.005 (0.010)	− 0.024	0.014	0.597	–	–	–	–
med-high (n = 750)	†	0.017 (0.008)	0.003	0.032	**0.020**	–	–	–	–
Partner status									
no partner in hh (n = 396)	†	0.003 (0.008)	− 0.012	0.019	0.669	–	–	–	–
partner in hh (n = 599)	†	0.020 (0.008)	0.005	0.036	**0.010**	–	–	–	–
Hearing aid use									
no (n = 885)	†	0.022 (0.008)	0.006	0.039	**0.008**	–	–	–	–
yes (n = 110)	†	0.000 (0.009)	-0.019	0.018	0.964	–	–	–	–
Education									
low (n = 459)		-	–	–	–	0.001 (0.005)	−0.007	0.010	0.753
med-high (n = 371)		-	–	–	–	0.012 (0.005)	0.002	0.023	**0.022**
Emotional loneliness									
Total sample (n = 995|829)		0.006 (0.007)	− 0.007	0.019	0.376	0.010 (0.004)	0.002	0.018	**0.013**
Subgroups:									
Gender									
men (n = 425|361)		0.019 (0.008)	0.002	0.035	**0.027**	0.018 (0.005)	0.008	0.029	**0.001**
women (n = 570|468)		− 0.006 (0.008)	− 0.022	0.010	0.466	0.002 (0.005)	−0.008	0.012	0.637
Partner status									
partner in hh (n = 598)		0.017 (0.008)	0.000	0.022	**0.044**	–	–	–	–
men (n = 341)		0.019 (0.009)	0.002	0.035	**0.031**	–	–	–	–
women (n = 257)		0.010 (0.013)	− 0.015	0.010	0.443	–	–	–	–
no partner in hh (n = 397)		− 0.005 (0.008)	− 0.021	0.034	0.584	–	–	–	–
men (n = 84)		0.017 (0.013)	− 0.009	0.037	0.194	–	–	–	–
women (n = 313)		− 0.010 (0.009)	− 0.027	0.035	0.241	–	–	–	–
Hearing aid use									
no (n = 885)	†	0.018 (0.009)	0.001	0.036	**0.039**	–	-	–	–
		0.017 (0.009)	− 0.001	0.034	0.065	–	-	–	–
yes (n = 110)		–0.010 (0.010)	− 0.029	0.021	0.333	–	-	–	–
CVC									
0 CVCs (n = 551)		0.018 (0.008)	0.003	0.012	**0.021**	–	–	–	–
≥ 1 CVCs (n = 417)		− 0.007 (0.007)	− 0.021	0.042	0.316	–	–	–	–
Chronic diseases									
0 (n = 121)		–	–	–	–	0.013 (0.009)	−0.005	0.030	0.165
≥ 1 (n = 708)		–	–	–	–	0.010 (0.004)	0.001	0.018	**0.025**
Education									
low (n = 459)		–	–	–	–	0.002 (0.005)	−0.008	0.011	0.714
med-high (n = 370)		–	–	–	–	0.023 (0.007)	0.012	0.034	**<0.001**
Depression									
Total sample (n = 992|829)		0.005 (0.010)	− 0.013	0.024	0.576	0.007 (0.006)	−0.003	0.018	0.179

*SR: Self-reported hearing status; SNT: Speech-in-noise test hearing status. ◊Logarithm transformed (log[well-being variable + 1]) regression coefficient, SE, 95%CI and p-value. -: No significant interaction by this variable, no stratified analyses performed. hh: household; med: medium; CI: Confidence interval; CVCs: Cardiovascular conditions (stroke, myocardial infarction, hypertension, diabetes mellitus, claudication). All models were adjusted for gender, age, hearing aid use, and baseline wellbeing. Summed sample sizes may vary due to missing values. †Additionally, we adjusted for the following covariates: SR hearing, social loneliness model (all subgroups): self-reported vision (confounder) and level of education (suppressor). SR hearing, emotional loneliness model (subgroup non-hearing aid users): number of chronic diseases (confounder).

The effect for men may also be explained by gender differences in social relations. Men are more likely to find an intimate attachment figure in marriage. This is in contrast to women, who also find protection from emotional loneliness in other close ties (Dykstra & de Jong Gierveld, 2004). The significant three-way interaction with gender and partner status showed an effect only for men living with a partner in the household. It is likely that the hearing impairment places such a burden on close relations that men's experienced deficit becomes especially apparent when living with a partner in the household. The negative impact that hearing impairment can have on a couple's relationships is well-documented (e.g. Scarinci et al, 2008). Jones et al (1987) showed that 40% of the couples with one of the spouses having hearing problems perceived

Table 4. Estimated effect sizes of hearing status on social and emotional loneliness for subgroups: men (both self-reported and speech-in-noise test hearing status on emotional loneliness); non-hearing-aid users (self-reported hearing status on social loneliness); medium-high education (speech-in-noise test hearing status on emotional loneliness).

	T_1 SR hearing status (range 3–12)*		*T_2 emotional loneliness (range 0–6)*		*T_1 SNT hearing status* (range − 9.20 to 5.10 dB)*		*T_2 emotional loneliness (range 0–6)*	
Men	Mean	3.59	0.68	*Increase*†	Mean	− 5.00	0.55	*Increase*†
	+ 1 SD	4.54	0.75	0.07	+ 1 SD	− 2.65	0.71	0.16
	+ 2 SD	5.48	0.82	0.07	+ 2 SD	− 0.30	0.88	0.18
	+ 3 SD	6.43	0.90	0.08	+ 3 SD	2.05	1.07	0.19
Med-high education	–	–	–	–	Mean	− 5.59	0.65	*Increase*†
	–	–	–	–	... + 1 SD	− 3.47	0.84	0.19
	–	–	–	–	... + 2 SD	− 1.35	1.06	0.22
	–	–	–	–	... + 3 SD	0.77	1.30	0.24
	T_1 SR hearing status (range 3–12)*		*T_2 social loneliness (range 0–5)*					
Non-HA users	Mean	3.75	0.59	*Increase*†	–	–	–	–
	+ 1 SD	4.83	0.68	0.09	–	–	–	–
	+ 2 SD	5.90	0.78	0.10	–	–	–	–
	+ 3 SD	6.98	0.88	0.10	–	–	–	–

*SR: Self-reported hearing status, a higher score indicates poorer hearing; SNT: Speech-in-noise test hearing status in dB signal-to-noise ratio, a higher score indicates poorer hearing. †Increase in loneliness score per SD-step worsening of hearing status score. HA: hearing aid, med: medium. -: no significant interaction by this variable, no stratified analyses performed. Entered values of independent variables (per subgroup): Men: age: group mean; baseline emotional loneliness: group mean; hearing aid use: no. Non-hearing-aid users: age: group mean; gender: men; baseline social loneliness: group mean; self-reported vision: group mean; level of education: low. Medium-high education: age: group mean; gender: men; baseline emotional loneliness: group mean; hearing-aid use: no.

their relationship as less personal, with loss of intimate talk limiting physical and emotional intimacy. It should be mentioned, though, that the non-significance ($p = 0.194$) of the somewhat smaller effect for men living alone may be due to a limited sample size of that group ($n = 84$). Altogether, the presence of an adverse effect on emotional loneliness for men and absence of an effect for women seems consistent throughout our findings.

We also found adverse effects for persons living with a partner on social loneliness. As social loneliness concerns deficits felt in social integration and embeddedness, rather than deficits felt in close relations in emotional loneliness, other explanatory mechanisms than those mentioned above seem to apply here. It is undisputed that hearing problems can hamper social roles and interactions and can lead to social withdrawal. The data may imply that hearing-impaired persons compare themselves more strongly to their socially, relatively well-functioning partner than would be the case if they lived alone. In addition, it is accepted that couples generally have larger social networks than persons living alone (e.g. Broese van Groenou & Deeg, 2010) which seems to support our hypothesis.

The finding that only hearing-impaired persons with medium or high education experienced more social loneliness may also be explained by differences in social participation. Among others, Broese van Groenou & Deeg (2010) have shown that higher-educated older persons have higher levels of social participation. As a consequence, the social limitations caused by hearing impairment may be felt more strongly by this socially active group.

The SR data seem to show a consistent pattern regarding the occurrence of adverse effects on loneliness in non-hearing-aid users. No adverse effects were found for hearing-aid users. This suggests that hearing aids may indeed help prevent negative consequences on social participation and intimate attachment relations. The findings should be interpreted with caution though, as we asked respondents whether they '*usually* used a hearing aid'. The users could thus represent the more satisfied, successful users. Nonetheless, the findings suggest beneficial psychosocial effects of amplification which is in accordance with previous findings. For instance, Mulrow et al (1990) found that hearing aids significantly diminished adverse quality of life effects, including depression.

Finally, we observed a significant negative effect on emotional loneliness for persons with chronic diseases. Although the effect was somewhat stronger for those having none, it remained non-significant ($p = 0.165$). Regarding the CVC subgroups, the effect was significant only for those without CVCs. Nonetheless, a similar underlying mechanism can be hypothesized: it may be that hearing impairment has a relatively large impact on an older person's psychosocial health when it is the only impairment (s)he has to cope with, while the impact diminishes when it has to 'compete' with other conditions. Following this line of reasoning, the non-significant effect ($p = 0.165$) of the no chronic diseases-group may just be attributable to the relatively small group size ($n = 121$ vs. $n = 708$).

No significant effects were observed for depression. This was unexpected, as most longitudinal studies performed so far reported significant relations (e.g. Wallhagen et al, 1996; Strawbridge et al, 2000; Saito et al, 2010). Similar to our study, Chou (2008) found no effect. This may be explained in three ways. Firstly, in both studies, attrition was selective which may have diluted the effect: those lost to follow-up were significantly older and had frailer health, also regarding hearing and depression. Secondly, late-life depression often has a fluctuating course (Beekman et al, 2002). Depressive symptoms may occur shortly after the emergence of hearing problems, but may diminish over time due to coping mechanisms. As in our and Chou's (2008) study, a follow-up of four and two years was used, respectively, and the effects may have weakened. This line of reasoning seems strengthened by the significant cross-sectional association both Kramer et al (2002) and we found using data from the LASA study. However, Wallhagen et al (1996) found a significant adverse effect even when using six years of follow-up. Lastly, the use of antidepressants was not considered in our and Chou's (2008) study which may have masked the effect. As an exploration, we excluded respondents who were depressed (CES-D ≥16) at baseline by which we aimed to exclude most antidepressant users. The effects in these samples were similar to those in the original samples, suggesting that antidepressant use did not play a vital role in our data. In addition, the longitudinal studies that did find a significant effect on depression did not account for antidepressant use either (Wallhagen et al, 1996; Strawbridge et al, 2000; Saito et al, 2010).

To our knowledge, this study is the first to describe the predictive abilities of both a self-report hearing measure and a speech-in-noise test on depression and loneliness. Adverse effects on emotional and social loneliness were present for both hearing measures. Adverse subgroup effects were found for men, those without comorbidity (CVCs or chronic diseases), and those with high SES (income or education). However, some subgroup effects only applied to one of the hearing measures (i.e. partner status and hearing-aid use subgroup effects appeared in the self-report models only, see Table 3). Overall, we could not observe a better predictive value for the self-report measure compared to the objective functional measure, as has been suggested by some (e.g. Tambs, 2004; Hallberg et al, 2008). Instead, partly different effect modifiers applied to each hearing measure. The reason may be that the hearing status measures tap into different hearing constructs. The three SR items refer to common daily life communication situations in the activity/participation domain, while the SNT seems to assess the function of speech discrimination in a noisy background (ICF, WHO, 2001). Throughout the literature, correlations between self-report scales and objective measures are often moderate (e.g. Noble, 1978; Rowland et al, 1985) which was also the case in our study ($r = 0.47$).

Strengths and limitations

To date, interaction effects have scarcely been investigated. As has been mentioned, some studies investigated interactions of hearing status with age and gender (e.g. Nachtegaal et al, 2009; Tambs, 2004) and found different effects for the various subgroups. In addition, two studies tested for effect modification by hearing-aid use (Nachtegaal et al, 2009), and comorbidity and SES (Saito et al, 2010), but they found none. However, the great majority of the studies did not consider interaction effects at all. In fact, the mixed results outlined in the introduction may be partly ascribed to the presence or absence of certain subgroups effects, depending on the representation of the subgroups in the total sample. The current findings emphasize the importance of considering subgroup effects in future research. This holds for studies on psychosocial consequences of hearing impairment, but may also apply to intervention studies.

Another strength is the longitudinal design. It allowed investigation of prediction rather than cross-sectional association. In addition, bias by confounding variables could be adjusted for. Additionally, the data originated from a large community-based sample, allowing extrapolation to the general older population. Finally, we distinguished between social and emotional loneliness, which, to our knowledge, has not been investigated before in relation to hearing status. The findings strongly suggest that differentiating these has added value as the adverse effects occurred in partly differing subgroups.

Our study had some limitations. There was a selective loss to follow-up which may have diluted the effects. In addition, the effect of deterioration in hearing on psychosocial wellbeing was not investigated, while interpersonal differences in rate of deterioration and associated effects could have occurred. This seems important considering the degenerative nature of presbyacusis and interpersonal differences in its course.

Conclusion and Implications

Poor hearing status can have significant adverse effects on emotional and social loneliness for subgroups of older persons. Although individual effect sizes seem modest, the disease burden may be considerable on a population level. Partly differing subgroup effects appeared for the SR and the SNT measure. In general, two important groups at risk for loneliness seem to be men and non-hearing-aid users. Future research should confirm the subgroup effects and investigate underlying mechanisms. These findings may contribute to developing tailored loneliness prevention programs aimed at specific groups of older hearing-impaired persons and their significant others. In addition, the findings seem to provide further support to advocate hearing-aid use to prevent or combat social isolation.

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