Change in Psychosocial Health Status Over 5 Years in Relation to Adults' Hearing Ability in Noise

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Objectives: The aim of this study was to establish the longitudinal relationship between hearing ability in noise and psychosocial health outcomes (i.e., loneliness, anxiety, depression, distress, and somatization) in adults aged 18 to 70 years. An additional objective was to determine whether a change in hearing ability in noise over a period of 5 years was associated with a change in psychosocial functioning. Subgroup effects for a range of factors were investigated.

Design: Longitudinal data of the web-based Netherlands Longitudinal Study on Hearing (NL-SH) (N = 508) were analyzed. The ability to recognize speech in noise (i.e., the speech-reception-threshold [SRTn]) was measured with an online digit triplet test at baseline and at 5-year follow-up. Psychosocial health status was assessed by online questionnaires. Multiple linear regression analyses and longitudinal statistical analyses (i.e., generalized estimating equations) were performed.

Results: Poorer SRTn was associated longitudinally with more feelings of emotional and social loneliness. For participants with a high educational level, the longitudinal association between SRTn and social loneliness was significant. Changes in hearing ability and loneliness appeared significantly associated only for specific subgroups: those with stable pattern of hearing aid nonuse (increased emotional and social loneliness), who entered matrimony (increased social loneliness), and low educational level (less emotional loneliness). No significant longitudinal associations were found between hearing ability and anxiety, depression, distress, or somatization.

Conclusions: Hearing ability in noise was longitudinally associated with loneliness. Decline in hearing ability in noise was related to increase in loneliness for specific subgroups of participants. One of these subgroups included participants whose hearing deteriorated over 5 years, but who continued to report nonuse of hearing aids. This is an important and alarming finding that needs further investigation.

Key words: Adults, Digit triplet test, Hearing status, Loneliness, Prospective study, Psychosocial functioning.

(Ear & Hearing 2016;37;680–689)

INTRODUCTION

Studies suggest that the level of hearing impairment is negatively associated with an individual's psychosocial health (e.g., Kramer et al. 2002; Tambs 2004; Nachtegaal et al. 2009a). This implies that a person's hearing status may have predictive value for future psychosocial problems, which could be used to prevent or treat such problems. However, the longitudinal relationship between hearing status and psychosocial problems is still subject to debate. Only a small number of prospective studies investigating the relationship between hearing status and various parameters of psychosocial health have been conducted and the outcomes of these studies are not always in agreement (Table 1). In some of these studies, a moderate to severe self-reported hearing impairment at baseline appeared to be associated with higher levels of depression 1 year later (Wallhagen et al. 1996; Strawbridge et al. 2000), 3 years later (Saito et al. 2010), or even over 16 years later (Kiely et al. 2013). However, other studies failed to find such an association (Chou 2008; Pronk et al. 2011). Evidence supporting a relationship between the existence of hearing impairment at some moment in time and feelings of loneliness some years later was found more consistently (Strawbridge et al. 2000; Wallhagen et al. 2001; Pronk et al. 2011).

Furthermore, several studies have investigated the impact of a change in hearing on an individual's psychosocial health status. Faster decline in hearing ability in noise appeared to be associated with a stronger increase in social and emotional loneliness in older participants with moderate level of impairment at baseline (Pronk et al. 2014). In addition, the same study reported that emotional loneliness increased with hearing decline, predominantly for those who had recently lost their partner. A decline in hearing ability in noise appeared to be associated neither with a change in depression (Pronk et al. 2014) nor with a change in anxiety (thesis of Pronk 2013). Another study found no statistically significant differences in psychological distress over time between older participants with self-reported declining hearing and those with stable hearing status (Corna et al. 2009). Additional longitudinal studies investigating the change in hearing status and the simultaneous change in psychosocial health over time are needed to further clarify these relationships.

Apart from the commonly studied indicators, such as loneliness and depression, other parameters can provide insight into an individual's psychosocial health status. For instance, a cross-sectional study by Nachtegaal et al. (2009a) showed that poorer hearing ability in noise was associated with higher levels of distress and somatization, which Lipowski (1988) defined as the tendency to experience somatic symptoms in response to psychological stress and to attribute them to physical illness. This, in turn, leads them to seek medical help. Only two studies were identified that investigated the longitudinal relationship between hearing and psychological distress. Corna et al. (2009) investigated the relationship between a transition in self-reported hearing impairment and generalized psychological distress. A borderline significant difference in older adults with declining hearing compared with those with a stable hearing status was reported; and Gopinath et al. (2012) reported that older hearing-impaired adults had an increased risk of experiencing emotional distress and restrictions in social engagement

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<zdoi; 10.1097/AUD.0000000000000332>

TABLE 1. Overview of longitudinal studies about the relationship between hearing status and psychosocial health

	Descriptive Information of the Studies					Longitudinal Relationship Between Hearing Status and:			
First Author (Year)	Study Population	Country	Follow-Up (Year)	Hearing Ability	Outcome Measure	Loneliness	Depression	Anxiety	Other Parameters of Psychosocial Health
Strawbridge et al. (2000)	50–102 yrs N = 2461	USA	1	Self-report 3 situations	DSM-III-R	Yes	Yes	-	-
Wallhagen et al. (2001)	50–102 yrs N = 2442	USA	1	Self-report 3 situations	DSM-III-R	Yes	Yes	-	-
Chou (2008)	>65 yrs N = 3782	England	2	Self-report 5-point scale	CES-D	-	No	-	-
Corna et al. (2009)	>50 yrs N = 1113	Canada	6	HUI 4 t-groups	Generalized distress	-	-	-	No relationship with distress
Saito et al. (2010)	>65 yrs N = 580	Japan	2–3	HHIE-S No vs. Yes	Geriatric depression scale	-	Yes	-	-
Pronk et al. (2011)	63–93 yrs N = 996/830	The Netherlands	4	Speech-in-Noise test Self-report	LON-scale CES-D	Yes, for subgroups	No	-	-
Gopinath et al. (2012)	49+ at T0 N = 2334	Australia	5	Audiometry	HHIE-S	-	Yes	-	Relationship with emotional distress
Kiely et al. (2013)	65–103 yrs N = 1611	Australia	16	Audiometry	CES-D	-	Yes	-	-
Pronk et al. (2014)	63–93 yrs N = 1178	The Netherlands	3–7	Speech-in-Noise test	LON-scale CES-D	Yes, for subgroups	No	No*	-

**Results about anxiety as reported in the thesis of Pronk (2013).*

CES-D, Center for Epidemiologic Studies Depression Scale; DSM-III-R, Diagnostic and Statistical Manual of Mental Disorders major depressive episodes scale; HHIE-S, Hearing Handicap Inventory for the Elderly Screening Version; HUI, Health Utility Index; LON-scale, De Jong Gierveld Loneliness scale.

after 5 years. Studies including additional psychosocial parameters, such as distress and somatization, are needed to provide a broader perspective of how the consequences of hearing impairment may impact daily life.

Other limitations of the existing literature are that nearly all studies were conducted with samples of adults aged 60 years and over and that mainly self-reported hearing or pure-tone audiometry were used to quantify hearing (Table 1). As younger adults may assess their hearing problems differently (Lutman et al. 1987) and the impact of hearing impairment on psychosocial health may be stronger in younger age groups (Tambs 2004; Nachtegaal et al. 2009a), there is a need to assess hearing ability (in noise) and psychosocial health in younger populations. Testing hearing ability in noise offers a direct measurement of how well a person understands speech in the presence of noise, a common adverse listening circumstance in daily life.

Based on the knowledge gaps in the relationship between hearing and psychosocial health described above, the aim of the present study was to determine the longitudinal relationship between a decline in hearing ability in noise and psychosocial health in a broad age range of subjects. Therefore, we posed the following research questions: (1) Is impaired hearing ability in noise in adults aged 18 to 70 years associated with an increase in loneliness, anxiety, depression, distress, and somatization (collectively referred to as psychosocial health parameters)?; (2) Is a change in hearing ability in noise over 5 years associated with a change in the psychosocial health parameters over the same period? (3) Do age, gender, education, chronic conditions, living arrangements, marital status, general health, initial hearing ability, and the use of a hearing aid modify these associations?

MATERIALS AND METHODS

Data Collection

Baseline (T0) and 5-year follow-up data (T1) from the Netherlands Longitudinal Study on Hearing (NL-SH study) were used. The NL-SH is an ongoing prospective cohort study that examines the relationships between hearing impairment and several domains in the lives of adults aged 18 to 70 years. The NL-SH includes a convenience sample of Dutch adults with and without hearing impairment; data collection is online. The NL-SH uses both the National Hearing test (NHT; see next paragraph) and an extensive online questionnaire on hearing status, health, work, and health care use. Reminders by e-mail and by regular mail are sent to participants who fail to respond. More details about the study design can be found on the NL-SH Web site (www.hooronderzoek.nl, in Dutch) or in earlier publications (e.g., Nachtegaal et al. 2009a, b; Stam et al. 2014).

The T1 measurements were performed 5 years (±1 month) after each individual's original T0 measurement. Data of participants who completed the T0 measurements in 2006, 2007, or 2008, and their corresponding T1 measurements in 2011, 2012, or 2013, were included in the present study. The procedures of data collection at T0 and T1 were similar, with one exception: At T0, participants first performed the NHT followed by the questionnaire. At T1, the questionnaire was completed first. After completing the T1 questionnaire, participants were directed to the NL-SH website where they could perform the NHT again (Stam et al. 2015). The NL-SH study is approved by the Medical Ethics Committee of the VU University Medical Center (Amsterdam, The Netherlands).

Hearing Ability in Noise

In both the measurement rounds, the participant's ability to recognize speech in noise was tested with the NHT (Smits et al. 2004, 2006). A total of 23 digit triplets (e.g., 6-2-5) were presented against a background of stationary masking noise. The noise level was fixed during the test, and the speech level varied according to a one-up, one-down procedure. NL-SH participants were instructed to adjust the overall volume level of their speaker or headphone to their most preferred level. After each incorrect response, the subsequent triplet was presented at a 2-dB higher level. In case of a correct response, the subsequent digit triplet was presented 2 dB lower. Listeners responded by typing the digits on their keyboard or tapping the digits on the computer screen. At the start of the test, participants indicated which type of transducer they were using, either headphones or loudspeakers. They were instructed to perform the NHT in a quiet room. When headphones were used, the digit triplets were presented to both ears.

The speech-reception-threshold in noise (SRTn) was calculated by taking the average signal to noise ratio (SNR) of the last 20 presentations, corresponding to 50% recognition of digit triplets. According to the reference data by Smits et al. (2006), this continuous score can be categorized into three categories: good (SRTn < -5.5 dB), insufficient ($-5.5 \leq$ SRTn ≤ -2.8 dB), or poor (SRTn > -2.8 dB) hearing ability. The validity and reliability of the NHT have been proven to be good in several studies (Smits et al. 2004, 2006; Nachtegaal et al. 2009b).

After completion of the NHT at T0, participants were asked whether they had performed the test with (aided) or without hearing aids (unaided). At T1, the group of participants who had used their hearing aids were instructed to perform the NHT twice: once with and once without hearing aids. In the present study, only SRTn data were included that were obtained from unaided conditions and for which the same transducer was used at T0 and T1 (either headphones or loudspeakers). Data from cochlear implant users at T1 were excluded, as it was unknown how participants with a cochlear implant performed the NHT at T0 (with or without cochlear implant). Outliers were determined by calculating standardized residuals, as part of linear regression analyses with the SRTn at T1 as an outcome, and the SRTn T0 as a determinant in the model. SRTn scores with standardized residuals ≥3 dB were considered as outliers and excluded from the analyses.

Psychosocial Functioning

Distress, Depression, Anxiety, and Somatization • The four-dimensional symptom questionnaire (4DSQ) was used to assess distress, depression, anxiety, and somatization. The 4DSQ has proven to be a reliable and valid instrument (Terluin et al. 2004, 2006). Distress refers to "the direct manifestation of the effort people must exert to maintain their psychosocial homeostasis and social functioning when confronted with stress." Symptoms of distress include worrying, tension, and poor concentration. Depressive thoughts, such as having the feeling that everything is meaningless, were grouped within the depression scale. Anxiety, avoidance behavior, and irrational fears were encompassed by the anxiety scale. Items on somatization were also included in the questionnaire.

In general, the items had the following wording: "During the past week, did you feel....?" Participants chose one of five

response categories ranging from "no" to "very often or constantly." We used the scoring algorithm as proposed by the developers (Terluin et al. 2006): the coding of these categories was 0 (no), 1 (sometimes), or 2 (regularly; often; very often or constantly). Missing values on the item scores (ranging between 0 and 7 missing values per item) were replaced by the mean value of the remaining scale items (imputation). This method was also chosen to allow comparison of the current data with data from a previously performed cross-sectional NL-SH study (Nachtegaal et al. 2009a). Sum scores were calculated when a minimum number of items within a scale were completed, according to the developers' guidelines (Terluin et al. 2006). For distress, the criterion was 10 completed items out of 16, 4 out of 5 items for depression, 8 out of 12 items for anxiety, and 10 out of 16 items for somatization. When this criterion was not fulfilled, a sum score was not calculated for that participant.

The version of the 4DSQ used in the NL-SH included 49 items instead of 50 items. As two items about depressive feelings had related wordings, one was omitted in the NL-SH study (in consultation with Mr. B. Terluin, MD, PhD). To preserve comparison with other studies using the 4DSQ, a sum score for the depression scale was calculated by double counting the remaining of the two items.

Loneliness • The 11-item loneliness scale of De Jong Gierveld & Kamphuis (1985) was used to assess emotional and social loneliness. It is a robust, reliable, and valid instrument to determine loneliness (Van Tilburg & De Leeuw 1991). The scale consists of two subscales: social loneliness (five items) and emotional loneliness (six items). Social loneliness relates to deficits in social integration and embeddedness, whereas emotional loneliness reflects the absence of an intimate attachment figure, such as a partner or a best friend (Weiss 1973). An example of an item is "I miss having a really close friend." Answer categories were 0 (no!), 1 (no), 2 (more or less), 3 (yes), or 4 (yes!). On a positively formulated item, such as this, the response categories 2, 3, or 4 were recoded as 1 (indicating loneliness) and categories 0 and 1 into 0 (no loneliness). On a negatively formulated item, the response categories 0, 1, or 2 were recoded into 1 (indicating loneliness) and the answers in categories 3 and 4 into 0 (indicating no loneliness). The item scores were summed when at least 10 out of 11 items were completed, resulting in a total sum score between 0 and 11 points. Higher scores on the loneliness scales indicated more feelings of loneliness.

Covariates

Research has shown that demographic factors and health parameters are associated with both hearing status and psychosocial health (e.g., Gopinath et al. 2012; Pronk et al. 2014). Hence, these factors were adopted as covariates in this study.

Data regarding age, gender, educational level, marital status, and living arrangement were collected using standard questionnaires. Age at T0 was used in the analyses as a categorical variable, with the following categories: 18 to 29, 30 to 39, 40 to 49, 50 to 59, and 60 to 70 years. Education was divided into three levels: low (not finished elementary to lower vocational school), mid (general intermediate to general secondary school), and high (higher vocational school to post academic education). Marital status was dichotomized into (1) married or having a registered partnership or (0) neither. Change in marital status included four categories: stably married, entered matrimony, divorced, and stably not married. Living arrangement was categorized as living alone versus living together or with others, and the change in living arrangement into four categories: stably living with others; started living with others; started living alone; and stably living alone.

The occurrence of chronic medical conditions was measured with a standard list as used by Statistics Netherlands. The instructions were as follows: "Below is a list of 27 chronic medical conditions or diseases. Please tick the box for a chronic condition or disease if present now or was present during the last 12 months." Examples of chronic conditions are diabetes, cardiovascular disease, and respiratory conditions; for further explanation, see Stam et al. (2014). The total number of chronic medical conditions was calculated. Four categories were created to describe change in chronic conditions: stable no chronic conditions, increase, decrease, and stable having one or more chronic conditions.

General health status was assessed using the visual analog scale of the EuroQol5-D questionnaire (Kind et al. 2005); www.euroqol.org. The EuroQol5-D questionnaire records the participant's self-rated health on a scale from 0 (worst imaginable health) to 100 (the best imaginable health).

Four categories were created to describe change in hearing aid use: stable use, start using, quit using, and stable nonuse. Note that in the regression analyses, we ultimately used three categories of change in hearing aid use because the number of participants who quit using hearing aids was very small. These participants were added to the stable nonhearing aid use group (in concordance with Pronk et al. 2014). Hence, the categories in the analyses were stable use, start using, and nonuse.

Study Population

In total, 1546 participants completed the measurement round at T0, of whom 1433 were invited to participate in the 5-year follow-up measurement. Of the 914 participants who completed the NHT and the questionnaires at T1, we analyzed data from a total of 508 participants. Reasons for exclusion from the analyses were no unaided scores at T0 (136 participants), different transducers at T0 and T1 (237), used a cochlear implant at T1 (26), and outliers in SRTn scores (5). For two participants, no psychosocial health scores could be calculated because the number of missing values exceeded the limit.

Statistical Analyses

First, descriptive statistics (mean, SDs, and ranges) were calculated and described for each variable. The relationship between SRTn and psychosocial outcomes was analyzed in two ways. First, longitudinal linear regression analyses, that is, generalized estimating equations (GEE analyses; Twisk 2013), were performed to analyze the "average" relationship over time between SRTn and psychosocial outcomes. GEE analysis corrects for the dependency of the observations over time, which had to be taken into account as the NL-SH participants were measured twice. Advantages of GEE are that all available data at both T0 and T1 are included in the analysis and that the "within-subjects" and "between-subjects" relationships are analyzed simultaneously. The result of a GEE analysis is one regression coefficient (β) with a double interpretation in which both relationships are represented (Twisk 2013).

As the GEE analyses do not provide effect sizes (βs) for the within-subjects and between-subjects relationships separately, we continued our analysis by calculating the change scores between T1 and T0 for both SRTn and each psychosocial health outcome (e.g., ΔSRTn = $SRTn_{T1} - SRTn_{T0}$). For each psychosocial health outcome, linear regression analyses were used to determine whether the change in SRTn (determinant) was associated with the change in psychosocial health. As all distributions of the psychosocial health outcomes were skewed to the right, log transformations (ln [score + 1]) were performed to normalize the data. Note that in the "Results" section with the GEE analyses, the backward transformed regression coefficients and 95% confidence intervals (95% CIs) are reported to facilitate interpretation.

For all analyses, both unadjusted and adjusted regression coefficients (βs) and 95% CI were calculated. In addition, age (as a continuous variable), gender, educational level, marital status, living arrangement, chronic conditions, general health status, hearing aid use, and initial category of hearing ability were tested for their potentially modifying effect, by adding interaction terms separately to the model. As one could hypothesize that a deterioration in SRTn would affect psychosocial health only when a deterioration in SRTn took place, all analyses were completed in both the complete dataset (N = 508) and on a subset of participants who did not remain in the good SRTn category at T1 (N = 289). All statistical analyses were performed with SPSS, version 20.0.

RESULTS

Table 2 shows the demographic and health status characteristics of the present study sample at baseline. The mean age of the participants was 47 years (SD: 4 years, range 18 to 69 years). More women than men participated and there were more participants with a high level of education compared with those with a low level. The majority of the participants were married, and most of the participants lived with others. Having one or more chronic health conditions was reported by approximately 75% of the respondents.

Table 3 presents the changes in SRTn, psychosocial health outcomes, and other variables over a period of 5 years for the total group. Overall, significant increases were observed in the SRTn and social loneliness scores; general health status worsened significantly over time ($p < 0.05$).

Table 4 shows the results of the longitudinal relationship between SRTn and each of the psychosocial health outcomes, as determined by the GEE analyses. Poor hearing ability in noise was significantly associated with social and emotional loneliness (adjusted model 1 β for social loneliness: 0.02; 95% CI: 0.00 to 0.03; *p*: 0.028; and for emotional loneliness: 0.02; 95% CI: 0.00 to 0.03; *p*: 0.030). Note that each regression coefficient obtained with GEE analyses represents both the within-subject change and the between-subjects difference. For example, in social loneliness a change of 1 dB SNR within one participant was associated with a change of 0.02 points, while 1 dB SNR difference between participants was also associated with 0.02 points. Similarly, a model additionally adjusted for the influence of hearing aid use over time (entitled model 2) showed significant longitudinal associations between SRTn and social and emotional loneliness. Effect sizes remained the same by additional adjustment for hearing aid use over time. Hearing ability in noise was not longitudinally associated with distress, depression, anxiety, and somatization.

TABLE 2. Demographic and health status baseline characteristics of the present study sample (N = 508)

	Values at T0
	N (%)
Demographic variables	
Gender	
Men	186 (36.6)
Women	322 (63.4)
Age	
18–29 years	62 (12.2)
30–39 years	68 (13.4)
40–49 years	130 (25.6)
50–59 years	175 (34.4)
60–70 years	73 (14.4)
Educational level*	
Low	78 (15.4)
Mid	145 (28.6)
High	284 (56.0)
Living arrangement†	
Alone	110 (21.8)
With others	395 (78.2)
Marital status	
Not married	166 (32.7)
Married	342 (67.3)
Hearing and health status	
SRTn‡	
Good hearing status	275 (54.1)
Insufficient hearing status	133 (26.2)
Poor hearing status	100 (19.7)
Hearing aid use§	
Yes	77 (15.2)
No	428 (84.8)
Chronic health conditions	
None	130 (25.6)
One or more	378 (74.4)

*One missing value for educational level.
†Three missing values for living arrangement.
‡According to Smits et al. (2006), scores on the National Hearing test were categorized in three categories: good (SRTn > 5.5 dB), insufficient (−5.5 ≤ SRTn ≤ 2.8 dB), and poor hearing ability (SRTn > −2.8 dB).
§Three missing values for hearing aid use.
SRTn, speech-reception-threshold in noise; dB SNR: decibel signal to noise ratio.

Subgroup analyses showed that in participants with high educational level, a poorer SRTn was associated with social loneliness (Table 4): adjusted model 2 β: 0.03; 95% CI: 0.01 to 0.05; *p*: 0.005). Educational level was not a significant effect modifier in the relationships with any of the remaining psychosocial health outcomes. Also, none of the variables gender, age, chronic health conditions, general health status, marital status, living arrangement, and hearing aid use appeared to be significant modifiers in the relationships between hearing ability and any of the psychosocial outcomes.

As GEE analysis does not provide effect sizes (βs) for the within-subjects and between-subjects relationships separately, we continued our analyses by identifying the extent of the "within-subjects" effects with multiple linear regression analysis (Table 5). None of the associations in the total group (N = 508) were statistically significant. In the model relating hearing ability with social loneliness, interaction terms for educational level, change in hearing aid use, and change in marital

TABLE 3. Description of the change in hearing, psychosocial health status, and other variables over a 5-year period (N = 508)

Changes in Continuous Variables			T0		T1		Change Over 5 Years				
Variable Name	Range of Scale	Description of Scale	Mean	SD	Mean	SD	Mean Change	SD	% Change*	*p*	Range
SRTn	–10.4–+4 dB SNR	Best to worse ability	–5.08	3.16	–4.73	3.26	0.35	2.44	2.43	**0.001**	–9.40 to 8.20
Social loneliness	0–5 points	Less to most severe	1.67	1.78	1.87	1.75	0.20	1.62	4.00	**0.005**	–5.00 to 5.00
Emotional loneliness	0–6 points	Less to most severe	1.55	1.91	1.62	1.92	0.07	1.75	1.17	0.388	–6.00 to 6.00
Anxiety	0–23 points	Less to most severe	1.60	2.69	1.57	3.05	–0.03	2.88	0.13	0.830	–18.55 to 16.00
Depression	0–12 points	Less to most severe	0.97	2.19	0.91	2.09	–0.06	2.01	0.50	0.517	–9.00 to 12.00
Distress	0–32 points	Less to most severe	7.96	6.83	7.57	6.93	–0.40	6.46	0.12	0.168	–21.53 to 27.00
Somatization	0–30 points	Less to most severe	6.87	5.28	6.64	5.32	–0.22	4.47	0.73	0.260	–23.00 to 15.00
General health status	0–100 points	Worse to best imaginary	77.63	18.99	72.77	23.92	–5.28	25.54	5.28	**<0.001**	–92.00 to 90.00
Changes in Other Variables		Categories of Change						N	%	*p*	
Chronic health conditions		Stable none						68	13.4	**<0.001**	
		Increase						62	12.2		
		Decrease						53	10.4		
		Stable one or more						325	64.0		
Living arrangement		Stable living alone						90	17.8	**<0.001**	
		Started living with others						20	4.0		
		Started living alone						15	3.0		
		Stable living with others						380	75.2		
Marital status		Stably not married						141	27.8	**<0.001**	
		Entered into matrimony						25	4.9		
		Divorced						21	4.1		
		Stably married						321	63.2		
Use of hearing aid(s)		Stable nonuse						370	73.3	**<0.001**	
		Started to use						58	11.5		
		Quit using						5	1.0		
		Stable using						72	14.2		

Significant p values are bolded.
**% change was calculated by mean change/range of change.*
SRTn, speech-reception-threshold in noise; dB SNR: decibel signal to noise ratio.

TABLE 4. Results of GEE analyses of the longitudinal relationship between SRTn and psychosocial health outcomes

	Social Loneliness		Emotional Loneliness		Distress	
	β (95% CI)	*p*	β (95% CI)	*p*	β (95% CI)	*p*
Total sample (N = 508)						
Unadjusted model	0.02 (0.00 to 0.03)	**0.011**	0.02 (0.01 to 0.04)	**0.003**	0.02 (–0.00 to 0.03)	0.087
Adjusted model 1	0.02 (0.00 to 0.03)	**0.028**	0.02 (0.00 to 0.03)	**0.030**	0.00 (–0.02 to 0.02)	0.783
Adjusted model 2	0.02 (0.00 to 0.03)	**0.025**	0.02 (0.00 to 0.03)	**0.032**	0.01 (–0.01 to 0.03)	0.428
Adjusted model 2						
Low educational level	–0.00 (–0.04 to 0.04)	0.944				
Mid educational level	0.01 (–0.03 to 0.04)	0.715				
High educational level	0.03 (0.01 to 0.05)	**0.005**				
	Depression		Anxiety		Somatization	
	β (95% CI)	*p*	β (95% CI)	*p*	β (95% CI)	*p*
Total sample (N = 508)						
Unadjusted model	0.02 (0.00 to 0.03)	**0.031**	0.02 (0.01 to 0.04)	**0.004**	0.01 (–0.00 to 0.03)	0.118
Adjusted model 1	0.01 (–0.00 to 0.02)	0.203	0.01 (–0.00 to 0.03)	0.073	–0.02 (–0.02 to 0.01)	0.438
Adjusted model 2	0.01 (–0.01 to 0.03)	0.198	0.01 (–0.00 to 0.03)	0.138	0.00 (–0.01 to 0.21)	0.573

Significant p values are bolded

The following variables were included as covariates in the adjusted models 1: gender, age, educational level, chronic health conditions, general health status, marital status, and living arrangement. Hearing aid use was additionally included in the adjusted models 2. All these factors, plus SRTn score at T0, were also tested as potential effect modifiers. Results were stratified for subgroups in case of a significant interaction term ($p < 0.05$), and these subgroups are shown in the table.

CI, confidence interval; GEE, generalized estimating equations; SRTn, speech-reception-threshold in noise.

status were found to be significant ($p < 0.05$). However, after adjustment for all covariates, only a few associations remained significant. In the subgroups of participants with stable nonuse of hearing aids or those who entered into matrimony, a decline in hearing ability was significantly associated with an increase in both emotional and social loneliness.

Table 5 also shows the results of analyses in the subset of 289 participants whose hearing ability declined over 5 years. Again, none of the associations was statistically significant. Of the tested interaction terms, educational level, marital status, baseline SRTn category, and change in general health status were statistically significant in the relationship with social loneliness. However, after adjustment for all covariates, a significant subgroup effect was only found in those participants who had a low educational level at T0 (adjusted model 2 β: −0.16; 95% CI: −0.31 to 0.01; *p*: 0.041) or those who entered into matrimony (unadjusted β: 0.41; 95% CI: −0.11 to 0.71; *p*: 0.013).

DISCUSSION

The present study investigated the longitudinal relationships between hearing status and a range of psychosocial health parameters. Over the 5-year study period, poorer hearing ability in noise in adults aged 18 to 70 years was significantly associated with both social and emotional loneliness, but not with anxiety, depression, distress, and somatization. The finding that hearing and loneliness are longitudinally related is in agreement with the results of previous prospective studies (Strawbridge et al. 2000; Wallhagen et al. 2001; Pronk et al. 2011).

The within-subjects change in hearing ability in noise, measured at baseline and at 5-year follow-up (Table 5), was not significantly associated with a change in the psychosocial health parameters over the same period, except for some subgroup effects for educational level, marital status, and hearing aid use in the relationships with social and emotional loneliness. Poorer hearing ability over 5 years was associated with an increase in social loneliness over the same period only for higher-educated participants. In the additional analyses in participants with declining hearing ability over time (Table 5, N = 289), a weaker impact of hearing impairment on social loneliness for people with a lower educational level was found. Previously, a subgroup effect for medium to high educational levels was reported in a population-based sample of older adults (Pronk et al. 2011), but in the publication about rate of change in hearing ability and rate of change in loneliness, a subgroup effect for education was not reported (Pronk et al. 2014). It may be that the change scores did not reach statistical significance due to the size of the random measurement error compared with the small systematic changes over time.

For participants who entered into matrimony over the 5-year period, a significant association was found between a decline in hearing ability and increased feelings of social loneliness. A study reported that the degree of self-reported hearing capacity in older adults is important for the start of new relationships (Broese van Groenou et al. 2013). For those participants who entered into matrimony with declining hearing ability, it could be that additional relationships had to be started, or a different social role had to be developed, resulting in lower feelings of being socially embedded. However, in the Netherlands, it is common for couples to live together before they get married. It is questionable whether their daily lives, including friendships and family relationships, will change much after officialising their relationship by marriage. It must be noted, however, that the number of participants who entered matrimony was small (N = 25), and the average changes in the psychosocial health outcomes were minimal. Nevertheless, the effect appeared to be significant. It deserves to be further investigated in future research.

Previous research suggested that the uptake of hearing aids may have a beneficial effect on well-being (e.g., Arlinger 2003; Pronk et al. 2011). In our analyses, a significant increase in social and emotional loneliness with decreasing hearing

TABLE 5. Results of multiple linear regression analyses between change scores in SRTn and change scores in psychosocial health

	Δ Social Loneliness$_{T1-T0}$		Δ Emotional Loneliness$_{T1-T0}$		Δ Distress$_{T1-T0}$	
	β (95% CI)	*p*	β (95% CI)	*p*	β (95% CI)	*p*
Total sample (N = 508)						
Unadjusted model	0.04 (–0.02 to 0.10)	0.183	0.04 (–0.02 to 0.10)	0.222	0.12 (–0.11 to 0.35)	0.291
Adjusted model 1	0.04 (–0.02 to 0.09)	0.234	0.04 (–0.02 to 0.10)	0.209	0.12 (–0.10 to 0.35)	0.289
Adjusted model 2	0.04 (–0.02 to 0.10)	0.233	0.04 (–0.03 to 0.10)	0.245	0.11 (–0.12 to 0.34)	0.337
Adjusted model 1						
Stable nonuse hearing aid(s)	0.09 (0.02 to 0.16)	**0.017**	0.08 (0.01 to 0.16)	**0.037**		
Stable use hearing aid(s)	–0.10 (–0.26 to 0.06)	0.216	–0.02 (–0.19 to 0.15)	0.821		
Started to use hearing aid(s)	–0.01 (–0.16 to 0.13)	0.848	–0.10 (–0.23 to 0.03)	0.137		
Adjusted model 2						
Stably not married	–0.06 (–0.19 to 0.07)	0.356				
Entered into matrimony	0.50 (0.22 to 0.78)	**0.002**				
Divorced	–0.32 (–1.31 to 0.67)	0.462				
Stably married	0.03 (–0.04 to 0.11)	0.370				
Sub sample (N = 289)						
Unadjusted model	0.01 (–0.05 to 0.08)	0.664	0.02 (–0.05 to 0.09)	0.520	0.08 (–0.19 to 0.35)	0.558
Adjusted model 1	0.01 (–0.05 to 0.07)	0.733	0.02 (–0.05 to 0.08)	0.653	0.06 (–0.21 to 0.32)	0.678
Adjusted model 2	0.01 (–0.06 to 0.07)	0.817	0.01 (–0.06 to 0.08)	0.745	0.03 (–0.23 to 0.29)	0.821
Unadjusted model*						
Stably not married	–0.10 (–0.23 to 0.03)	0.127				
Entered into matrimony	0.41 (–0.11 to 0.71)	**0.013**				
Divorced	0.02 (–0.39 to 0.43)	0.918				
Stably married	0.02 (–0.06 to 0.09)	0.679				
Adjusted model 2						
Low educational level	–0.16 (–0.31 to 0.01)	**0.041**				
Mid educational level	0.05 (–0.09 to 0.20)	0.467				
High educational level	0.03 (–0.06 to 0.11)	0.529				

	Δ Depression$_{T1-T0}$		Δ Anxiety$_{T1-T0}$		Δ Somatization$_{T1-T0}$	
	β (95% CI)	*p*	β (95% CI)	*P*	β (95% CI)	*P*
Total sample (N = 508)						
Unadjusted model	0.04 (–0.03 to 0.11)	0.276	0.01 (–0.09 to 0.11)	0.857	0.02 (–0.14 to 0.18)	0.837
Adjusted model 1	0.04 (–0.03 to 0.11)	0.267	0.01 (–0.09 to 0.12)	0.808	–0.00 (–0.16 to 0.16)	0.987
Adjusted model 2	0.04 (–0.03 to 0.11)	0.303	–0.00 (–0.11 to 0.10)	0.957	–0.01 (–0.17 to 0.15)	0.901
Sub sample (N = 289)						
Unadjusted model	0.04 (–0.04 to 0.13)	0.322	0.02 (–0.11 to 0.14)	0.812	0.01 (–0.18 to 0.20)	0.919
Adjusted model 1	0.04 (–0.05 to 0.12)	0.388	0.00 (–0.12 to 0.13)	0.942	–0.01 (–0.20 to 0.18)	0.916
Adjusted model 2	0.03 (–0.05 to 0.12)	0.456	–0.01 (–0.14 to 0.12)	0.856	–0.02 (–0.21 to 0.16)	0.793

Significant p values are bolded.

The following variables were included as covariates in the adjusted models 1: gender, age, and educational level at T0 and the changes in chronic health conditions, general health status, marital status, and living arrangement. In the adjusted models 2, change in hearing aid use was additionally included as a variable with three categories (stable use [including those small group of participants who quit using]; started to use; and stable nonuse). All these factors, plus SRTn score at T0, were also tested as potential effect modifiers. Subgroup effects were reported in case of a significant interaction term ($p < 0.05$) and when the subsequent association between change in SRTn and psychosocial outcome was statistically significant ($p < 0.05$).

**Because of a too limited number of participants in some of the subgroups, the adjusted models could not be performed.*

CI, confidence interval; SRTn, speech-reception-threshold in noise.

ability appeared for a subgroup of stable nonusers. In contrast, in the group of participants who started to use hearing aids, their change in hearing ability was not significantly associated with changes in social and emotional loneliness. These results seem to indicate that hearing aid use may help prevent a further increase in loneliness in individuals with hearing impairment, but further investigation is needed to prove these findings.

Besides hearing aid use, educational level and marital status, none of the other potential effect modifiers appeared to be significant in the models. In previous studies, some other subgroups of participants were identified as being prone to loneliness. For instance, an adverse loneliness effect in women was reported (Chen 1994). A subgroup effect for men was observed in the relationship between SRTn and emotional loneliness in another study (Pronk et al. 2011). However, in the present study, interaction terms for gender were not found to be statistically significant for any of the psychosocial health outcomes. Neither were subgroups found at risk for loneliness with regard to age, chronic conditions, general health status, and living arrangement. As changes in, for instance, marital status or living arrangement were not frequently reported by the participants, it should be noted that insufficient power of the data may have weakened the possibility for some interactions to appear. We therefore recommend that potential effect modifiers and mediators be included in future longitudinal studies investigating the impact of hearing on psychosocial health, as more evidence is needed to claim subgroup effects.

Some previous studies reported finding a significant relationship between hearing and depression (e.g., Wallhagen et al. 1996; Strawbridge et al. 2000), but others did not (Chou 2008; Pronk et al. 2011, 2014). In the present study, we found no longitudinal relationships between hearing status and depression. It should be noted that we measured depressive feelings, not depression, unlike the other studies. Also, there is evidence showing that feelings of depression fluctuate (Beekman et al. 2002). It may be that depressive feelings occur shortly after experiencing hearing decline, but may diminish over time due to successful coping efforts. These kind of effects are challenging to investigate in epidemiological studies, and may explain why only some studies found relationships between hearing problems and depression.

Strengths and Limitations

The present study is one of the first longitudinal studies in adults examining the decline in hearing and the associated psychosocial consequences in adults over a large age range. However, there are limitations to this study that need to be taken into account when interpreting the results. First, the measurement error in the change in hearing ability in noise may have affected our findings. The measurement error of the NHT was found to be approximately 1 dB (Smits & Houtgast 2005), limiting the sensitivity of the test to detect small changes in hearing. In addition, NHT does not measure all aspects of speech recognition in daily life, but primarily auditory aspects (bottom-up factors). Second, the average changes in the psychosocial health outcomes were found to be minimal. It may be that that the negative effects actually do not occur across time for the total group (but for subgroups only, as noted above), but it is also plausible that the assessment tools were not sensitive enough to measure subtle changes in psychosocial health across time. In case of the latter, refinement of assessment tools needs to be addressed in future research. Yet another explanation may be related to social desirability when answering the NL-SH questionnaire. This may have caused an underestimation in the change in psychosocial functioning over time. However, as the NL-SH study is a web-based study, it can be expected that the phenomenon of social desirability played only a minor role. Participants completed the questionnaire unsupervised, most likely at home at their own pace. Third, NL-SH participants did not belong to a clinical sample of people with psychosocial health problems. This can explain why the baseline symptomatology of psychosocial problems was low compared with other studies. As it is likely that adults with severe depression or loneliness chose not to participate in such a study (Bhopal 2002), some selection bias may have occurred. Finally, the current results do not give an answer to the questions how long it takes before psychosocial problems start to develop with a deteriorating hearing or whether hearing problems are a cause of loneliness. We therefore cannot prove directionality of the results. These kind of topics need further investigation in future studies.

CONCLUSIONS

This study showed that hearing ability in noise is associated with an increase of loneliness over 5 years in subgroups of adults, ranging in age between 18 and 70 years. The subgroups comprised participants with higher educational level, those who entered into matrimony, and those with stable pattern of hearing aid nonuse. Emotional and social loneliness increased in participants whose hearing deteriorated over 5 years, but who did not report using hearing aids at the two measurement points. No significant longitudinal associations were found between hearing ability and anxiety, depression, distress, or somatization. For all variables included in this study, changes over the 5-year interval appeared to be small. The current findings call for studies with longer follow-up intervals with more frequent measurement moments to obtain further insights into the longitudinal relationships between hearing ability, psychosocial health, and hearing aid use.

ACKNOWLEDGMENTS

The authors thank the participants of the NL-SH study. The authors also thank the assistance of Hans van Beek in managing the database and developing and maintaining the study website.

The first measurement round of the NL-SH study was financially supported by the Heinsius Houbolt Foundation, The Netherlands. Phonak AG, Switzerland supported the second measurement round. A research visit by the first author to Phonak AG in Switzerland was supported by the EMGO Institute for Health and Care Research Travel grant.

The authors have no conflicts of interest to disclose.

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Received November 4, 2014; accepted April 8, 2016.

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