Chapter 1

GENERAL INTRODUCTION
What does it mean to have a hearing impairment nowadays? In 2013, the above poem was posted on the Dutch Facebook page for deaf or hearing-impaired people by Anita Noordhuis. It illustrates the emotional, physical, and social struggle an adult with hearing impairment may experience in daily life. This personal experience stands not on its own: hearing loss is ranked highest among the chronic conditions accounting for moderate to severe disabilities worldwide (WHO, 2008). The International Classification of Functioning, Disability and Health (ICF-model) describes functioning and disability of health and health-states (WHO, 2001). Nowadays this model is widely applied in the field of Audiology (e.g., Hickson & Scarinci 2007; Granberg et al., 2014). The ICF-model underlines the complex interactions between body structures and functioning (the loss of hearing ability), activity limitations (e.g., speech comprehension in noise), participation limitations (e.g., in social life), environmental factors (e.g., room acoustics), and personal factors (e.g., age, gender, educational level).

Different definitions are used to estimate the prevalence of hearing problems. Usually such estimates are based on self-reported outcomes, pure-tone audiometry, or tests that

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1 Poem published with permission of the author.
determine individuals’ speech recognition ability in background noise. Although these differences may lead to different estimations of the number of people with hearing loss, it can be concluded that hearing problems are a common chronic health condition worldwide. Reports of the WHO show that approximately 27 percent of men and 24 percent of women aged over 45 years have a mild or more severe pure-tone hearing loss (WHO, 2008). It is estimated that 360 million people worldwide suffer from disabling hearing loss (WHO, 2014). According to the latest available data in the Netherlands, approximately 2.2 million people over 19 years of age are reported to have problems with following a conversation in a group of three or more other people (National Institute for Public Health and the Environment [RIVM], 2014a).

It is well known that the prevalence of hearing loss grows with increasing age (Morell et al., 1996; Agrawal et al., 2009; Cruickshanks et al., 2010; Lin et al., 2011; Mitchell et al., 2011; Kiely et al., 2012). For instance, findings of a large scale population-based sequential cross-sectional study among people in the USA (Agrawal et al., 2008; Lin et al., 2011) shows that the prevalence of hearing loss (PTA loss0.5, 1, 2, 4 kHz; best ear >25 dB HL) was 0.6 percent in those aged 20 to 29 years. It slightly increased to 2.0 percent and 5.8 percent for the age groups 30 to 39 years and 40 to 49 years, respectively. After the age of 50, the prevalence of hearing impairment was found to be doubled for each following age decade. In the age group of 50 to 59 years it was reported to be 15.0 percent; increasing towards 31.0 percent (60 to 70 years) and 63.1 percent (over 70 years). Although the prevalence of hearing loss is highest amongst the oldest age groups, also in younger populations, for instance those in the working age, hearing loss is a prevalent chronic condition.

**Epidemiological studies about hearing**

Epidemiology can serve as a method to investigate the complex interactions between all components of the ICF model. Epidemiology is “the science that investigates the pattern of diseases in populations, to help understanding both their causes and the burden they impose” (Bhopal, 2002). With regard to hearing impairment, it means that epidemiologists are interested in the determinants and consequences of hearing loss in daily life. Prospective observational studies on hearing in which participants are measured frequently over a period of time are scarce. The main reason for this is that such long-term studies are costly, and it is time-consuming to perform follow-up
measurements in a large group of participants. Examples of such studies in the field of Audiology are the Framingham Heart Study (Gates et al., 1990), Blue Mountains Hearing Study (Mitchell et al., 2011), the Longitudinal Aging Study Amsterdam (LASA) (Pronk et al., 2011; Pronk et al., 2013; Pronk et al., 2014), the Maastricht Aging Study (Linssen et al., 2014), the Ebeltoft Health Promotion Project (Karlsmose et al., 2000), and the Epidemiology of Hearing Loss Study (Cruickshanks et al., 2010). The majority of these studies focus on older adult populations (>60 years). Hearing loss was also not the main focus in some of these studies, limiting in depth investigation about the determinants and consequences of hearing problems.

Research has shown that problems with understanding speech in noise is one of the major complaints of people with hearing problems (Plomp & Mimpen, 1979; Kramer et al., 1998). Tests investigating people’s ability to understand speech in background noise using digit triplets as speech material have been applied widely over the last ten years. The National Hearing Test (NHT) (Smits et al., 2004; Smits et al., 2006), as included in the current thesis as an objective measure of individual hearing ability status in daily life, is such a test. First the test was developed as a screening test by telephone and later, an Internet version was launched (www.hoortest.nl) (Smits et al., 2006). To date, the NHT has been included in some epidemiological studies. For several years, hearing ability in noise has been measured within the LASA study (Pronk et al., 2011; Pronk et al., 2013; Pronk et al., 2014). Recently, the first results were published based on cross-sectional data from the large-scale population-based project by the UK Biobank (Dawes et al., 2014), also applying digit triplets in noise.

**NL-SH study: baseline and five-year follow-up measurement**

In 2006, the department of Otolaryngology-Head and Neck Surgery, section Ear & Hearing at the VU University Medical Center commenced the National Longitudinal Study on Hearing (NL-SH). Internationally it is also being referred to as the Netherlands Longitudinal Study on Hearing. The NL-SH is a prospective cohort study implemented via the Internet, and is still ongoing (www.hooronderzoek.nl) as shown in Figure 1. The NL-SH is a unique cohort, as it includes adults over a large age range from 18 to 70 years, and hearing impairment is the central topic under investigation. Hearing status is determined by the online speech-in-noise test (NHT) and also by self-reported measures.
General introduction

The NL-SH questionnaire contains a set of validated questions about socioeconomic status, health and psychosocial health status, participation in work and other domains of life, and use of health care.

Based on the cross-sectional baseline data of the NL-SH study, collected between 2006 and 2008, relevant conclusions could be drawn. For instance, it was reported that poorer hearing ability in noise was related to poorer psychosocial functioning (Nachtegaal et al., 2009a) and a higher need for recovery after work (Nachtegaal et al., 2009b). Repeated measurements within a subgroup of NL-SH participants on topics of productivity at work have also confirmed relationships with hearing ability (Nachtegaal et al., 2010). With regard to the use of health care, no differences were found in both the use and costs between normally hearing and hearing-impaired adults (Nachtegaal et al., 2012).

The NL-SH database was expanded to become a longitudinal database from 2011 onwards. A second measurement round after five years is being performed (Figure 1). By measuring hearing status every five years, as well as the various aspects of life in all participants, it is possible to investigate the course of hearing ability in relation to a
range of conditions and variables (e.g., change in psychological, social, and emotional function, changes in participation in work, and use of health care). Participants who completed their first measurement between 2006 and 2009 were invited for the second measurement round between 2011 and 2014. A third measurement round is planned from 2016 onwards, extending the NL-SH database to a ten-year follow-up period.

The large NL-SH database consists of data on many different aspects concerning people’s daily life. In this thesis, the following topics are studied:

- The co-existence of additional chronic conditions besides impaired hearing ability
- Participation in work life for people with and without hearing difficulties
- Changes in hearing ability over a period of five years
- Deterioration in hearing ability over a period of five years and its concurrent effect on psychosocial health

**The co-existence of additional chronic conditions besides impaired hearing ability**

A future trend in Dutch public health is the increase in the number of people with chronic disease, which is forecasted to continue (RIVM, 2014b). This is not only because of the aging population, but also unhealthy behaviors are accounting for this (e.g., psychical inactivity or consumption of unhealthy food). It is expected that the number of people with a chronic disease will increase from 5.3 million in 2011 (32 percent of the Dutch population) to 7 million in 2030 (40 percent of the Dutch population). The number of people with two or more chronic diseases is also predicted to increase. The co-existence of two or more chronic health conditions in an individual can be described by the term *comorbidity*, whereas the focus is on one index disease (Feinstein, 1970). In case of multiple chronic conditions, not focusing on one particular condition as index disease, the term *multimorbidity* is generally used (Valderas et al., 2009). Comorbidity and multimorbidity are important topics in health care, as the existence of two or more chronic conditions may play a role in the clinical encounter.

It has been reported that adults with hearing impairment have a higher probability to suffer from additional health problems concurrently with their hearing impairment (Kramer et al., 2002). Besides the obvious co-existence of hearing loss with ear, nose,
and throat (ENT) affections, such as tinnitus, dizziness, and balance problems (Davis et al., 2007), studies have reported relationships between hearing loss and diabetes (Crews & Campbell, 2004; Helzner et al., 2005; Bainbridge et al., 2008; Agrawal et al., 2009) and with cardiovascular disease (Gates et al., 1993; Cruickshanks et al., 1998; Yiengprugsawan et al., 2012). However, the evidence was not always consistent, as in other studies these relationships were not revealed (Lin et al., 2011; Helzner et al., 2011). Thus, so far there exists uncertainty in literature about the firm relationship between hearing status and these conditions.

A limitation of existing studies is that often, only a selection of chronic conditions were under investigation. Studies in which extensive lists of chronic conditions were included are scarce. This restricted scope limits a broader interpretation of the health status of people with hearing impairment. The studies as presented in this thesis provide more insight into the relationship between hearing ability and a range of co-existing chronic health conditions in young, middle-aged, and freshly older adults.

**Participation in work life for people with and without hearing difficulties**

According to the official database on registrations of Dutch general practitioners, 187,189 men and 119,997 women in the age of 15 to 64 years were diagnosed with age-related hearing loss (ARHL) or noise-induced hearing loss (NIHL). Each year approximately 22,000 adults of working age are newly diagnosed with hearing loss (RIVM, 2014a). These numbers indicate that a remarkable amount of adults in the working age have to deal with hearing impairment. The effects of educational, social and economic levels show complex interactions (Ruben, 2000) arguing that the relation of hearing with each of these factors is difficult to establish. Hearing loss has been associated with lower socioeconomic status (e.g., Cruickshanks et al., 1998; Beria et al., 2007; Agrawal et al., 2008; Cruickshanks et al., 2010; Hasson et al., 2010) as well as an increase in the likelihood of unemployment and reduced labor force participation (Parving & Christensen, 1993; Hogan et al., 2009).

So far, research has focused on restricted categories of work (being employed or not) while other categories of unpaid work are also of interest when viewed within a context of a larger economic structure. People who are not in the labor force can still be productive in society, for example by performing voluntary work, doing household
work, or taking care of children. It is important to expand our knowledge on the association between hearing impairment and work status in various categories. This is relevant from practice and research perspectives (i.e., for the development and evaluation of specific rehabilitation programs for workers with hearing impairment), but it is also relevant for policy makers, given the European Union emphasis on participation of older people (60+) in the labor force (European Commission, 2010).

Decline in hearing ability over time, and possible psychosocial consequences

Most evidence about the prevalence of hearing problems and psychosocial consequences comes from cross-sectional studies. In these type of studies, the parameters of interest (e.g., loneliness, depression, distress, social isolation) are measured once and the differences between groups of individuals are determined. However, when the development of hearing status over time and its consequences are known, it is possible to assess changes within individuals. Longitudinal study designs are needed to reveal the development of adverse psychosocial effects as consequences of hearing loss.

Research on the decline in speech recognition in noise over time is predominately conducted in relatively older adult populations (Divenyi et al., 2005; Dubno et al., 2008; Pronk et al., 2013a). As socioeconomic status and health possibly have an impact on the course of adults’ speech recognition over years, it is important to investigate changes in speech recognition also in younger study populations. It is also informative to investigate the differences between younger and older age groups, as hearing deterioration may start earlier than in old age (>70 years).

When an individuals’ hearing ability deteriorates over a period of time, this may lead to psychosocial consequences as described in the poem at the start of this introduction. Feelings of loneliness or higher levels of distress can show up. In longitudinal studies, loneliness and depression are commonly studied and show negative effects of hearing impairment on these parameters (e.g., Wallhagen et al., 1996; Strawbridge et al., 2000; Kiely et al., 2012). However, also studies exist in which hearing status was not found to be longitudinally associated with psychosocial consequences (Chou, 2008; Corna et al., 2009). In other studies, poorer hearing ability in noise or a decline in hearing ability were related with increased feelings of loneliness in older adults, but no relationship
was determined with depression (Pronk et al., 2011; Pronk et al., 2014). This contradiction in findings may be induced by the influence of different subgroups on the overall relationship of hearing status and psychosocial aspects. For instance, it has been reported that the effects of hearing on psychosocial health were different for younger than for older age groups (Tambs, 2004; Nachtegaal et al., 2009a). This possible age effect, and other potential modifying effects are under investigation in one of the studies included in this thesis.

**Outline of this thesis**

The current thesis presents studies that include data collected at the baseline and the five-year follow-up measurements of the NL-SH study. Outcomes of an online digit-triplet speech-in-noise test (NHT) are used to establish people’s hearing ability in noise in all these studies. Chapter 2 focuses on the association with chronic conditions, such as diabetes and cardiovascular disease, concurrent with hearing impairment. In Chapter 3 the topic of comorbidity is explored from another perspective. It is investigated whether hearing impairment was associated with the use of some specific types of medication, and also with polypharmacy. Chapter 4 provides more insight into the relationship between hearing ability and participation in different categories of work. Besides paid and unpaid work, socioeconomic parameters such as educational achievement, level of income, and being a primary income earner were under investigation. In Chapter 5 the average change in adults’ speech recognition over the five-year period is reported. Subgroup effects for various socioeconomic and health-status factors were explored. Chapter 6 focuses on the psychosocial consequences of a deterioration in speech recognition. Finally, Chapter 7 concludes by summarizing and discussing the main findings of this thesis and important methodological issues. Also recommendations for future studies are provided.
REFERENCES


