General discussion
OUTLINE

The aims of the research described in this thesis were to provide insight into the determinants of hearing loss in older persons (Chapter 2), the psychosocial consequences of hearing loss in older persons (Chapters 3 and 4), the aspects relevant to adults’ functioning and disability with hearing loss (Chapter 5), and possible interventions following adult hearing screening (Chapter 6). In the current Chapter, the main findings of the whole thesis will be discussed and placed into context, followed by methodological considerations and implications for future research and clinical practice.

MAIN FINDINGS

The main epidemiological findings of this thesis are depicted in Figure 1.

Factors influencing older adults’ declining ability to recognize speech in noise

In Chapter 2 the relevant determinants of adults’ declining ability to recognize speech in noise were studied. Speech-reception-threshold-in-noise (SRT) data and data of the potential determinants originated from 1298 older persons (57-93 years old) from the general population and covered three to seven years of follow-up. Firstly, the multilevel
models showed that, on average, older persons’ SRT increased (i.e., deteriorated) by 0.18 decibel (dB) per annum. This rate was faster in relatively older groups (notably 75 years and over). Secondly, the models revealed that older persons’ decline in information processing speed relevantly influenced their decline in speech-in-noise recognition over time. This finding is depicted in the left part of Figure 1. Eighteen percent of the increase in SRT was influenced by decline in information processing speed. None of the other factors (i.e., fluid intelligence, global cognitive functioning, cardiovascular comorbidity, alcohol use, smoking, baseline age, level of education, gender) relevantly influenced older persons’ decline in speech-in-noise recognition.

**Adverse effects of hearing loss on older adults’ psychosocial health**

In the studies presented in Chapters 3 and 4, the longitudinal associations between hearing status and psychosocial health were examined in a large population-based sample of older adults. In Chapter 3 the main determinants were baseline self-reported (SR) hearing status and speech-in-noise test (SNT) hearing status. The psychosocial outcomes included four year follow-up depression, social loneliness, and emotional loneliness. In addition, the modifying effects of various demographic factors, health-related factors, and that of cognition were explored. After adjusting for baseline psychosocial health, age, gender, hearing aid use, and other relevant confounders, the linear regression models showed significant associations between higher (i.e., worse) hearing status scores and higher (i.e., worse) social and emotional loneliness scores. However, these associations were confined to specific subgroups:

- men (emotional loneliness)
- those living with a partner (social and emotional loneliness)
- those without cardiovascular conditions (emotional loneliness)
- those with one or more chronic diseases (emotional loneliness)
- those with a higher level of education (social and emotional loneliness)
- those with a higher level of income (social loneliness)
- non-hearing aid users (social loneliness and borderline significance for emotional loneliness).

These effects were absent in their counterpart groups (i.e., women, those living without a partner, etcetera). Some of these effects were only significant for one of the hearing measures. Generally, the effect sizes were relatively modest. No effects were found on depression. The effect of poor hearing status on loneliness and the modifying effects of the various factors are displayed in the upper right part of Figure 1.
Chapter 4 shows the findings of the investigation of the association between the rate of decline in older adults’ ability to recognize speech in noise and the rate of decrease in psychosocial health. Again, effect modification by various demographic factors, health-related factors, cognition, and by baseline SRT was explored. The associations were examined using SNT data and psychosocial health data of 1178 older persons (57-97 years) originating from the general population, covering a period of three to seven years of follow-up. Psychosocial health included social loneliness, emotional loneliness, depression, and anxiety. Difference scores were calculated between the three subsequent measurements (i.e., T2-T1; T3-T2) for the SRT and the psychosocial outcomes and their associations were examined in multilevel models. All models were corrected for age, gender, change in hearing aid use, and relevant confounders. A faster increase (i.e., deterioration) in SRT was significantly associated with more increase in loneliness, but only for:

- those with a moderate baseline hearing status (social and emotional loneliness)
- those who recently lost their partner (emotional loneliness).

These effects were absent in their counterpart groups (i.e., those with a good or poor hearing status, those with a stable partner status). No effects appeared on depression and anxiety. The significant adverse loneliness effects are depicted in the lower right part of Figure 1.

**Functioning and disability in hearing loss from the patient perspective**

In Chapter 5 we investigated the relevant factors involved in adults’ functioning with hearing loss. These factors were mapped using the International Classification of Functioning, Disability and Health (ICF; World Health Organization 2001). Focus-group data and individual-interview data of 36 Dutch and South-African adults with hearing loss were collected, transcribed verbatim, and analyzed using qualitative content analyses and ICF linking according to preset rules. In total, 145 unique ICF categories were identified from 2508 meaning units (i.e., transcript fragments with a clear common topic). In addition, various Personal factors were identified as playing a role in functioning and disability. Most of the ICF categories concerned activities and involvement in life situations that were affected by hearing loss (i.e., the ICF Activity & Participation component, as well as factors outside the informants that influenced these (i.e., the ICF Environmental factors component). 34% and 33% of all identified categories belonged to these components, respectively. Fewer categories related to descriptions of Body functions and Body structures involved in hearing loss (27% and 6%, respectively). The majority of the categories that were recognized directly or indirectly referred to Activities & Participation,
and to *Environmental factors* relevant for oral communication (e.g., conversation, remunerative employment, instrumental aids, quality of environmental sound). Many of the other *Environmental factors* that were recognized belonged to the ICF Chapters on support and relationships, and on attitudes and behaviours of others. The relevance of the latter two was also reflected in certain *Personal factors* that were identified. Such *Personal factors* included coping with hearing loss and personal attitudes towards hearing loss. More specifically, these often concerned the acceptance of hearing loss, openness about hearing loss, and hearing loss stigma. Lastly, relevant *Body functions* related to negative emotions and to the low ‘energy level’ that many informants experienced as a result of the extra effort they had to make to understand speech. The findings illustrate the widespread impact of hearing loss on various aspects of adults’ lives. Because hearing loss clearly affects communication to a great extent, the social disabling effect is evident. However, as communication and hearing in more general terms is required for numerous basic activities, many more aspects of functioning can be affected. In addition, the findings stress the potential importance of physical consequences of hearing loss, which, in turn, affect functioning, such as with fatigue.

**Interventions following hearing screening in adults**

The systematic literature review presented in Chapter 6 describes the various interventions that have been offered to adults who were found positive for hearing loss as part of a hearing screening procedure. A special focus was on identifying alternative interventions, i.e., interventions other than hearing aid fitting. In total, 37 studies were found that described an adult hearing screening program conducted in a general adult population, and thus were included in the review. Data extraction revealed that most (26) of the screening programs referred screen-positives to a hearing specialist without further rehabilitation being standardized within the screening program. Most of the others (7) led to a particular hearing aid rehabilitation program. Four studies offered interventions comprising communication program elements (e.g., speech reading, hearing tactics) or advice on environmental aids. In conclusion, only some of the hearing screening programs performed thus far offered other rehabilitation options as an addition to, or as an alternative to hearing aid fitting. Most included a referral to a hearing specialist or comprised the immediate provision and fitting of hearing aids. Alternatives interventions like communication programs may be valuable as an addition to or as a replacement of hearing aid fitting, but this requires further research.
CHAPTER 7

METHODOLOGICAL CONSIDERATIONS

Use of data from the Longitudinal Aging Study Amsterdam (LASA)

All the epidemiological data used for this thesis were derived from the LASA cohort. The use of longitudinal data from a population-based cohort study such as LASA has major strengths but also holds a number of potential weaknesses. Both will be discussed below.

Longitudinal design

An important strength of using LASA data is that they allow the examination of associations using a longitudinal design that covers multiple years of follow-up. As such, the natural course of hearing loss, its determinants, and its psychosocial consequences could be studied over time. More specifically, the data allowed us to model change in determinants of hearing loss (Chapter 2), consequences of hearing loss, (Chapter 3 and 4), and change in hearing loss itself (Chapters 2 and 4). Further, the data allowed us to ascertain that the exposure preceded the outcome in Chapter 3. This temporality criterion is important for evidencing causality (Evans, 1995). In addition, in Chapter 3 the longitudinal design allowed us to correct for the possible bias of a cross-sectional association between self-reported hearing and psychosocial health. This could occur when a person with poor psychosocial health has a more negative view of their hearing status because of that, as compared to a person with better psychosocial health (Lee et al., 2010; Tambs, 2004).

Further, the data allowed us to study the psychosocial consequences associated with the rate of hearing decline (Chapter 4). We used a sophisticated longitudinal technique, i.e., multilevel analysis to investigate this (Goldstein, 1995). When using normal scores (i.e., no difference scores) in a multilevel model, the regression coefficient reflects both the intra-individual and inter-individual association (Twisk, 2003). Applied to our determinant and outcomes, the intra-individual association would reflect that persons who decline faster in their hearing status deteriorate more in their psychosocial health than persons whose hearing status declines at a slower pace. The inter-individual association would reflect that persons with poorer hearing status have poorer psychosocial health than persons with better hearing status. When normal scores are used, the contribution of each effect (i.e., the intra- and inter-individuals effect) cannot be determined. However, because in Chapter 4, we calculated difference scores in our statistical models, we were able to filter out the association of interest: the one based on differences within individuals.

The LASA data further allowed us to also include potential confounders and effect modifiers longitudinally in the statistical models (Chapter 4). This is important, as in old
Sample

Another strength of using LASA data is that the data were collected in a population-based sample. This increases the external validity of the findings (Evans 1995) in terms of extrapolation to the general older population. It does bring us to a first possible limitation of using cohort data. An inevitable phenomenon in longitudinal studies, especially among older persons, is loss to follow-up. This is not a problem per se, but becomes worrisome when it occurs selectively. Huisman et al. (2011) investigated attrition in the original LASA cohort over seventeen years of follow-up. They found that attrition due to mortality, refusal, frailty, or inability to contact the respondent occurred significantly more often in relatively older respondents, in those with more chronic diseases, and in those with cognitive impairment. Unfortunately, also in all LASA subsamples that were used in this thesis, attrition was selective. Drop-outs were generally older, had poorer hearing, and had poorer psychosocial health. This may have weakened the relationships between hearing loss and loneliness, and between hearing loss and cognition. Next, it may have contributed to the non-significance of some of the relationships, such as that between hearing loss and depression. However, we did use a sophisticated longitudinal technique (multilevel analysis) in Chapters 2 and 4, which has the important advantage of optimal data use. Respondents are allowed to have a different number of repeated measurements and are not excluded in case of one or more missing values. Twisk & De Vente (2002) found that using such techniques makes imputation of missing data unnecessary in the case of continuous outcome measures. As we used continuous outcome measures only, the use of the multilevel analysis technique may have reduced the risk of underestimating the associations to some extent.
Follow-up interval and time lag

Another potential disadvantage of using longitudinal cohort data is that the follow-up measurements occur at set intervals, i.e., three or four years in LASA, while a shorter follow-up may have been more desirable. Ideally, the interval between the exposure and the outcome is chosen such that it reflects the time frame that is necessary for the event to establish given its natural course (Bouter & Van Dongen, 2000, pp. 118). In the case of Chapter 2 it may be argued that a shorter follow-up was not necessarily required, as the main constructs of interest (i.e., age-related hearing and cognition loss) generally decline at a slow pace. Accordingly, this decline may only become detectable after a period of several years. For hearing, this is clear from the small average increase in SRT per annum observed in Chapter 2 (i.e., 0.18 dB). For cognition, this is supported by findings of Dik et al. (2000), who found rather small and steady deteriorations over time in general cognitive functioning (MMSE score: decreased 0.8-1.7 points across six years) and in information processing speed (Coding Task score: decreased 1.5-3.1 points across six years). In Chapter 3 however, the focus was on the effects of baseline hearing status on follow-up psychosocial health. It was already suggested in the discussion of the Chapter that the four-year follow-up period was perhaps too long for a depression effect to last. As depression often has a fluctuating course (Beekman et al., 2002), the hearing loss may have been adapted to during this time period. A closer look into longitudinal studies which also incorporated a time lag in their models reveals the use of various follow-up times. Strawbridge et al. (2000), Chou (2008), Saito et al. (2010), and Wallhagen et al. (1996) investigated the effects of baseline self-reported hearing status on 1-year, 2-year, 3-year, and 6-year follow-up loneliness and depression measures (Strawbridge et al., 2000; Wallhagen et al., 1996) or depression measures only (Chou, 2008; Saito et al., 2010). When considering the depression effects, there does not seem to be a clear trend: the mixed findings remain reflected across the various follow-up times. For the studies investigating loneliness, only the long, 6-year follow-up study by Wallhagen et al. (1996) failed to find significant effects. However, they did find significant adverse effects on other outcomes of social functioning. These were the single-item outcomes `not feeling close to others` and `feeling left out even in a group`. They appear to be closely related to loneliness. So, for loneliness, adverse effects of hearing loss seem to emerge, even when long follow-up periods covering multiple years are used.

Another potential limitation to applying a time-lag design is that hearing status at follow-up, i.e., at the time of the psychosocial health measurement, is not considered in the statistical model. Hearing status at follow-up could influence follow-up psychosocial health cross-sectionally, and this is not modelled. In addition, as baseline hearing status is used as a determinant, the findings do not allow any conclusions to be drawn about the
effects that are associated with aggravating hearing loss, adaptation to hearing loss, and about the effects associated with the rate of hearing decline. Especially the latter caveat was addressed in Chapter 4. The results showed that the rate of hearing decline indeed is a significant determinant of loneliness increase (for persons with an already insufficient hearing status and for persons who recently lost their partner). Further, Chapter 4 provided possible explanations for the interaction by baseline SRT based on theory on coping and adaptation mechanisms. Hereby, some insight into the other caveats mentioned was provided (i.e., effects associated with aggravating hearing loss and adaptation to hearing loss).

As was described in Chapter 4, no time lag was incorporated into the models. In other words, the change scores of the SRT and those of the psychosocial health outcomes were considered for the same periods and were analyzed as such. Therefore, it cannot be assumed that the hearing loss preceded the decrease in psychosocial health, and thus strictly, we could not evidence the direction of the causal relationship (Evans, 1995). This was already shortly touched upon in the discussion of Chapter 4, but is discussed further in the current Chapter under ‘Future research and implications’.

**Subgroup-specific effects: Partner status**

One subgroup effect observed in Chapter 4 may question the robustness of one of the subgroup effects of Chapter 3. In Chapter 3 we found that a poor baseline hearing status caused increased emotional loneliness at follow-up in persons living with a partner in the household, while Chapter 4 showed that hearing loss caused increased emotional loneliness in persons who recently lost their partner. Could the effect on emotional loneliness found for those living with a partner in fact be (partly) explained by the hearing loss experienced by those who lost their partner between baseline and 4-year follow-up? In total, 63 out of the 598 respondents who lived with a partner at baseline had lost their partner by the time of the four-year follow-up. In an additional, exploratory analysis (not shown in any of the previous Chapters) we excluded these 63 respondents and re-ran the analysis. The relationship remained significant and did not weaken; it increased in strength marginally ($B_{SR \text{ hearing status}}=0.019$, $p=0.034$; instead of the initial $B_{SR \text{ hearing status}}=0.017$, $p=0.044$). In conclusion, partner loss did not explain the subgroup effect found for those living with a partner and the subgroup effect for those living with a partner thus appears robust.

Nonetheless, it seems important to remain critical of prior research findings in the light of new findings. One should consider whether new findings ‘point in the same direction’ and
seemingly opposing effects should be investigated further. Longitudinal data analysis can be an important tool for this.

**Speech-in-noise test as a measure of objective hearing status**

In all epidemiological studies of this thesis, we used a SNT to measure hearing status. A major strength of using such a test is that it holds high face validity. A lot of everyday communication occurs in the presence of background sounds (music, voices, traffic) and problems with understanding speech in noisy environments is a primary complaint in hearing-impaired persons (Kramer et al., 1998; Stark & Hickson, 2004). A limitation of a SNT is that it does not detect early high frequency hearing losses, impaired sound localization, or middle ear problems (Smits et al., 2004; Smits & Houtgast, 2005). Regarding the latter, the studied samples probably included some respondents with conductive hearing loss who scored well on the test while they did experience problems in daily life. However, it could be argued that most of hearing loss cases were captured by the SNT as the majority of the hearing loss cases in older adults concern sensorineural hearing loss (Gates & Mills, 2005). Another limitation is that the SNT’s precision (i.e., measurement error of around 1 dB; Smits & Houtgast, 2005) may have been limited relative to the change in speech-in-noise recognition over time that occurred within respondents. This could have particularly obscured the associations under study in Chapter 4, as the measurement error was expressed twice because of the use of difference scores. An additionally complicating factor is that the measurement error is somewhat larger in higher (worse) SRT scores (Smits & Houtgast, 2005). Consequently, imprecise SRT measurement could have masked a significant loneliness effect in those with poor baseline SRT scores in Chapter 4.

**Hearing loss affects loneliness, but not depression and anxiety?**

This thesis covers four psychosocial health outcomes: depression, social loneliness, emotional loneliness, and anxiety. The quotations by Harry, Anne, Susannah, and Jake at beginning of Chapter 1 of this thesis suggest that significant effects may be expected on all four outcomes. However, we found significant adverse effects on the loneliness measures only. Most prior longitudinal studies did find significant associations with depression (Saito et al., 2010; Strawbridge et al., 2000; Wallhagen et al., 1996). Two prior studies found a significant relationship with anxiety, although both applied a cross-sectional design and did not correct for potential confounders (Eriksson-Mangold & Carlsson, 1991; Tambs, 2004). Further, the study by Eriksson-Mangold & Carlsson (1991) did not concern a
population-based sample, and the effect found by Tambs (2004) was small. Throughout the Chapters of this thesis, various methodological limitations have been suggested to explain the absent effects on depression and anxiety. However, it could also be due to a different reason: hearing loss may not necessarily affect generic, psychosocial outcomes so much, but may predominantly affect psychosocial outcomes, i.e., loneliness. Another possible explanation relates to the communication-oriented hearing measures that were used in this thesis. Both explanations will be discussed below.

**Psychosocial health**

All the psychosocial constructs investigated in this thesis can be viewed as forms of negative emotions and research has shown that fear, loneliness, and sadness are closely related (Shaver et al., 1987). Some researchers even suggested that loneliness and depression are both forms of sadness or unhappiness, with depression being broader in scope (Shaver & Brennan, 1991). As an example, the depression scale (CES-D) used in our studies holds an item asking if the respondent felt lonely during the past week. However, recent research showed that loneliness and depression are distinct and separable constructs (Cacioppo et al., 2006a;b). Following this line of thought, in our samples, hearing loss may predominantly have affected the social component of respondents’ health: loneliness. Further, research has shown that the relationship between depression and loneliness is reciprocal: depressive symptoms predict feelings of loneliness, and simultaneously, feelings of loneliness predict depressive symptoms (Cacioppo et al., 2006b). This suggests that loneliness resulting from hearing loss could indirectly contribute to increased depressed mood. However, this was not examined in the current thesis and may be addressed in future research.

The anxiety measure used in Chapter 4, the HADS-A, measures generic anxiety (Zigmond & Snaith, 1983). It does not contain items specifically referring to social anxiety but rather includes items like ‘I get a sort of frightened feeling as if something awful is about to happen lately’, and ‘I feel tense or wound up lately’. It could be that particularly social anxiety is induced by hearing loss, as is also reflected in Susannah’s excerpt in Chapter 1. Eriksson-Mangold & Carlsson (1991) investigated the relationship between hearing handicap and anxiety in older adults with mild-to-moderate hearing impairment. They found a significant relationship with generic and phobic anxiety, although the analyses were not corrected for possible confounders. Inspection of the phobic anxiety findings on item level showed that hearing-impaired persons were afraid to travel, felt uneasy in crowds, felt that they had to avoid places, and felt nervous when left alone more often. Except for the latter, these findings indeed suggest that anxiety in hearing-impaired adults
particularly concerns fear associated with anticipated communication problems in social settings.

**Communication-oriented hearing measures**

Both hearing measures used in this thesis (i.e., the SNT and the self-reported hearing measure) reflected speech perception difficulties. However, as may also be inferred from the focus groups findings of Chapter 5, depressed mood or anxiety could result from various activity limitations and participation restrictions that do not explicitly involve live face-to-face communication. Further, the self-report measure used in this thesis did not explicitly assess experienced participation restrictions, nor were emotional reactions due to hearing loss directly measured. These aspects of disability may have been expressed better if a different self-report measure had been available instead.

With regard to non-communication disabilities leading to depressed mood, examples could relate to reduced enjoyment of music or theatre during leisure or hobby. It could even concern reduced enjoyment of sound in itself. A different activity limitation that may contribute to depressed mood relates to problems watching TV. Problems watching TV or listening to the radio are reported very frequently by older hearing-impaired persons (Stark & Hickson, 2004). This is not surprising, given that watching TV is the activity occupying most of older adults’ leisure time (Horgas et al., 1998). Effects on depressed mood could therefore be substantial. Depressed mood through hearing loss may also stem from the notion of ‘getting old’ (Wallhagen, 2010) and the experience of loss of physical function in general. The latter can be accompanied by grief and associated emotions of anger, denial, sadness, or frustration (Brennan & Bally, 2007). In summary, these aspects of hearing disability may not have been strongly reflected in the current thesis’ hearing measures, subsequently hampering significant associations with depressed mood.

With regard to disabilities leading to anxiety, examples could relate to environmental sounds. It is known that age-related hearing loss causes difficulty identifying and distinguishing between environmental sounds. These are sounds which persons have come to rely on, and their impaired perception can therefore affect safety and security as well as daily life functioning (Brennan & Bally, 2007). With regard to safety and security, relevant environmental sounds can include warning sounds such as alarms, smoke detectors, sirens, fast moving vehicles and other traffic noise, cracking tree limbs, and growling dogs. Difficulties perceiving such sounds also became apparent from the discussions in the focus group study (Chapter 5), especially with regard to the problems this caused for participating in traffic (e.g., riding a bicycle in busy traffic). With regard to activities of daily life functioning, several studies found a significant association between
hearing loss and limitations in activities of daily living (e.g., Gopinath et al., 2012a). This included mobility items such as being able to walk across a small room and getting to places of walking distance. It is assumed that these relationships can be partly explained by impaired postural balance associated with hearing loss and subsequent (fear of) falling (Viljanen et al., 2009a;b). However, it is also expected that it is the decreased environmental acoustic information available that emerges as uncertainty and subsequent impaired functioning in mobility (Dargent-Molina et al., 1996; Gopinath et al., 2012a; Viljanen et al., 2009a). So, as problems in localization of sound and associated disability were not measured by the hearing measures of the current thesis, this could have added to the non-significant association with anxiety to some extent.

There are indications that self-report measures of hearing disability (or: ‘handicap’) may be most sensitive to predicting poor psychosocial health. Two studies compared the ‘predictive’ power for psychosocial health of an objective hearing measure (i.e., pure tone average), and of a self-reported hearing measure (Lee et al., 2010; Tambs, 2004). Tambs (2004) found better predictive power for the self-report measure, while Lee et al. (2010) found a significant effect for the objective measure only. Unfortunately Lee et al. (2010) did not report which self-report measure they used. Tambs (2004) simply asked the respondents: ‘Do you have a hearing loss of which you are aware?’ Based on the findings by Tambs (2004), it could be concluded that the self-report measure reflected disability experienced from hearing loss better than the objective pure-tone-average measure did, and therefore was a better predictor for poor psychosocial health. However, as the study had a cross-sectional design, Tambs (2004) concluded that its better predictive ability was ‘most probably’ the reflection of a reporting bias. Recently, Gopinath et al. (2012b) performed a similar study in which the predictive abilities for quality of life of a ‘hearing handicap’ measure and a pure tone measure were examined using a longitudinal design. Their hearing handicap measure assessed activity limitations, participation restrictions, and associated emotions (i.e., the Hearing Handicap Inventory for the Elderly-Screening version; Ventry & Weinstein, 1983). They found that self-perceived hearing handicap rather than measured hearing impairment per se had a significant impact on a greater number of SF-36 indices. The latter included: ‘role limitation due to physical problems’, ‘general health’, ‘bodily pain’, and ‘social function’. However, this study did not include any objective hearing measures, nor did it include a self-reported hearing measure that assessed communication difficulties (such as the measures used in this thesis). Adding such measures would allow comparison of the predictive abilities of the various hearing constructs. A cross-sectional study by Dalton et al. (2003) did include a communication-oriented self-report measure in addition to the HHIE-S and a pure tone audiometry measure. Like Gopinath et al. (2012a), Dalton et al. (2003) aimed to compare the predictive abilities of hearing measures for quality of life (SF-36) and examined this in the
same study population. The ‘communication-difficulties’-measure Dalton et al. (2003) used measured experienced communication difficulties in specific listening situations and thus was similar to the self-report measure we used in Chapter 3. It was observed that, of the three hearing measures examined (i.e., pure tone audiometry, HHIE-S, and self-reported communication difficulties), hearing handicap (HHIE-S) resulted in the greatest differences in SF-36 scores between those with and without hearing loss. In conclusion, the findings by Dalton et al. (2003) and Gopinath et al. (2012b) suggest that hearing measures assessing the activity limitations, participation restrictions, and associated emotions experienced may be most sensitive to predicting impaired quality of life. In line with this, it seems plausible that this also holds for mood outcomes such as depression and anxiety.

In summary, it is possible that the relationships between the communication-based hearing measures used in the current thesis and the range of disabilities experienced that were important for mood were too weak to yield significant effects on depression and anxiety. Future studies additionally including other self-report measures such as the HHIE-S may elucidate this.

**Subgroup effects**

A strong feature of this thesis was its ability to explore whether different psychosocial effects of hearing loss existed for specific subgroups of older persons (Chapters 3 and 4). Various subgroup-specific effects were identified and several underlying mechanisms were hypothesized.

In epidemiology, consideration of effect modification by a particular variable is considered important and superior to the relationship found for the total sample: it is considered part of the reality of the association (Ely, 1992). In our studies, a form of so-called qualitative effect modification occurred: i.e., the direction of the effect depended on the effect modifier (Kamangar, 2012). More specifically, there was an association in one subgroup, but no association in the other. Statisticians warn that statistically significant interactions may be an artefact which arise due to, for instance, differential confounding, differential bias, and random variation (chance findings) (Kamangar, 2012).

Differential confounding occurs when the association between the exposure and the outcome is confounded in one subgroup but not in the other. However, this was taken into account in all our stratified analyses because we checked whether there were confounders within the separate subgroups (in the models containing the interaction terms). Differential bias or measurement error means that the biases or errors are limited
to one subgroup. An example is the gender discrepancy we found for emotional loneliness. Research suggests that women may answer more truthfully to questions about their hearing ability, as it has been found that men report less problem awareness and more denial than women (Erdman & Demorest, 1998a; b; Garstecki & Erler, 1999). However, as a similar gender effect on emotional loneliness was also found for SNT hearing loss, this particular bias did not seem to play an important role in our data.

Lastly, critics may state that the interactions we found for gender, partner status, baseline SRT, hearing aid use, comorbidity, and socioeconomic status may be due to random variation because of the large number of analyses. Several arguments can be given to counteract this statement. Firstly, we had reasons for examining the effects modifiers based on previous studies’ findings. Several studies showed that there are age, gender, and socioeconomic differences in problem awareness of hearing loss and coping with hearing loss (Erdman & Demorest, 1998a; b; Garstecki & Erler, 1999). In addition, various studies had already indicated differences in psychosocial health effects resulting from hearing loss across age, gender (Chen, 1994; Ives et al., 1995; Nachtegaal et al., 2009a; Tambs, 2004), and hearing aid use (Mulrow et al., 1990; 1992; Gopinath et al., 2009).

Further, prior research has shown that psychological responsiveness to chronic functional impairments, such as vision impairment, can be moderated by disease duration (Bevan, 1965; Schilling & Wahl, 2006; Schilling et al., 2011). This was judged as an important rationale to investigate the moderating effect by baseline SRT in Chapter 4. Secondly, we applied a stricter cut-off for the p-value of the interaction terms in Chapter 3 than is customary (i.e., p<0.05 instead of p<0.10) (Twisk, 2007) in order to reduce the likelihood of finding significant effects by chance. Thirdly, we observed consistency for various subgroup effects across our findings, making statistical effects due to random variation less likely. We observed similar trends across the two loneliness variables in Chapter 3 (i.e., only (borderline) statistically significant effects for those with a higher SES, those with a partner in the household, and those without a hearing aid). We also observed similar trends across the two hearing measures within the same outcome variable in Chapter 3 (i.e., relatively stronger emotional loneliness effects for those without comorbidity; significant emotional loneliness effects for men only; significant social loneliness effects for those with a higher SES only). Lastly, there was consistency with regard to an interaction effect by partner status (found both in Chapters 3 and 4).

Fourthly, we hypothesized several explanatory mechanisms for the subgroup effects throughout the Chapters that could be backed up by findings from other studies and by theories.

It should be noted that for some of the identified effect modifiers, the particular variable may not be the ‘true’ factor modifying the relationship. For instance, when considering the subgroup effect for men, not gender per se, but rather the use of coping strategies or
the importance of a partner relationship for the protection against emotional loneliness may have been the true effect modifier. In that case, gender, or the other factors for which effect modification was found would rather be indicative of a group having a certain (set of) effect modifier(s).

**External validity of the focus group findings**

In the focus group study described in Chapter 5, the sample consisted of informants with a wide variety of demographic and hearing loss characteristics. For instance, some informants had had hearing loss since childhood or birth, while most of the others had acquired it later in life. Although a maximum variation strategy was applied for age, gender and degree of hearing loss, this was not done for hearing loss duration. Maximum variation strategy means that for a particular characteristic that is judged important for the studied phenomenon, maximum diversity is strived for within the sample. It could be that hearing loss duration influenced the range of disabilities that were experienced and the environmental adjustments that were made. People born with hearing loss have lived with it their entire lives and could have adapted themselves and their environment accordingly. Their acceptance of their hearing loss and environmental changes could for instance be in more advanced stages. This appeared to be the case for two Dutch informants. They explained that: they were in an advanced stage of accepting their hearing loss because they had been hearing-impaired their whole life, they mainly saw benefits of their hearing aids and assistive listening devices because otherwise they could barely hear at all, they used a range of hearing tactics they had learned to apply throughout their lives, and they had made various adjustments in their house and workplace environment in terms of room acoustics. These examples suggest that duration of hearing loss is a characteristic for which maximum diversity should additionally have been applied. However, the origin of the hearing loss and the degree of hearing loss were highly correlated in our sample (most of the severely or profoundly hearing-impaired persons were also the ones born with it). Because maximum variation in sampling was applied to degree of hearing loss, we expect that sufficient variation for hearing loss duration was automatically ascertained.

Further, we categorized the focus groups into three age categories. This was to avoid a limited shared frame of reference with regard to family and working life, which we expected to hamper the flow of the group conversation and would have negatively affected the richness of the data. However, we did not check whether the age groups indeed differed with regard to the range of ICF categories that was identified from the transcripts.
If substantial differences had emerged, this would have raised the question of justification for Core Sets for Hearing Loss that apply to all adults. Should there for example not be separate Core Sets for adults of working age (in the Netherlands 18-67 years) and adults past retirement age (67 years and over)? For instance, a different version of the Hearing Handicap Inventory for the Elderly (HHIE; Ventry & Weinstein, 1982) exists for younger adults, i.e., the Hearing Handicap Inventory for Adults (HHIA; Newman et al., 1990). Three age-sensitive items (e.g., attendance of religious services) out of the 25 items in total are replaced by items on hearing/understanding co-workers, clients, or customers in this version.

As a counter argument, the Core Sets for Hearing Loss represent a range of categories of functioning and hearing loss relevant for adults living with hearing loss. So, when some categories such as participation in remunerative employment do not apply, these can be simply skipped and the other relevant ICF categories of the Core Set can still be mapped.

**External validity of the systematic review findings**

In the systematic literature review of the post-screening interventions (Chapter 6), the aim was to provide the total range of possible interventions ever offered to adults found screen-positive for hearing loss. We chose to include studies describing screening programs in general adult populations only. Programs that were offered to specific populations such as patient groups (e.g., Alzheimer’s disease patients, intensive care unit patients) or nursing homes residents were excluded. It was assumed that these populations would have too much complicating comorbidity and that the content of the intervention would be tailored too strongly to their characteristics, making them inapplicable to the general adult population. In addition, it was expected that the intervention would be tailored to a secondary care setting, and as such would only be applicable in that setting. Many of these frail groups are for instance home- or bedbound. However, it could be that these influences were limited, and that the interventions did not differ so much from the interventions of the included studies. Consequently, it may be that some interventions were missed.

**RECOMMENDATIONS FOR FUTURE RESEARCH**

**Hearing loss and cognition**

The results of the present thesis indicate that decline in information processing speed over time relevantly influences decline in speech-recognition ability in noise over time. The test used (i.e., an adapted version of the Coding task by Savage (1984), however, is,
like many information processing tasks, not a pure measure of information-processing speed (Lezak et al., 2004). Additionally other processes like attention and (working) memory function are involved (Bouma et al., 1996; Lezak et al., 2004). As LASA did not include separate cognitive tests of attention and memory, their contribution to the change in SRT could not be determined in our study. It is recommended that this is examined in future longitudinal research. Further, as was already mentioned in the discussion section of Chapter 2, our study did not allow clear conclusions on cause and effect between cognitive decline and hearing decline. We therefore suggest that this is addressed in future research as well. Longitudinal data originating from large community-based samples seem required here. Further, it is recommended that the speech-in-noise test includes sentences as speech material against fluctuating noise or babble. These conditions resemble daily life more closely and are assumed to rely more heavily on top down cognitive functioning than steady state noise (e.g., Koelewijn et al., 2012).

Hearing loss, cognition, and loneliness

Although the current thesis focused on psychosocial health as an outcome of hearing loss, the role of loneliness may also be viewed as a possible mediator in the causal chain running from hearing loss to cognitive decline. This was one of the pathways advanced by Lin et al. (2013) as an explanation for the significant associations they observed between hearing loss and cognitive decline (global cognitive functioning and executive functioning), and hearing loss and incident cognitive impairment (global cognitive functioning). Several epidemiologic and neuroanatomic studies provide support for relationships between loneliness, social isolation or social resources on the one hand and cognitive decline or dementia on the other hand (Barnes et al., 2004; Bennett et al., 2006; Cacioppo & Hawkley, 2009; Fratiglioni et al., 2000). In this light, it could be speculated that loneliness may have been a mediating factor contributing to the significant longitudinal relationship between speech-in-noise recognition and information processing speed (Chapter 2). Taking it even one step further, cognitive decline resulting from loneliness and hearing loss, in turn may adversely affect speech perception abilities again. Future research should address the disentanglement of the complex interplay between hearing loss, cognition, and loneliness.

Subgroup-specific effects on psychosocial health

This thesis reported a number of subgroup-specific effects of hearing loss on loneliness. A number of explanatory mechanisms were suggested, most of which related to differences
in social participation, relationships, coping with hearing loss, and adaptation to hearing loss. Investigating the underlying mechanisms was beyond the scope of this thesis and we suggest that this is addressed in future research. There have been some attempts already to identify the factors mediating the effect of hearing loss on psychosocial health, such as mastery and self-esteem (Corna et al., 2009) and cognitive coping strategies (Garnefski & Kraaij, 2012). The study by Gafnefski & Kraaij (2012) concerned a cross-sectional study amongst hearing-impaired adults in which coping strategies were investigated as determinants of depression and anxiety. They found that ruminative and catastrophizing ways of coping were related to more symptoms of depression or anxiety, whereas refocusing attention to more pleasant issues, disengaging from unattainable goals, and re-engaging in alternative, meaningful goals were related to fewer symptoms. However, the coping strategies were not examined directly as mediators of the relationship between hearing loss and mood. Another limitation was the cross-sectional design of the study allowing a bias to occur, i.e., depressed mood in itself leading to more frequent use or more frequently reported use of ‘maladaptive’ coping strategies. Corna et al. (2009) used a longitudinal design, and investigated mastery and self-esteem as mediators in the relationship between decline in hearing status and increase in psychological distress. They found that change in mastery and self-esteem over time partly explained the (borderline) statistically significant relationship between hearing decline and increased psychological distress. However, both Gafnefski & Kraaij (2012) and Corna et al. (2009) examined the ‘mediating effects’ within the entire study samples, and thus did not examine it for subgroups.

To our knowledge, the studies in this thesis belong to a small minority of studies that explored possible subgroup-specific psychosocial effects resulting from hearing loss. A number of the effect modifiers tested in this thesis have never been examined before. Following the ‘consistency criterion’ of causality by Evans (1995), replication of the interaction effects in other large population-based studies will further establish the subgroup effects found.

It is important that the subgroup effects are examined with longitudinal data originating from large, population-based data sets. As such, change in hearing and psychosocial health can be modelled and possible effect modifiers and confounders can also be considered longitudinally. Further, extrapolation to the general older population can be assured. We suggest that future studies additionally focus on the psychosocial effects associated with the rate of hearing decline, as, to our knowledge, Chapter 4 of this thesis describes the only study in which this was examined to date.
CHAPTER 7

RELEVANCE AND CLINICAL IMPLICATIONS

The Western society is aging. The persisting increase in longevity and the aging of the baby boomer cohort are expected to cause further expansion of the hearing loss disease burden (e.g., Davis, 1990; Vos et al., 2013). Current treatments are not yet able to halt age-related hearing loss, so all older adults faced with hearing loss are challenged to adapt to and cope with the generally ongoing and progressive decline. Assuming that a longer life span also implies a longer period of age-related cognitive decline, the results indicating a significant influence of cognitive decline on speech-in-noise recognition further underline the relevance of this thesis’ findings to the aging population.

Hearing loss and cognition

The current thesis revealed that a moderate proportion of the decline in speech-in-noise recognition over time can be explained by the decrease in information processing speed, a central feature of cognitive aging (Salthouse, 1996). Although the precise causal relationship is yet to be determined, the notion that cognitive slowing and the execution of more complex hearing tasks like speech-perception in noisy backgrounds are associated is relevant. This has implications for clinical practice. There should be increased attention, both in audiologists and more generic health professionals, that the two are related. Based on this thesis’ findings, assessing older persons’ speech recognition ability in challenging hearing conditions such as noise seems key. Kricos (2006) suggested how audiologists may use informal appraisal as well as existing behavioural and electrophysiologic tests and questionnaires when evaluating older adults for hearing aid fitting and rehabilitation. With regard to cognition, she discusses several tools that audiologists could use to get a better insight into the patient’s cognitive capacities, including attention, information processing speed, working memory, and general cognitive functioning. Kricos (2006) further recognized that formal cognitive tests should be considered when appraising the individual’s lifestyle and communication goals, because cognitive factors will be most relevant to those who need to communicate in challenging situations and least relevant to those who usually communication in more ideal or highly supportive environments. Pichora-Fuller & Singh (2006, pp. 52) additionally reported that ‘perhaps the biggest need is to find relevant and clinically practical measures of cognitive processing so that audiologists can distinguish individual differences in healthy older persons whose audiograms in the speech range vary from normal to moderate or severe hearing impairment (Rakerd et al., 1996)’. 
General Discussion

Hearing loss and loneliness

This thesis further indicates that hearing loss in older adults can cause significant adverse effects on social and emotional loneliness in subgroups of older persons. Loneliness has been associated with decreased wellbeing, depression, and mortality (Dykstra, 2009; Holwerda et al., 2012; Cacioppo et al., 2006b). Research has even indicated that the quality of personal relationships is one of the best predictors of health and life expectancy (Dykstra, 2012). Furthermore, isolated people lack the health advantages of being connected to other people, as networks contribute to a healthy lifestyle, provide access to information for disease prevention, reduce psychological stress, and enhance beneficiary physiologic responses (Berkman et al., 2000). Finally, loneliness is a societal problem as it undermines social cohesion. Lonely persons have less exchange with others or the quality of the interactions is less, both leading to poorer social networks. It limits contribution to society because lonely people simply have limited access to it. In older adults between 65 and 79 years of age, around 20-35% report to be lonely ‘often’, which is already rather high, but is similar to younger adults. However, loneliness increases to around 40-50% in those aged 80 years and over (Dykstra, 2012). Important reasons for a decreasing social network are decreased health and associated decreased mobility (limiting effective maintenance of a broad social network), and loss of the partner, more distant family, friends and acquaintances because of death (Van Baarsen & Van Groenou, 2001; Van Tilburg, 2008).

The current thesis adds to this body of knowledge by identifying hearing loss as a significant risk factor of loneliness in specific subgroups of older persons. Although some of the subgroup effects warrant further investigation, the effects for men, those living with a partner, and those not using a hearing aid seem sufficiently consistent throughout our findings, and can be sufficiently supported by theoretical rationale to consider them as plausible high risk groups. In addition, older adults who recently lost their partner, and those whose hearing declines from an already insufficient hearing status appear high-risk groups for experiencing increased loneliness on the account of their rate of hearing loss.

The results indicate that the loneliness effects of hearing loss are modest. However, considering that the subgroups still represent a large proportion of older persons, hearing loss will eventually affect almost any aging person to some extent, and loneliness in its turn is associated with many severe adverse outcomes, the loneliness impact can be considered significant and important. Clinicians should be aware of loneliness risks in these subgroups with regard to existing and progressing hearing problems. Monitoring the rate of hearing loss, the home situation concerning partner status, and associated feelings of loneliness seems a justified approach. Further, the findings underline the importance of hearing aid fitting as an effective intervention to prevent loneliness. Given the subgroup
effect observed for partner status, involving partners in rehabilitation seems a fruitful approach. The importance of including the partner or other significant others in rehabilitation has long been emphasized (Hallberg & Barrenäs, 1993; Hétu et al., 1993; Kiessling et al., 2003; Stephens & Kramer, 2010a). Significant others can play an important role throughout the personal and emotional stages of change the person with hearing loss goes through. In addition, the significant other will be more aware of the difficulties experienced by the person with the hearing loss and may contribute to maintaining or restoring the quality of their relationship. Preminger (2003) compared two groups of hearing-impaired older adults who followed a group audiologic rehabilitation class. In one of the groups, hearing-impaired older adults participated together with a significant other, which was the spouse or partner in most cases. In the other (control) group, only the individual hearing-impaired person participated. Decreases in hearing handicap were found more often and were of greater magnitude in the group with the significant others than in the control group. Lastly, it has become clear that the partner can suffer considerably from their partner’s hearing loss as well (i.e., third party disability; Scarinci et al., 2008; 2009). It follows that involving them in the rehabilitation can potentially provide a relief from their burden, too (Preminger, 2003). Whether clinical practices generally comply with the recommendations to actively involve significant others in their standard rehabilitation is unfortunately questionable, according to Stephens & Kramer (2010b, pp. 100). This deserves further attention.

**Hearing loss and functioning & disability**

The findings of the focus group study of this thesis show that besides poor psychosocial health, hearing loss can result in many disabilities experienced in various aspects of functioning. Not only obvious activities and life situations directly relating to communication, interpersonal interactions, and relationships are affected, but additionally other activities and situations are affected because they require effective communication (e.g., employment) or require good sound perception in a more broad sense (e.g., in traffic, or to recognize alarm sounds). Care professionals should be aware of these disabilities. Additionally, they should consider the wide range of environmental and personal factors influencing disability experienced by the person being assessed. The findings additionally indicate the need to recognize the various negative emotions adults experience as a consequence of their hearing loss, plus the physical fatigue resulting from increased listening effort. The latter supports the current developments in audiological research in which a growing focus is on assessing listening effort (e.g., Kramer et al., 1997; Zekveld et al., 2011) and need for recovery (Nachtegaal et al., 2009b), and how these may be diminished through intervention. Once the Core Sets for Hearing Loss become widely
available, they can assist hearing professionals to assess a patient’s most vital components of functioning and disability.

At the moment of writing the current Chapter, the ICF Core Sets for Hearing Loss project had successfully progressed through phase I (preparatory phase) and II (consensus phase). The results of the preparatory studies (including those of Chapter 5) were presented at an international consensus conference. Seventeen hearing loss professionals and four persons with hearing loss from fourteen different countries decided which ICF categories should be included in the first version of the ICF Core Sets via the Delphi method. 117 categories were selected for inclusion for the Comprehensive Core Set (i.e., for comprehensive, multidisciplinary assessment of a person’s functioning with hearing loss) against 27 for the Brief Core Set (i.e., for a brief, minimal assessment). Currently, they can be accessed online1. The project will now proceed into the third and final validation phase in order to examine the content validity and feasibility of the Core Sets (Danermark et al., 2010).

**Interventions following hearing loss screening**

The final Chapter of this thesis indicates that the scientific attention for post-screening interventions serving as an alternative or an addition to hearing aid fitting is still modest. At the same time, there are strong signals that a holistic approach in which there is attention for alternative, non-technical interventions such as communication programs is gaining momentum within the field of audiology (Boothroyd, 2007; Danermark et al., 2010; Kiessling et al., 2003; Stephens & Kramer, 2010b; Laplante-Lévesque et al., 2010). Based on this thesis’ findings, it is premature to recommend that alternative interventions such as hearing tactics, speech reading, counselling, and education about hearing loss, should be offered as part of hearing screening programs. However, the large number of older adults with hearing loss that are under recognized and under treated do call for rigorous action and perhaps a shift in the current treatment paradigm is needed (e.g., see Lin, 2012; Smith et al., 2011). Identifying the effectiveness of screening programs including alternative intervention options could be an important first step.

**CONCLUSION**

The results of this thesis indicate the relevant influence of declining cognition on older persons’ ability to recognize speech in noisy environments. Next, the results show that

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hearing loss causes loneliness in older persons. A key message is that only specific subgroups of older persons seem to be affected. Based on the findings, important subgroups at risk include men, non-hearing aid users, those living with a partner, those who recently lost their partner, and persons whose hearing declines from an already insufficient hearing status. Other findings of this thesis show that hearing loss has a widespread impact on adults’ functioning and disability, and indicate the importance of environmental and personal factors involved. The latter findings added to the development of the ICF Core Sets for Hearing Loss, which should ultimately lead to a comprehensive, valid, user-friendly, and universal mode of assessing adults’ functioning and disability with hearing loss, both in the clinic and in research. The final results of this thesis show that interventions alternative to or additional to hearing aid fitting, such as communication programs, have rarely been offered to adults found screen-positive for hearing loss.

The current findings underline the need to further address the determinants and the consequences of hearing loss in older adults, both in research and clinical practice. With regard to research, longitudinal data from large population-based studies are essential for evidencing causal relationships and unraveling explanatory mechanisms. Further, the final findings of this thesis underline that the investigation of offering post-screening interventions as an alternative or as an addition to hearing aid fitting deserves further attention.
REFERENCES


