Employees with Aided Hearing Impairment:

An Interdisciplinary Perspective

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*This thesis is dedicated to the loving memory of my mother. It is
your shining example that I try to emulate in all that I do.*

Thank you.

ABSTRACT

In Sweden 13% of the general adult population (16-84 years), with or without hearing aids (HAs), report that they have difficulties following a conversation when more than two people are involved. This means that more than one million people in Sweden (9 500 000 inhabitants in total) report subjective hearing difficulties. Observations further indicate that that people with hearing impairment (HI) have an unfavorable position in the labor market. Individuals with HI report poorer health more frequently and estimate their own health to be worse than their normally-hearing peers. Increased unemployment, early health-related retirement and sick leaves are also more common for people with hearing loss compared to the population at large.

The focus of the present thesis is employees with mild-moderate aided HI in the labor market. The research project had three general aims: 1) to develop knowledge about how HI interacts with cognitive abilities, and different types of work-related sound environments and work-related tasks, 2) develop tests and assessment methods that allow for the analysis and assessment of perceived problems in clinical settings and 3) to develop knowledge that enables the possibility to provide recommendations of room acoustics and work-related tasks for employees with HI. Four studies were carried out. The studies presented in papers I-III are quantitative laboratory studies focusing on health related quality of life, cognition and effort and disturbance perceived in different types of occupational noise (daycare, office and traffic). Paper IV is a qualitative interview study aiming at exploring the conceptions of working life among employees with mild-moderate aided HI.

The results from papers I-IV clearly demonstrate that noise has negative effects on employees with mild-moderate aided HI. In addition to generating significantly greater effort and disturbance, it is further reported from the participants that noise at work in combination with a HI has an impact on daily life. This includes a sense of exposure during work hours, physical and mental fatigue after work, and withdrawal from social situations in the work environment and leisure activities. None of the participants with HI performed significantly worse on the visual working tasks employed in this project compared to their normally-hearing peers. This thesis shows that employees with HI objectively perform the employed

working tasks at a level similar to a well-matched normally-hearing control group. Instead, the findings of this thesis indicates that working in a noisy environment with a HI occurs at the expense of this group reporting significantly worse results on subjective measurements, including greater effort and disturbance, and lower physical health status. Interviews with these participants further confirm that these effects are indeed mostly due to noise at the workplace which could have a negative impact both physically, mentally and socially during and after work hours.

The main findings of this thesis demonstrate that there is a need for extensive services for employees with HI even after a HA fitting. This thesis therefore emphasizes the importance of identifying the need for assistive listening devices, examining the room acoustics of the individual's work setting and providing the workplace with information about the consequences of having a HI in order to facilitate communication at work. The latter is especially important as colleagues showing support and employers making adjustments at the workplace (technically or acoustically) are facilitating factors that would benefit both employees with HI and those with normal hearing. Additional research should focus on including and comparing other types of cognitive tests, work-related noises and working tasks. More research is also needed to unravel the complex area of research between factors such as cognitive processes, hearing and effort.

LIST OF PAPERS

Paper I

Hua H, Karlsson J, Widén S, Möller C, Lyxell B. (2013). Quality of life, effort and disturbance perceived in noise: A comparison between employees with aided hearing impairment and normal hearing. *International Journal of Audiology*, 52 (9), 642 – 649.

Paper II

Hua H, Emilsson M, Ellis RJ, Widén S, Möller C, Lyxell B. (2014). Cognitive skills and the effect of noise on perceived effort in employees with aided hearing impairment and normal hearing. *Noise & Health*, 16 (69), 79-88.

Paper III

Hua H, Emilsson M, Kähäri K, Widén S, Möller C, Lyxell B. (in press). The impact of different background noises: Effects on cognitive performance and perceived disturbance in employees with aided hearing impairment and normal hearing. *Journal of the American Academy of Audiology*.

Paper IV

Hua H, Anderzén-Karlsson A, Widén S, Möller C, Lyxell B. (under review). Being part of the labor market – Conceptions among employees with aided hearing impairment. *International Journal of Audiology*.

TABLE OF CONTENTS

INTRODUCTION	1
Disability research	1
<i>Critical realism – an interdisciplinary approach</i>	<i>1</i>
Hearing impairment	2
Context	3
<i>Target population</i>	<i>3</i>
<i>Previous research on the target population</i>	<i>4</i>
Noise	6
<i>The effects of noise</i>	<i>6</i>
Cognitive functions	8
<i>Cognitive hearing science</i>	<i>8</i>
<i>Working memory capacity</i>	<i>9</i>
<i>Executive functions</i>	<i>10</i>
<i>Hearing impairment and cognition in adverse conditions</i>	<i>10</i>
OVERALL AIMS	15
EMPIRICAL STUDIES	17
General method	17
Participants	17
<i>Papers I-III</i>	<i>17</i>
<i>Normative population in paper I</i>	<i>17</i>
<i>Paper IV</i>	<i>18</i>
Data collection in papers I-III	19
<i>Audiological tests</i>	<i>20</i>
<i>Short-Form 36</i>	<i>20</i>
<i>Hearing Handicap Inventory for Adults</i>	<i>20</i>
<i>Borg CR-10 scale</i>	<i>20</i>
<i>Cognitive tests</i>	<i>21</i>
<i>Work-related tasks</i>	<i>23</i>
<i>Background conditions for the work-related tasks</i>	<i>25</i>
Data collection in paper IV	26
General procedure	26

<i>Papers I-III</i>	26
<i>Paper IV</i>	28
Analysis of data	28
<i>Paper I</i>	28
<i>Paper II</i>	28
<i>Paper III</i>	29
<i>Paper IV</i>	29
Ethical considerations	30
<i>Papers I-III</i>	30
<i>Paper IV</i>	30
Summary of the papers	31
<i>Paper I</i>	31
<i>Paper II</i>	32
<i>Paper III</i>	34
<i>Paper IV</i>	35
GENERAL DISCUSSION AND FUTURE DIRECTIONS	37
Main findings	37
<i>Performance in the work-related tasks</i>	37
<i>Perceived effort and disturbance in noise</i>	38
<i>Are explicit processes involved when noise is present?</i>	39
<i>Impact of working with a mild-moderate hearing impairment</i>	40
Clinical implications	42
Methodological discussion	43
Interdisciplinary perspective	44
Future directions	46
CONCLUSIONS	47
ACKNOWLEDGEMENTS	49
REFERENCES	53
PAPERS I-IV	

INTRODUCTION

Disability research

The current framework of this thesis is disability research, an area that covers biological, psychological, social and cultural aspects of functioning, impairment and disability (Danermark & Gellerstedt, 2004b). Traditionally, disability research has been conducted using theoretical models of medical and social approaches. One limitation of using either of the models separately is that none of them can provide a holistic view of disability. In the current thesis, functioning and disability are conceptualized as an interaction between an individual's health condition, contextual and personal factors (WHO, 2001). When conducting interdisciplinary disability research, one can be faced with many choices (e.g. methods, what to study, under which circumstances, etc.). Metatheory is essentially about two things: 1) ontology and 2) epistemology. Ontology is the study of how reality is constituted, whereas epistemology is a branch of philosophy concerned with the limit and scope of knowledge we can have about reality. These two dimensions are two starting points that every scientific practice proceeds from, which in turn affect the researcher's choice of methodology (Danermark et al, 2007). In the following section, in order to provide a more comprehensive view of employees with hearing impairment (HI) from an interdisciplinary perspective, a metatheoretical approach that includes both quantitative and qualitative methodology will be introduced.

Critical realism – an interdisciplinary approach

Critical realism is a philosophical theory of reality and human knowledge. Critical realism posits that humans are capable of learning objectively about the world, without interference from human psychology or other subjective factors that color our perception of knowledge.

However, to see the world as it really is, one must learn and reflect critically upon what has been learned and on how it was colored by the limits of human perception. Critical realism proposes that reality is divided into an objective and a subjective dimension. According to this approach, reality exists objectively, but the knowledge of this reality is socially influenced. According to Bhaskar and Danermark (2006), a prerequisite for interdisciplinary research is level thinking. This statement is in agreement with critical realism which claims that reality (or certain phenomena such as employees with aided HI) can be understood from different levels (biological, psychological, social, etc.). Level thinking is thus a central concept in a critical realistic interdisciplinary perspective. Within each level there are various mechanisms that can influence and even generate other processes at other levels.

Nonetheless, to see the relationship between different levels and mechanisms, some form of integration of the produced knowledge has to take place. A further basis of critical realism is therefore integration of knowledge. Thus, critical realistic interdisciplinary research can only be conducted if: 1) level thinking, 2) identification of mechanisms and 3) integration of new knowledge are included within a research project.

In summary, different philosophical approaches have different ways of understanding reality and how to acquire knowledge. Critical realism is a theory of science that states that we are capable of learning objectively about the world. In order to do that we have to be critical to the new knowledge as it is socially influenced by human perception and local truths. Critical realism is therefore appropriate when conducting interdisciplinary disability research as it advocates the use of a mixed methodology, i.e. the use of both quantitative and qualitative methods. The emphasis is on how to integrate new knowledge on different levels using different methods in order to provide a more comprehensive view of the studied phenomena. For that reason, in the current research project, the methodology used and results generated will be discussed using this approach.

Hearing impairment

HI is the most frequent sensory deficit in human populations, affecting more than 360 million people in the world (WHO, 2014). HI is a partial or total inability to hear. Depending on where the disruption is located within the auditory pathway (peripheral or central), HI can be divided into three types: 1) conductive, 2) sensorineural and 3) mixed hearing loss. Conductive hearing loss occurs when sound is not conducted efficiently through the ear canal to the eardrum and the ossicles of the middle ear. Some possible causes of conductive hearing loss could be malformations of the outer ear, blockage in the ear canal or middle ear diseases. This type of loss generally generates a reduction in sound levels and can in most cases be surgically or medically managed. Hearing aid (HA) rehabilitation could also be a treatment of choice for restoring audibility and the outcome is usually good when the loss is conductive. Sensorineural hearing loss is a type of hearing loss in which the root cause lies in the cochlea, auditory nerve or central processing centers of the brain. Most of the time, sensorineural hearing loss cannot be medically or surgically corrected. This is the most common type of permanent hearing loss and may arise from many different causes including aging, noise exposure, ototoxic chemicals and genetic factors. Lastly, as the name implies, a mixed hearing loss is a loss that involves a combination of both conductive and sensorineural components (Arlinger, 2007).

Hearing ability is commonly described in terms of detection thresholds for pure tones over a specific frequency range. An audiogram shows the difference in decibel (dB) between actual pure tone thresholds and average thresholds of people with normal hearing. This quantity is denoted dB hearing level (dB HL). A common way of quantifying hearing loss is in terms of pure-tone thresholds averaged over four frequencies: 500, 1000, 2000 and 4000 Hz. This average is usually referred to as the pure-tone average (PTA). In addition to different types of HI, hearing loss can also be divided into different degrees. Degrees of hearing loss refer to the severity of the loss. Table 1 shows the classification of severity according to WHO (Mathers et al, 2000).

Table 1. Degrees of hearing loss.

Degrees of hearing loss	Pure tone average
Normal hearing	25 dB HL or less
Mild	26-40 dB HL
Moderate	41-60 dB HL
Severe	61-80 dB HL
Profound/deafness	81 dB HL or greater

The most obvious symptom of HI is a loss of ability to detect soft sounds, regardless of type. However, in a sensorineural hearing loss, additional auditory functions are disrupted across a wide range of perceptual processes such as decreased frequency and temporal resolution, abnormal growth of loudness and an impaired ability to localize sound sources (Moore, 2002). In a sensorineural hearing loss, HA benefit is usually limited to quiet rather than noisy situations due to the cochlear damage. Thus, speech recognition in individuals with, aided or unaided, HI is often unsatisfactory when noise is present.

Context

Target population

In Sweden 13% of the general adult population (16-84 years), with or without HAs, report that they have difficulties following a conversation when more than two people are involved. This means that more than one million people in Sweden (9 500 000 inhabitants in total) report subjective hearing difficulties (Statistics Sweden, 2012). Observations further indicate that people with HI have an unfavorable position in the labor market. Individuals with HI

report poorer health more frequently and estimate their own health to be worse than their normally-hearing peers. Increased unemployment, early health-related retirement (11% of men and 16% of women with HI) and sick leaves are also more common for people with hearing loss compared to the population at large (Statistics Sweden, 2003).

Health care professionals frequently meet individuals with HI who experience difficulties at work. The situation is further complicated by the fact that there is a lack of tests and methods for diagnosis of problems. The majority of tests used today within hearing health care are almost exclusively audiological tests aimed at restoring audibility (e.g. pure tone audiometry and HA fitting). Moreover, there is currently little research focusing on the work situation of employees with HI where the interaction between an individual's hearing ability, cognitive abilities, sound environment and type of tasks that are to be performed are taken into account. In the current thesis, employees with mild-moderate aided HI will be studied.

Previous research on the target population

To date, research on occupational performance in adults with HI has focused mostly on studies of health aspects using quantitative questionnaires (Grimby & Ringdahl, 2000; Gellerstedt & Danermark, 2004; Kramer et al, 2006; Nachtegaal et al, 2009). In a study by Danermark and Gellerstedt (2004a), a questionnaire about psychosocial work environment, health and wellbeing was sent out and answered by 445 employees with HI. The results showed that imbalances between demand and control were experienced to a higher degree among employees with HI than their normally-hearing peers and that neck problems were most frequently reported when compared to other health-related problems (e.g. headache, back, sleep). The results further showed a gender difference in psychological wellbeing, where women tended to report a higher degree of feeling irritated and frustrated than men at the workplace. Female employees with HI also reported health related problems, such as insomnia, more frequently than men. Kramer et al (2006) has observed similar results and demonstrated that sick leave due to distress occur more frequently for this group in general than for their normally-hearing peers. In addition to health effects, there are implications that there is also a higher need for recovery after work in this population. In a study by Nachtegaal et al (2009), hearing status in relationship to psychosocial characteristics and the need for recovery after work was assessed in 925 working adults with normal hearing and with HI, and a questionnaire focusing on these two topics was answered via the Internet. The results showed a significant association between decreased hearing and the need for recovery

after work. The results also showed that for every dB of worsening signal-to-noise ratio, the odds of showing a considerable need for recovery increased by 9%. Similar to the statistics proposed by Statistics Sweden (2012), these research findings clearly confirm that employees with HI are indeed a vulnerable group in the labor market. Even though it is not possible to determine the origin of the health effects using the employed questionnaires, some of the authors have speculated that it might be due to the extra effort and concentration needed from this group when communicating under challenging listening situations at work (Danermark & Gellerstedt, 2004a; Nachtegaal et al, 2009).

Qualitative methods have also been utilized to examine the work situation of employees with HI (Hetú et al, 1988; Hallberg & Carlsson, 1991; Jennings et al, 2013). For example, Hetú et al (1988) investigated hearing difficulties among employees with HI, and interviews on hearing problems and their consequences were conducted with the participants and their spouses. The results corroborate speculations where the participants stated that listening and communicating under challenging conditions do indeed require extra effort. As a result of the noise and HI, anxiety, stress, isolation in groups and negative self-image are also more common in this group. However, despite the current findings, it should be stated that working with a HI is better than not working at all. Grimby and Ringdahl (2000) have previously studied the effect of having a job on quality of life in participants with hearing loss. They report that employees with hearing loss constitute a potential risk group for general deterioration in quality of life than the normally-hearing population. Moreover, participants who were fully employed reported a higher quality of life than subjects with similar hearing loss who were retired. The authors concluded that education, having a job and a strong will-power seem to influence each other and were related to a maintained quality of life. The authors further reported that a majority of the study sample had undergone intervention steps, such as being fitted with HAs, thus suggesting that intervention from aural rehabilitation might improve quality of life for this population as well.

To sum up, research on occupational performance in employees with HI has mostly used questionnaires to examine health effects of working with a HI, and not so much on laboratory studies with controlled conditions and measures of cognitive performance. Findings further show that the consequences of having a HI are far-reaching for this group, and that the effects on physical health status are substantial, including neck problems and a higher demand for recovery after work. Moreover, psychosocial consequences have been observed, demonstrating that this group tends to have negative self-image and anxiety at

work. It is speculated that HI, in conjunction with excessive occupational noise, may be the main reason for these consequences.

Noise

Noise is defined as unwanted sounds. Loud sounds that disturb people or make it difficult to hear targets sounds are noise. Acoustic noise can be anything from quiet but annoying to loud and harmful for the ears. Noise is measured in dB and the A-weighted level (dBA) is the most commonly used measure. This means that sound is measured in a manner similar to how the human ear perceives it, as the ear is less sensitive to low audio frequencies. The equivalent sound level (Leq) is the average sound level over a specific period of time (Johansson, 2002). In Sweden, due to the harmful effects of noise, the limit for occupational noise is 85 dBA over an 8-hour working day. If noise levels exceed this limit, the personnel can only be exposed to the higher levels over a shorter period of time. On the other hand, this limit is a compromise legislated by The Swedish Work Environment Authority and is not a risk free regulation (SWEA, 2005). According to the International Organization for Standardization (ISO, 1999:2013), it is estimated that 50% of all individuals that have been exposed to noise levels at 85 dBA, eight hours a day, five days a week, for 10 years will develop a HI. In addition to noise level, how much a specific noise can affect an individual depends on other characteristics of the noise such as duration of exposure, what information the noise contains, how predictable it is and which other tasks are being performed while being exposed to it (Kjellberg et al, 1996). At the moment, research on noise and its economic cost is very limited, and no specific numbers have been reported regarding noise-related disorders and the cost for society. However, in a recent review study, it has been observed that loss of productivity is directly proportional to the average intensity level of the noise, regardless of profession type (Maldikar, 2011).

The effects of noise

As stated above, excessive noise (unwanted noise over 85 dBA) can be harmful to the ears and cause HI. However, additional physiological effects of noise have also been observed in other studies (Lusk et al, 2004; Babisch, 2011; Sjödin et al, 2012; Basner et al, 2014). For example, both laboratory studies of human beings and long-term studies of animals have been able to provide biological mechanisms and plausibility for the theory that long-term exposure to noise affects the cardio-vascular system. This in turn can lead to disorders, including hypertension, ischemic heart diseases and stroke. Research within this area has repeatedly shown that exposure to noise increases systolic blood pressure, changes heart rate, and causes

the release of stress-hormones. In a study by Sjödin et al (2012), stress-related health problems among 101 pre-school employees with normal hearing were investigated. The adverse effects of noise were analyzed using validated questionnaires and saliva cortisol samples, and data collection was conducted during one full week at each pre-school. Their results show that stress and energy output were pronounced and that 30% of the study sample experienced burnout syndromes. The burnout symptoms were further associated with reduced sleep quality and morning sleepiness. In addition, the obtained levels of cortisol supported the conclusion that this group of employees does experience daily stress at work. In another study by Jahncke et al (2011), physiological effects of two open-plan offices with low (39 dBA) and high (51 dBA) noise levels were examined in a simulated open-plan office. The study sample comprised of 47 students with normal hearing. In each session the participants were instructed to work for 2 hours on tasks involving working memory capacity (WMC). Physiological measures of stress (cortisol and catecholamine) were also obtained. However, there was no effect of noise on the physiological measures in this study and the authors concluded that the effect of short-term noise exposure on cognitive performance might not be mediated by changes in physiology.

In addition to the physiological health effects, decreased cognitive performance and increased annoyance have also been observed when noise is present. Noise annoyance is a fundamental concept in the area of environmental effects of sound. Generally, it is perceived as a negative evaluation of environmental noise, but its meanings are quite broad and diverse. Noise annoyance is a multifaceted concept covering primarily immediate behavioral noise effects aspects, such as perceived disturbance (PD) or interference with intended activities (Guski et al, 1999). The term “annoyance” can be used interchangeably with subjective terms, such as “disturbing” or “irritating” (Guski, 1997). Intelligible competing speech is usually considered a negative feature of the work environment, and the degree of intelligibility of competing speech has been found to correlate positively with self-rating scales of PD. As Venetjoki et al (2006) have demonstrated in a group of normally-hearing participants, the more intelligible the competing speech is, the higher self-rating scales of PD are reported.

Research on normally-hearing participants have also demonstrated that competing speech has negative effects on cognitive performance (Knez & Hygge, 2002; Schlittmeier et al, 2008; Ebissou et al, 2013). In a study by Schlittmeier et al (2008), three experiments tested the impact of low background speech (35 dBA) of both good and poor intelligibility, in

comparison to quiet and highly intelligible speech not lowered in level (55 dBA). Mental arithmetic, verbal short-term memory and verbal-logical reasoning were employed as measurements of cognitive performance, and self-rating scales of PD were also reported by the participants after completing each task under each experimental condition. The results showed that performance was significantly impaired by highly intelligible competing speech (55 dBA) on the short-term memory and mental arithmetic tasks, but not in verbal-logical reasoning. However, ratings of PD were consistent over all three experiments where quiet was rated least disturbing, and low background speech with poor speech intelligibility was rated less disturbing than good and highly intelligible speech in 35 and 55 dBA, respectively.

Taken together, research has demonstrated that the detrimental effects of noise are far-reaching and cause negative physiological, subjective and cognitive consequences for employees working in excessive noise. These results clearly speak in favor of the reduction of high noise levels and noise comprising competing speech in the workplace. Furthermore, long-term exposure to excessive noise might cause serious health risks for the individual.

Cognitive functions

Cognitive hearing science

In audiology and speech-understanding research, the influence of cognitive factors on speech recognition in adverse conditions has been recognized relatively late. In earlier studies, it has been demonstrated that cognitive skills are indeed associated with general speech understanding, such as speed of information processing, lexical access, phonological processing skills and WMC (Hällgren et al, 2001; Lunner, 2003; Lyxell et al, 2003; Larsby et al, 2005; Rönnberg et al, 2008). This relation between bottom-up and top-down processing has led to the development of a new emerging research area called cognitive hearing science. A general conclusion of recent advances within cognitive hearing science is that the important features of modelling include the interplay between automatic/implicit and deliberate/explicit types of processing. For example, recent research within this field has demonstrated that explicit, top down mechanisms that depend of WMC may determine successful adaption to signal processing algorithms in HAs for individuals with HI (Lunner et al, 2009; Ng et al, 2013). Thus, cognitive hearing science is an interdisciplinary research field concerning the interactions between human hearing and cognition. In the current research project, tests of WMC and executive functions (EFs) have been employed and used within

the theoretical framework. Therefore, in the following sections, WMC and three types of EFs will be presented.

Working memory capacity

Working memory involves the ability to simultaneously process and store information over a short period of time (Daneman & Carpenter, 1980; Baddeley, 2012). The ability to process and understand language is an example of when simultaneous processing and storage of information is required. However, the processes that make up working memory are not fully explored and there are several proposed models describing different components with different functions. One of these proposed models of working memory, which is also one of the most widely used, is the multi-component model proposed by Baddeley and Hitch (1974). It suggests that working memory is a common system that addresses multiple tasks and sensory signals. The model has several parts with different functions and limited capacities. The most recent revision of the model consists of four parts; the central executive, the phonological loop, the visuospatial sketchpad, and the episodic buffer (Repovs & Baddeley, 2006; Baddeley, 2012).

The central executive component acts as a coordinator responsible for managing and delegating activities to three different slave systems in working memory. The three slave systems in the model are the visuospatial sketchpad, the episodic buffer and the phonological loop. These three components are responsible for short-term storage dedicated to a specific content domain, meaning that each component is responsible for the specific type of information that is to be processed. The visuospatial sketchpad is responsible for visual and spatial information, the phonological loop handles auditory information and the episodic buffer is dedicated to linking information across domains to form integrated units of visual, spatial, and verbal information with time sequencing. The episodic buffer is also assumed to have links to long-term memory and semantic meaning. All components are related to the central executive component and long-term memory, but not to each other in the model.

Working memory is a central part of our daily lives in terms of abilities such as planning, math counting, reading, learning and problem solving. The most typical way to operationalize general WMC is to employ complex span-tasks. Daneman and Carpenter (1980) designed a test called the Reading span test which measures general WMC. This test is one of the most widely cited, and adapted, in studies investigating working memory (Daneman & Merikle, 1996). Generally, written sentences are presented in sets, and after each sentence, the individual has to judge whether the presented sentence was absurd or not.

The sets are presented in ascending order and, in addition to judging absurdity; the individual is also cued to recall the first/last word post-stimulus presentation. In other words, the Reading span tests taps into cognitive skills such as semantic processing and storage of information over a brief period of time.

Executive functions

Even though WMC has been operationalized using complex span tasks, it has been suggested that the performance of these types of tasks is also related to higher-level cognition such as episodic memory, reasoning and reading comprehension (Bayliss et al, 2005; Unsworth & Engle, 2007). In particular, Engle and Kane (2004) have argued that WMC is related to the ability to control attention under conditions of interference or distraction (e.g. solving a cognitive task in a noisy environment). The term executive functioning has often been referred to as attentional control and includes control functions related to inhibition of prepotent responses, shifting mental sets, updating task demands, planning and goal maintenance among others. However, models of EF differ considerably and there is a continuous debate over whether EF should be conceptualized as a unitary construct or several diverse functions (McCabe et al, 2010).

Miyake's theory of EF proposes that higher level functions of planning and decision making rests on three basic and distinct aspects of EFs: 1) inhibition, 2) shifting and 3) updating. Inhibition refers to the ability to deliberately suppress responses that are predefined in any given situation. Shifting refers to one's cognitive ability to switch between different tasks or mental states. Updating involves the ability to continuously monitor and quickly add/delete content within working memory (Miyake et al, 2000). The main point with this theoretical framework is that EFs reflect both unity (common EFs skills) and diversity of each component (distinction between components). In other words, aspects of updating, inhibition, and shifting are related, yet each remains as a distinct entity. This approach has been used by several research groups and has thus been proven to be a valid assessment of at least several EFs that have been thoroughly studied (van der Sluis et al, 2007; Garon et al, 2008; Hull et al, 2008). Therefore, in the current research project, the model of EF proposed by Miyake et al (2000) will be used.

Hearing impairment and cognition in adverse conditions

While physiological and subjective assessments and cognitive measures clearly speak in favor of reducing high noise levels at the workplace for individuals with normal hearing, only

limited empirical evidence exists regarding corresponding effects on performance in people with HI. As previously mentioned, studies have been able to confirm that there is a clear link between hearing loss and noisy environments, where high sound levels puts an extra strain on working memory in people with HI (Larsby et al, 2005; Rönnberg et al, 2008). Research has further confirmed that explicit processes are involved in noisy situations when individuals with HI are extracting meaning from a signal in a noisy situation (Rönnberg et al, 2010; Rudner et al, 2012). Even though the negative effects of background noise on speech understanding of individuals with HI are well documented (Van Tasell, 1993; Humes, 2002), most studies concerning individuals with HI focus mainly on the performance in listening tasks and listening effort in noise (Hällgren et al, 2001; Larsby et al, 2005; Zekveld et al, 2011; Rudner et al, 2012), and not so much on the visual processing of information.

In recent times, there has been an emerging interest in listening effort and fatigue within the fields of audiology and cognitive hearing science (McGarrigle et al, 2014). These topics are of interest because they may provide applicable insights on the disability associated with HI and guidance in intervention strategies. The term “listening effort” is currently not clearly defined and has yet to be agreed upon. Generally, it is conceptualized as the cognitive resources necessary for speech understanding. Perceived fatigue, on the other hand, is defined as mental fatigue resulting from effortful listening. Investigators have attempted to measure listening effort and fatigue using a wide variety of methodologies. Generally, methods may be grouped into three distinct categories: 1) physiologic measures, 2) cognitive performance and 3) self-report. Physiologic measures have been used because it is presumably believed that it can reflect cognitive load. For example, investigators have measured effort using pupil dilation (Zekveld et al, 2010, 2011), skin conductance (Mackersie and Cones, 2011) or muscle tension (Cohen et al, 1992). However, while these measures provide involuntary responses non-invasively, physiological indices may be confounded by age, emotion and stress. This in turn can make it difficult to interpret and implement the findings. Thus, great care is required when employing this type of measurements.

Cognitive performance, measured by means of accuracy and reaction time (RT), has been employed as another method of measuring effort in various tasks. Recall tasks have been frequently used to evaluate listening effort. This method offers high face validity as people with HI try to remember and understand speech that they hear in daily life. In addition, RT may provide additional information as it is believed that it corresponds to speech processing rate. One downside of measuring cognitive performance as an indication

of listening effort is that these tasks may be subjects to floor effects in individuals with HI. Moreover, because HI increases with age, older adults are more likely to struggle with these types of tasks, even in the absence of a HI (Pichora-Fuller et al, 1995; Pichora-Fuller, 2008; Zekveld et al, 2009).

The final category of listening effort methodologies is self-reported tools. Self-reported ratings can stem from informal questions which ask the participants how effortful they found the task to be or how tired they are after performing a certain task. For example, the Borg CR-10 scale has been used to evaluate listening effort between different noise conditions in a group with HI in several investigations (Hällgren et al, 2005; Larsby et al, 2005). While subjective measurements have been used to evaluate effort, there are indications that subjective indices do not correlate strongly with objective outcome measures. Hence, one disadvantage of using subjective measurements is that they may not be the only appropriate indication of listening effort, even though it is sensitive enough to identify differences between different noise conditions. In a study by Larsby et al (2005), different speech noises were found to interfere with cognitive processing in individuals with HI and normal hearing. Four study groups were included in their study, and the sample consisted of both young/elderly with normal hearing and young/elderly with HI. Cognitive tests of speech understanding and self-rated effort using the Borg CR-10 scale were administered, respectively, in four background conditions: quiet and three types of speech or speech-like noise. The results demonstrated that the presence of noise compared to quiet clearly had a negative effect on accuracy, speed of performance in the speech processing tasks and subjective effort for the group with HI compared to the group with normal hearing. The results also showed that the elderly participants were more distracted by noise with temporal variation, and especially noise with meaningful content, than the young listeners.

As stated earlier, fatigue is generated by effortful listening. Similar to self-reported listening effort, subjective assessment of fatigue is measured by using some form of scale (Nachtegaal et al, 2009; Jahncke & Halin, 2012) or questionnaire (Kramer, 2006). This type of subjective measurement of fatigue has the disadvantage that it may be subject to interpretation differences between individuals as it could be difficult for an individual to pinpoint extreme tiredness, or to know what mental fatigue actually means, when performing a cognitive task. Jahncke and Halin (2012) have previously investigated whether open-plan office noise affects non-auditory performance and stress, and whether these effects varies between individuals with HI and normal hearing. Twenty hearing-impaired and 18 normally-

hearing participants took part in their study, and cognitive performance, reported fatigue and physiological stress were measured during work in a simulated open-plan office consisting of low and high noise levels at 30 dBA and 60 dBA, respectively. The results showed that there was a decreased performance in the group with HI for non-auditory tasks that involved recall of semantic information in high level office noise. Participants with HI also reported higher levels of fatigue and tended to have higher stress hormone levels during the high level noise exposure compared to low level noise. In the current research project, only visual tasks in various noise environments have been employed. Therefore, the term “perceived effort” (PE) will be used to denote self-reported effort while performing a certain visual task under a certain listening condition, whereas PD denotes the annoyance of a specific type of noise that the participants was exposed to.

OVERALL AIMS

The focus of the present thesis is employees with mild-moderate aided HI in the labor market. The research project had three general aims: 1) to develop knowledge about how HI interacts with cognitive abilities, and different types of work-related sound environments and work-related tasks, 2) develop tests and assessment methods that allow for the analysis and assessment of perceived problems in clinical settings and 3) to develop knowledge that enables the possibility to provide recommendations of room acoustics and work-related tasks for employees with HI. The studies presented in papers I-III are quantitative laboratory studies, whereas paper IV is a qualitative interview study. In papers I-III, the results of the participants with aided HI were compared to the results of a well-matched control group with normal hearing.

The aims in **paper I** were to compare health related quality of life (HRQoL) and self-reported hearing handicap between two groups of employees with normal hearing and aided HI. HRQoL was also compared to a normative population. The second aim was to compare PE and PD after completing a working task in office noise between the two study groups. **Paper II** was exploratory and examined the relationship between WMC, EFs and PE after completing a work-related task in quiet and in traffic noise. In **paper III**, the effects of four different types of background conditions (quiet, office, daycare and traffic) on cognitive performance and PD were examined, and comparisons within- and between-group were analyzed. The relationships between these different outcome measures were also analyzed in order to identify whether one particular robust test can be used and demonstrate the effect different types of background noise have on individuals in a clinical setting. Lastly, **paper IV** aimed at exploring the conceptions of working life among employees with mild-moderate aided HI. This study has a descriptive design, in which data was collected by means of semi-structured interviews which were analyzed using a phenomenographic approach.

Together, all conducted studies concerned the three general aims this project had. Separately, they differ in focus, where papers I-III aims at exploring HRQoL, cognitive abilities and effects of different types of noises in a laboratory setting, respectively, and paper IV on describing the conceptions employees with aided HI have of working life.

EMPIRICAL STUDIES

General method

In the present thesis both quantitative and qualitative methods have been used. Data collection occurred on three separate sessions. Quantitative data was collected in session 1 and 2, and qualitative data in session 3. Session 1 and 2 were always completed within 4 weeks of each other, and data in session 3 was collected 18 months after the second session. All participants with HI were recruited from the Department of Audiology, Örebro University Hospital. The participants with normal hearing were recruited through professionals working at the university hospital such as their family members, relatives and friends. In the following method sections, the quantitative and qualitative part of the research project will be described separately.

Participants

Papers I-III

Forty participants (21 males) with a mean age of 44.3 years (18-64 yrs) were recruited. The study sample consisted of both hearing-impaired ($n = 20$) and normally-hearing ($n = 20$) participants. All participants were students, part-time or full-time employees in Örebro County, Sweden. They were selected based on the following criteria: age > 18 years, normal hearing or mild to moderate binaural sensorineural hearing loss and undergone aural rehabilitation. The participants in the hearing-impaired group were fitted bilaterally and had at least 3 months HA experience before the inception of the studies. Exclusion criteria were: people who were retired due to age or with early retirement, people on long-term sick leave (90 days or more), and people with moderate-severe tinnitus, hyperacusis, psychiatric illnesses, dyslexia and other diseases/disabilities. In the current studies, some of the participants had part-time jobs. However, these participants were still active to a high degree in labor market working 70-90% of full time. The two groups (normally-hearing and hearing-impaired) were matched according to age and education level and did not differ significantly on these two variables ($p > 0.05$). Table 2 shows the demographic data for the two study groups.

Normative population in paper I

In paper I, the Short Form-36 (SF-36) profiles in the two study groups were also compared to a normative population, selected from the Swedish normative database. This database

consists of 8930 respondents (Sullivan et al, 1995; Sullivan & Karlsson, 1998). For each of the 20 participants with hearing loss, 29-30 controls were randomly selected from the database matched on age and gender. The normative sample comprised of 597 matched respondents (298 males) with a mean age of 48.0 years (SD = 11.7).

Table 2. Summary of demographic data for the participants in papers I-III.

Demographic variable	Group with HI			Group with NH		
	Male/Female	N	Mean (SD)	Male/Female	N	Mean (SD)
Sex	10/10			11/9		
Age			48.0 (12.0)			40.5 (14.0)
Education level						
- Junior high school		1			-	
- High school		9			6	
- University		10			14	
Work status						
- Student		1			3	
- Part-time		4			4	
- Full-time		15			13	
Occupation setting						
- School		5			7	
- Health care		4			5	
- Industry		6			3	
- Office		5			5	
PTA						
- Right ear			36.5 (6.0)			5.2 (6.3)
- Left ear			36.0 (7.0)			7.0 (7.2)
Speech recognition in noise (%)						
- Right ear			62.3 (17.0)			84.1 (6.5)
- Left ear			61.2 (16.9)			80.7 (4.1)

PTA: pure tone average

Paper IV

All participants with HI were informed about the interview study 18 months after participation in the quantitative part of the research project. Fifteen participants agreed to participate. Of the remaining five, three participants did not reply despite reminders being sent out to them, and two stated that they did not want to take part in the interview study. In addition to the 15 recruited participants, one pilot interview was also conducted based on the inclusion and exclusion criteria mentioned in papers I-III, and this interview was included in the final data. However, the current study sample still consisted of 15 participants as one participant later dropped out due to illness. Similar to the study sample in papers I-III, all participants were active to a high degree in the labor market (80-90% of full time). Table 3 summarizes the demographic data for the study sample.

Table 3. Demographic data of the study sample in paper IV.

Demographic variable	Male/Female	N	Mean (SD)
Sex	5/10		
Age			47.4 (14.0)
Education level			
- Junior high school		1	
- High school		7	
- University		7	
Work status			
- Part-time		3	
- Full-time		12	
Occupation setting			
- School		3	
- Health care		2	
- Industry		4	
- Office		6	
PTA			
- Right ear			39.6 (6.4)
- Left ear			34.0 (4.3)

PTA: pure tone average

Data collection in papers I-III

In the quantitative part of the research project, a variety of tests have been employed. Table 4 summarizes the tests that were reported for each paper.

Table 4. The tests reported for papers I-III.

Audiological tests	Paper I	Paper II	Paper III
Pure-tone thresholds	X	X	X
Swedish phonemically balanced words lists S/N+4	X	X	X
Self –reports			
Short-form 36	X		
Hearing handicap inventory for adults	X		
Borg CR-10	X	X	X
Cognitive tests			
Lexical decision-making		X	
Rhyme-judgment		X	
Reading span		X	
The sustained attention to response test		X	
The keep track task		X	
The number letter task		X	
Work-related tasks			
Extraction of information	X	X	
Arithmetic task			X
Orthographic decoding			X
Phonological decoding			X
Serial recall			X

Below follows a description of the tests employed in papers I-III.

Audiological tests

Air- and bone conduction thresholds were measured using standard audiological procedures in a sound-treated booth. PTAs were calculated at 0.5, 1, 2, 4 kHz for each ear and the hearing loss was categorized as mild-moderate hearing loss if PTA was 25-55 dB HL. The Swedish phonemically balanced (SPB) words lists, mixed with speech-weighted noise with a signal-to-noise ratio of +4 dB, were used as speech test material in noise (Magnusson, 1995). Each list is comprised of 50 monosyllabic words for recognition scoring and the participants were instructed to listen and repeat the word that followed a carrier phrase. Performance was scored as proportion of correctly identified words.

Short-Form 36

A validated Swedish version of the SF-36 was employed to measure generic HRQoL (Sullivan et al, 1995). The questionnaire consists of 36 items measuring physical and mental health status domains: Physical Functioning (PF), Role-Physical (RP), Bodily Pain (BP), General Health (GH), Vitality (VT), Social Functioning (SF), Role-Emotional (RE), and Mental Health (MH). Each item has a forced-choice response format, with two to six possible response options ranging from excellent to poor. Scores range from 0 to 100, with higher scores indicating better health status. A total score across the eight domains are not obtained; however, summary scores for physical (PCS) and mental (MCS) health are calculated using norm-based scoring with a mean of 50 (higher scores representing better health status).

Hearing Handicap Inventory for Adults

The Hearing Handicap Inventory for Adults (HHIA) was used to measure hearing handicap (Newman et al, 1990). The HHIA is a 25-item self-assessment scale composed of a 13-item emotional subscale and a 12-item social/situational subscale. Responses were scored as 4 points for “yes”, 2 points for “sometimes” and 0 points for “no”. Scores for the total HHIA range from 0 to 100. Previous studies of the HHIA have shown high internal consistency reliability and test-retest reliability (Newman et al, 1990, 1991).

Borg CR-10 scale

The Borg CR-10 scale was used to measure PE and PD (Borg, 1990). This scale is a combination of ratio and category scaling where verbal expressions and numbers are used congruently on a scale ranging from 0 (no PD at all) to 10 (extremely great). An “absolute

maximum” is located outside the number scale to avoid ceiling effect. The scale was given on a sheet of paper next to the computer to help the participants with the ratings, and they were instructed to first choose the verbal expression that best described their experience and then type in the number corresponding to the degree of effort or disturbance perceived for each of the five working tasks and four conditions, respectively. The Borg CR-10 scale was chosen as a measurement of disturbance because it has shown to be sensitive enough to verify differences between different background conditions in previous studies in individuals with HI and normal hearing (c.f. Hällgren et al, 2005; Larsby et al, 2005). Even though this scale was originally developed to measure PE, it is also a general and common tool for measuring intensity of experiences (Borg, 2008). This includes PD of different types of noise, and the scale has previously been used in several investigations for this specific purpose (Ljungberg et al, 2004; Ljungberg & Neely, 2007).

Cognitive tests

All tasks were administered in the anechoic chamber in quiet via a computer and the instructions were presented in written form and complemented with oral instructions by the test leader. Three of the cognitive tests, lexical decision-making, rhyme-judgement and reading span, are part of a cognitive test battery. The test battery has previously been described in detail in Rönnberg et al (1989) and the tests included in the test-battery are all well-established in the literature of cognitive psychology (Shoben, 1982; Baddeley & Wilson, 1985; Daneman & Merikle, 1996; Hällgren et al, 2001; Hertzog et al, 2003). A description of the cognitive tests follows below:

Lexical decision-making. The lexical decision-making test was used as a measure of lexical access. The task was to decide whether a combination of three letters constituted a real word or not. Six items were initially presented for practice and after that 40 items in total were presented and used for scoring. Half of the items were real words and they were all familiar Swedish three-letter words.

Rhyme-judgment. A rhyme-judgment test was used as a measure of phonologic ability. The task was to decide whether two simultaneously presented words rhymed or not. Words were presented visually on the computer screen. Four items were used for practice and after that 32 items were presented and used for scoring of the measurement. The outcome measures of the lexical decision-making and rhyme-judgment were the proportion of correct responses.

Reading span. The reading span test was used as a measure of WMC. The test used in the current study was a short version of the reading span test created by Rönnerberg et al (1989) based on the original test created by Daneman and Carpenter (1980). The task was to read 24 sentences and to decide whether the sentences were absurd or not, and, after reading sets of three, four or five sentences, to recall either the first or the final words of the sentences in correct serial order. The sets were always presented in the ascending order and the participants were cued to recall the first/last words post stimulus presentation. The outcome measure was the proportion of correctly recalled items.

The Sustained Attention to Response Test (SART). The SART was used as a measure of inhibition (Manly et al, 1999). One digit at a time was presented at the center of the computer screen. The task was to press the space bar as fast as possible when a digit was detected. However, if the digit was “3”, the participants were to withhold their response and await the next stimuli. Each digit remained on the screen until a response had been given or until 1 000 ms had passed. Trials were separated by an interstimulus interval of 500 ms. Of the 120 presented digits, 21 were the digit “3”. The outcome measure was the number of failures to withhold a response.

The keep track task. The keep track task, adapted from Miyake et al (2000), was used as a measure of updating of information. Each trial began with the presentation of four target categories at the top of the computer screen. After this, 15 (mono- or disyllabic) words including 1–4 exemplars from each of six possible categories (countries, colors, metals, fruits, relatives, and animals) were presented one at a time. Words were presented for 3000 ms with an interstimulus interval of 500 ms. At the end of each trial, the participants were asked to write down (in a dialogue box appearing on the screen) the last item from each of the four target categories. The target categories remained on the screen during the whole of each trial. Each trial required three updates for one of the categories (for example, four exemplars of this category were presented), and two, one and no update for the remaining three categories, respectively. By the presentation of the seventh word in each trial, at least one exemplar of each of the four target categories had been presented (i.e. during the presentation of words 8–15, the participants were required to hold four items active in working memory). Two practice trials were followed by six main trials. The outcome measure was the proportion of correctly recalled items.

The number-letter task. The number-letter task, adapted from Miyake et al (2000), was used as a measure of shifting ability. In this task, pairs consisting of one digit and one letter

(for example: 7G) were presented in one of the four corners of the computer screen. The pairs were presented one at a time and in a clockwise manner. The task was to decide whether the digit was odd or even when a pair was presented in the upper half of the screen, and whether the letter was a lower case or upper case when a pair was presented in the lower half of the screen. The participants responded by pressing one of four buttons marked with the words “odd”, “even”, “lower” and “upper”. Stimuli remained on the screen until a response had been given or until 10 s had passed. Twelve practice trials were followed by 38 main trials. Scoring was based upon difference in RT between two consecutive trials: 1) when the present trial was a shift trial and the preceding trial was a no-shift trial and 2) when the present trial was a no-shift trial and the preceding trial was a shift trial. The outcome variable reported to as “shifting” was thus the mean difference between trial 1 and 2.

Work-related tasks

Five tasks were included in this project as visual working tasks. All tasks were general working tasks and not related to any specific profession. They were always completed in an anechoic chamber, in four experimental conditions, in front of a computer. Two of the tasks, the extraction of information and arithmetic tasks, had two levels of difficulty. Below follows a description of each task.

Extraction of information. In this task, tables of 15 numbered items belonging to a semantic category (for example fruits) and both categorical (for example place of origin) and continuous (for example price) information about the items were presented on a computer screen. In each trial, the participants were asked to identify one target item based on a question presented below the table. The participants responded by typing the number (1-15) corresponding to the target item in a box appearing at the bottom of the screen. The tables remained on the screen until a response had been given, or until 60 s had passed. The level of difficulty was manipulated by using one constraint in the easy condition (“Which fruit has the highest price per kilogram?”) and three constraints in the difficult condition (“Which Portuguese fruit of which at least 14 000 kilogram has been sold has the highest price per kilogram?”). There were 16 easy and 16 difficult trials in total, and proportions of correct responses were used as outcome measures of performance.

Arithmetic task. The arithmetic task, in which participants were asked to solve addition problems, was a modified version of a task used by Duverne and Lemaire (2004). On each trial, one number and two to-be-added numbers (e.g. 16 and $9 + 5$) were presented adjacently to each other on the computer screen. The task was to indicate, by means of key press, which

one was the larger of the two (i.e. the single number or the sum of the two to-be-added numbers). The addition problems remained on the screen until a response had been given, or until 30 s had passed. Level of difficulty was manipulated by using single digit operands in the easy condition (e.g. $9 + 5$) and three digit operands in the difficult condition (e.g. $588 + 192$). To encourage exhaustive calculations in the easy task, the difference between the sum of the operands and the single number was never larger than ± 2 (e.g. 16 and $9 + 5$) and in the difficult task the single number was always approximately 1 % (or 5–10 in absolute numbers) from the sum of the operands. In all four conditions, the same 16 easy and 16 difficult arithmetic problems were used. To minimize recognition of problems across conditions, four unique randomized orders, with easy and difficult problems interspersed, were used.

Orthographic decoding. In the orthographic decoding task, participants were presented with two strings of letters at a time. The task was to indicate, by means of key press, which string constituted a correctly spelled Swedish word. The letter strings remained on the screen until a response had been given, or until 10 s had passed. Four lists with different stimuli were used in the four noise conditions. Each list consisted of 24–25 trials.

Phonological decoding. In the phonological decoding task, participants were visually presented with two strings of letters (real words vs. non-words) at a time. The task was to indicate, by means of key press, which string that sounded like a proper Swedish word. The letter strings remained on the computer screen until a response had been given, or until 10 s had passed. Four lists with different stimuli were used in the four noise conditions. Each list consisted of 19 trials. The outcome measures in the arithmetic, orthographic decoding and phonological decoding task was mean RT (based on correct and incorrect responses as well as omissions) and the proportion of correct responses. Trials in all three tasks were separated by an interstimulus interval of 500 ms.

Serial recall. In the serial recall task, eight digits were presented visually on the computer screen in each trial. The digits were presented one at a time for 350 ms and were separated by an interstimulus interval of 400 ms. After the presentation of the final digit, participants were asked to type in (in a dialog box appearing on the screen) each of the eight digits in the order of presentation. Participants were instructed to always write down eight digits recalled in their correct order. In each background condition, there were 10 trials. The outcome measure was the proportion of correct responses.

Background conditions for the work-related tasks

All the working tasks and measures of PE and PD were performed in the following four background conditions, each simulating a typical workplace setting with different sound level:

- Quiet setting. No noise was simulated in this condition.
- Office setting. The office noise used in the experiment was recorded in an office area, in the reception/call center room, at Örebro University. This space consists of three booths with two desks in each booth. This condition introduced intelligible speech of normal level of the receptionist answering phone calls.
- Daycare setting. The daycare noise was recorded in a daycare environment in Örebro. Recording took place in the children's playroom before the morning assembly where the children played freely. The number of children in the playroom varied between eight and twelve during the recording. In the middle of the room there was an open-space area covered by a large carpet. In one corner there was a life-size toy castle and in another corner there was playground decorated like a small kitchen and next to it a couple of tables and a few chairs. This condition introduced intelligible speech at normal to high levels, and consisted of the children talking, screaming and shouting every now and then.
- Traffic setting. The traffic noise used in the experiment was recorded at a crossroads in Örebro during morning traffic. The traffic noise consisted of sounds from cars and trucks driving past the recording location at a range of levels. No intelligible speech was introduced in this condition.

The three types of background noise were recorded by a microphone employing Ambisonics surround sound technique (Malham & Myatt, 1995). From the original recordings, around 15-19 minutes of each noise was extracted, edited and reproduced in an anechoic chamber (5.5 X 5.5 X 4.5 m). Six loudspeakers spaced 60° in a circle were used to reproduce the noise. The participants were seated in the center of the loudspeaker array with a computer performing the working tasks and ratings of PE and PD. The test administrator was always seated outside the anechoic chamber monitoring the participants and administrating the tests. Figure 1 shows how the participants were monitored outside the anechoic chamber and the research setting inside it. To ensure a realistic noise levels, the sound was reproduced with an

equivalent A-weighted sound pressure level of 56.6 dBA, 73.5 dBA and 72.5 dBA for the office, daycare and traffic noise, respectively, matching the level of the original recording locations. The final output of the noise was also looped so that it played continuously until the working tasks were completed by each participant.

Figure 1. The research setting where all tests were administered and inside the anechoic chamber where the participants did the work-related tasks.

Data collection in paper IV

In order to evaluate whether the interview guide was clear, understandable and capable of capturing the research questions, a pilot interview was conducted prior to the data collection. In phenomenographic research, the researcher strives to hold back their own pre-understanding and theories in order to capture the participants' understanding of the phenomenon. It is also important for the researcher to focus on describing the way a phenomenon is understood rather than explaining why the participants would have such understanding (Stenfors-Hayes et al, 2013). The interviewer intentionally adapted to these standpoints during the interviews. All interviews proceeded in an informal, conversational style based on the interview guide.

General procedure

Papers I-III

Data collection in papers I-III occurred on two separate sessions that were completed within four weeks. Figure 2 shows the general procedure.

Figure 2. The general procedure for session 1 and 2 in papers I-III.

Initially, all participants' demographic variables and hearing status were controlled using a demographic questionnaire and audiological tests, respectively. In addition, their individual HAs were checked by an audiologist. After that, the participants were seated in an anechoic chamber in which they completed the six cognitive tests (in quiet). The cognitive tests were performed in the following order: lexical decision-making, rhyme-judgment, reading span, SART, the keep track task, and the number letter task. This was followed by a session where the participants practiced on the five work-related tasks. Thereafter, the five work-related tasks were performed in the four experimental conditions. Two experimental conditions were completed for each session. Session 1 was completed within 2.5 hours, whereas session 2 was finished less than 1.5 hours. In order to counteract any practice effects, all conditions and all working tasks were counterbalanced for both groups. Immediately after completing a working task, the participants were asked to rate how effortful they found the task to be (*"Please rate the effort"*) and how disturbing they found the listening condition to be (*"Please rate the disturbance"*) using the Borg-CR 10 scale. The participants always completed all five working tasks in one condition before performing the next set of tasks in the next condition. The group with HI always wore their HAs when performing the working tasks. After the final condition, the participants filled in the SF-36 questionnaire. The HHIA

was posted to the 40 participants after completing the second session and they were instructed to complete the HHIA and return it in a self-addressed stamped envelope to the examiner.

Paper IV

Initially, all participants were asked about their demographics, such as age, current job, work status and whether they felt their hearing had changed significantly during the 18 months since participation in the quantitative part of the research project. After the initial questions, the participants were encouraged to describe their overall experiences of working with a HI and their thoughts on their working tasks, relationships with colleagues and of what importance HAs had during working hours. Moreover, they were also asked about their positive and negative experiences of these topics, and whether they perceived any complicating and/or facilitating factors at their workplace in general. Follow-up questions were asked for clarification purposes (Bowden & Green, 2005). All interviews were conducted at an Audiological Research Centre and each interview lasted 30-45 minutes.

Analysis of data

Paper I

For analysis of differences between the three groups regarding SF-36, PE and HHIA, a Mann-Whitney U-test was used. All tests were two tailed and conducted at a 5% significance level. The magnitude of group differences was further determined by calculation of effect sizes (ESs) in the SF-36. ES of a between-group difference was estimated by calculating the mean difference, divided by the pooled standard deviation. ES was judged against standard criteria proposed by Cohen (1978): trivial (0 to <0.2), small (0.2 to <0.5), moderate (0.5 to <0.8) and large (0.8+).

Paper II

A one-way analysis of variance (ANOVA) was initially performed on the results of all the cognitive tasks between the two groups (normally-hearing vs. hearing-impaired). Secondly, Pearson's correlation coefficients between each of the cognitive scores and demographic variables were calculated for the total sample. Thirdly, to analyze for within-group and between-groups differences in performance in the work-related task and PE, a factorial ANOVA was performed. This was followed with Bonferroni-adjusted post hoc pairwise comparisons. Finally, Pearson's correlation coefficients were used to examine the possible relationship between cognitive abilities and PE. All tests were two tailed and conducted at a 5% significance level.

Paper III

To analyze for significant differences, a mixed two-way ANOVA was performed, with four within-subject factors (PD in four experimental conditions) and one between-subject factor (hearing-impaired vs. normally-hearing). To examine interaction effects, pairwise t-tests were used. Pearson's correlation coefficients between RT and accuracy of cognitive measures, and cognitive performance (of the working tasks) and self-rated disturbance were also calculated to examine the possible correlation between the different variables. All tests were conducted at a 5% significance level.

Paper IV

All interviews were recorded using a dictaphone and transcribed verbatim. Analyses of the text were performed in accordance to the phenomenographic approach outlined by Dahlgren and Fallsberg (1991). This process is divided into seven steps:

1. Familiarization. Transcriptions of the interviews were read through carefully and an acquaintance of the data was achieved.
2. Condensation. Significant statements or meaning units made by the informants were selected for further scrutiny.
3. Comparison. The selected statements were compared in order to find sources of agreement or variation.
4. Grouping. Answers which appeared to be similar (of understanding the phenomenon) were allocated in the same category.
5. Articulating. A first attempt to describe the essential meaning of each category was made.
6. Labelling. The core meaning of each category were denoted a suitable linguistic expression.
7. Contrasting. Comparisons between the obtained categories, in regard to similarities and differences, were made in order to reach a higher level of abstraction.

In line with Dahlgren and Fallsberg (1991), the analysis did not follow the described sequence slavishly, but rather occurred as a constant interplay between the various steps. The research group continuously discussed the analysis process. The coding and classification of the interviews were continuously discussed by the second and third authors who both had different professional backgrounds than the first author, a reliability and validity assessment in qualitative research known as co-judging.

Ethical considerations

Papers I-III

The studies in papers I-III were approved by the regional ethics committee in Uppsala (Dnr: 2010/072). An information letter was sent to the participants prior to the data collection. Before signing the consent form, all participants were informed and thus aware about the risks, their tasks and how collected data would be handled. None of the participants were paid for their participation, but they received a movie voucher or a flower check for each session. In the current studies, all participants were exposed to noise levels at 56.6, 72.5 and 73.5 dBA for a shorter period of time (around 25-30 mins). If any of the participants were to feel discomfort due to the noise levels, they were all aware that testing would immediately be aborted. As stated before, the test leader (either a licensed audiologist or a research engineer) was always seated outside the anechoic chamber monitoring the participants via a camera positioned inside the chamber (figure 1). The participants could also speak to the test leader at any time via a microphone that was positioned next to the computer where they did all the tests. Before doing the cognitive tests, all participants were informed that none of the tests, separately or as a unity, was a measurement of their intelligence. In addition to the risks with noise levels and cognitive tests, it was also identified that there could be a minor risk of identifying a severe-profound hearing loss or that the test results in the audiogram would require further referral in the hearing clinic. If that were to happen, the licensed audiologists would know how to handle the situation. In the current project, none of the identified risk scenarios occurred.

Paper IV

For the interview study, an amendment was added to the ethics application used in paper I-III. Ethical approval for this amendment was approved by the ethics committee in Uppsala (Dnr: 2010/072/1). Similar to session 1 and 2, all participants got movie vouchers for their participation. No great risks for the participants were identified for taking part in this study. If any of the questions were to upset the participants or making them feel distressed, the interviewer would take a break and ask if they were able to continue the interview. In the current study, none the participants got such a reaction by the questions asked. Informed consent was obtained prior to the interviews.

Summary of the papers

Paper I

The aims of this study were to compare SF-36 and self-reported hearing handicap between two groups of employees with normal hearing and with mild-moderate aided HI, and the SF-36 results were also compared to a normative population. The second aim was to compare effort and disturbance perceived in the two study groups after completing a work related task in simulated office noise (56.6 dBA). A Swedish version of the SF-36 and the HHIA was used to determine HRQoL and self-reported hearing handicap, respectively. An extraction of information task was used as a work related task in the anechoic chamber, and the Borg-CR 10 scale was used to measure PE and PD after completing this task. Forty participants (21 males) with a mean age of 44.3 years (18-64 years) were recruited to the study. The study sample consisted of both hearing-impaired ($n = 20$) and normally-hearing ($n = 20$) participants. The normative sample comprised of 597 matched respondents. A Kolmogorov-Smirnov test for normality was first conducted to ensure a normal distribution on the two study groups (normally-hearing vs. hearing-impaired). The results from this test show that some variables were significant and some non-significant ($p = 0.05$), and because of the small study samples, Mann-Whitney U-test were used for testing of significant differences between groups.

In the SF-36, the two study groups scored equally or almost equally as high in RE, MH, VT and RP subscales. The normally-hearing group had higher scores than the hearing-impaired group in PF, BP, GH and SF. No significant differences emerged in any of the subscales when comparing the results between the group with HI and the normative population ($p > 0.05$). The findings suggest that employees with a mild to moderate HI using HAs report a relatively good HRQoL in relation to normally-hearing controls and the normative population. One significant difference emerged where the group with HI reported significantly lower PF compared to normally-hearing controls ($p = 0.04$). However, due to a larger variation in ratings of PF ($SD = 13.4$) for the group with HI, an analysis of individual data was performed. This showed that two participants with HI scored two times outside the SD of the mean in PF meaning that no significant difference between-groups would be observed if these two participants were removed (mean = 94.7, $SD = 5.5$, $p = 0.11$). When controlling for age, self-perceived hearing handicap, PTA, etiology and duration of HI, no indications were observed for as to why these two participants would score lower than rest of the group with HI. This finding indicates that individual differences for employees with HI

could still be fairly large within-group despite the wide range of exclusion criteria that was utilized for this study. Calculation of ESs further indicated moderate differences in PF and GH between the two study groups. The results from the HHIA further corroborate the findings from SF-36 where mild to moderate hearing loss caused mild difficulties in everyday life for the group with HI, and social/situational and emotional hearing handicap were equally affected. The current results also demonstrated that even though both groups found the office noise to be equally disturbing after performing the extraction of information task, the hearing-impaired group reported the task to be significantly more effortful to complete than the group with normal hearing ($p = 0.004$).

In sum, the present study showed that hearing-impaired employees report a relatively good HRQoL and no significant difference could be observed when comparing the results with the normative population, and their normally-hearing peers except in physical health status. The hearing-impaired employees also reported a mild self-perceived hearing handicap in everyday life. The current results therefore demonstrate that physical health status can be negatively affected even at a mild-moderate severity of HI and that a higher PE is reported from this group when performing a task in office noise, despite the regular use of HAs. These findings along with previous studies indicate that lower physical health status and increased PE in the presence of noise might be associated for employees with HI.

Paper II

The aim of this study was to examine the relationship between WMC, EFs and PE after completing a work-related task in quiet and in traffic noise in employees with aided HI and normal hearing. Participants in this study were identical to the two study groups reported in paper I. Six cognitive tests (lexical decision-making, rhyme-judgment, reading span, SART, the keep track task, and the number letter task) and an extraction of information task (both an easy and difficult version) were employed in this study. All participants completed the six cognitive tests before they did the extraction of information task in quiet and in traffic noise (72.5 dBA). After the extraction of information task was completed, the participants were immediately asked to rate how effortful they found the task to be using the Borg CR-10 scale on the computer.

The findings of this study showed that both groups performed at a similar cognitive level before they performed the extraction of information tasks. Significant correlations between some of the demographic variables and cognitive tasks also emerged in line with

previous research. That is, decreasing cognitive performance (WMC) with increasing age and increased performance (WMC, rhyme-judgment and updating) with higher education. No significant group differences were found when comparing PE in quiet and in noise in the easy and difficult task, meaning that both groups rated PE similarly in both conditions. When analyzing for within-group differences, significant differences emerged between the quiet and the noise condition for each level of difficulty of the task, meaning that the presence of noise yielded a significantly higher PE for both groups, regardless of task difficulty. Performance in the work-related task, on the other hand, showed that the noise did not affect performance for both groups. Post hoc analysis showed that both groups performed significantly lower in the difficult task ($p < 0.05$) compared to the easy task in both conditions, meaning that task difficulty, and not the presence of noise, affected their performance. However, it should be noted that there was a larger difference between the groups in the difficult task, where employees with HI scored, although not statistically significant, lower in quiet and in noise. One reason for this larger difference between-group might be due to the updating ability as the performance of the keep track task was trending towards statistical significant difference ($p = 0.06$), and that the extraction of information task was highly dependent on one's ability to update new information.

Interestingly, significant correlations were also found between PE in noise and updating ability, but not in quiet, where the ability to update information and PE in noise was significantly correlated with the easy task for the group with normal hearing and difficult task for the group with HI. This finding indicates that explicit processing might be involved to a higher degree for both groups in noise, even when the task is visual. In other words, regardless of hearing ability, the employees at work have to actively think about the task and devote cognitive resources to it during the presence of noise, even if the task is non-auditory, which involves executive processes (in this case: updating). The presence of noise does not affect performance, but it affected both groups differently due to the aided HI. More specifically, it affects how and when explicit processing capacity is engaged to solve the task at hand, and that a decreased performance relying on that specific process may lead to a greater PE for the individual in an adverse conditions. The current statistical significant correlations should be interpreted with caution as the strength of the correlation was not very strong ($R^2 = 0.3$ for the group with normal hearing and $R^2 = 0.2$ for the group with HI) when judged against the standard criteria proposed by Cohen (1978). In addition, despite the multiple correlations, a Bonferroni correction was not applied as it was felt that the increase in the risk of a Type 2 error occurring outweighed the potential benefits of reducing the risk

of a Type 1 error. Exact p-values were provided in order to enable the reader to evaluate whether applying a correction for multiple comparisons would have affected the outcome of the analyses. Future studies replicating the present findings would be of interest to conduct.

Paper III

The aim of paper III was to examine the impact of different types of background noise on cognitive performance and PD in employees with aided HI and normal hearing. Participants in this study were identical to the two study groups reported in papers I and II. In this study, four work related tasks (easy and difficult arithmetic task, orthographic decoding, phonological decoding and serial recall) were performed in four simulated work settings (quiet, office noise at 56.6 dBA, daycare noise at 73.5 dBA and traffic noise at 72.5 dBA). A mixed factorial design was conducted to examine the effects of noise under the four experimental conditions. RT and the proportion of correct answers in the working tasks were used as outcome measures of cognitive performance. The Borg CR-10 scale was used to assess PD of the four experimental conditions. After each working task was completed in each of the four background conditions, the participants were immediately instructed to rate how disturbing they perceived the noise to be.

The results demonstrated that both groups obtained high levels of performance and responded rapidly in the different working tasks across all background conditions. No significant between- or within-group differences in cognitive performance were observed across the four background conditions. Ratings of PD, on the other hand, showed that both groups rated PD according to noise level, where higher noise level generated higher PD. Generally, the lowest PD was observed in the quiet condition, and both groups rated PD of the three noise conditions significantly higher than the quiet condition. Interestingly, the present findings also indicate that the group with HI was more disturbed by higher than lower levels of noise (i.e. traffic and daycare setting compared to the office setting). This pattern was observed consistently throughout four working tasks where the group with HI reported a significantly higher PD in the daycare and traffic setting compared to the office noise. In addition, this effect of the high level noise was not observed in the group with normal hearing, who rated all three noise conditions equally similar in each working task, with the exception of reported PD between the daycare and office setting in the serial recall task. Correlation analyses were also performed separately for each group between RT and accuracy of the cognitive measures, and between cognitive performance and ratings of PD. No significant correlations were observed between these different outcome measures.

Taken together, even though the effects of noise did not affect cognitive performance for the group with HI, the findings of PD clearly speak in favour of reducing high noise levels at the workplace for employees with aided HI. This might be due to two main reasons. Firstly, the higher sensitivity to higher level of noise could be due to recruitment meaning that the group with HI perceived the high level noises to be louder than the normally-hearing group. Secondly, HAs were worn by the participants in all listening conditions which could have distorted incoming noise signals and consequently generating an even higher disturbance for the group with HI in the daycare and traffic setting. This finding could indicate that employees with HI are more tired at the end of the working day, despite performing their working tasks just as well as their normally-hearing peers. This in turn may cause participation restrictions in leisure activities outside work or even social isolation. In the current study, all participants were exposed to the different noises during a shorter period of time. However, if employees with HI were exposed to high level noise over a longer period of time this might even be one possible reason for the reduced physical health status and HRQoL in this group demonstrated in paper I. Furthermore, no significant correlations were observed between RT and accuracy of the working tasks, and between cognitive performance and PD. This indicates that, at the moment, no particular robust test can demonstrate the effects different types of background noise may have on individuals. Future studies developing tests that can measure both dimensions, as an indicator of people's perception of disturbance, in a clinical setting would be of interest.

Paper IV

The aim of paper IV was to explore the conceptions of working life among employees with mild-moderate aided HI. This study has a descriptive design, in which data was collected by means of semi-structured interviews and analyzed using a phenomenographic approach.

Fourteen of the participants with HI in papers I-III agreed to participate in the study. In order to evaluate whether the interview guide was clear, understandable and capable of capturing the research questions, a pilot interview was conducted prior to the data collection. The participant in the pilot interview was recruited via the Department of Audiology, Örebro University Hospital, based on the inclusion criteria in papers I-III, and this interview was included in the final data. All interviews were audio-recorded and transcribed verbatim. Analyses of the text were performed in accordance to the phenomenographic approach.

The analysis of the 15 interviews resulted in four main categories describing the participants' conceptions of working life: 1) difficulties in daily work, 2) impact on daily life,

3) communication strategies and 4) adjustments in work environment. A majority of the participants were aware that the difficulties perceived at work due to the HI, such as communication in groups, loud non-verbal noises, inconvenience with HAs and tinnitus had a direct negative impact on daily life. This impact on daily life could in turn generate a sense of exposure during work hours, and physical and mental fatigue after work. Withdrawal was a third major impact that could occur during work and even affect after work activities. Moreover, all participants stated that they used a variety of strategies in order to prevent or repair communication breakdowns at work. Adjustments in the work environment in the form of psychosocial support from colleagues, assistive listening devices and adjustments of room acoustics could facilitate their work situation. The current findings regarding fatigue, extra strain during challenging listening conditions and need for recovery after work are in line with previous literature and the findings of papers I-III. Interestingly, the current study also demonstrated that employees with HI nowadays are more aware about the effects of HI and what could be done to facilitate their situation, both acoustically and technically compared to previous studies. Many of the participants further stated that assistive listening devices and adjustments of room acoustics did not only benefit themselves, but also their normally-hearing colleagues at work.

In conclusion, the four identified descriptive categories show that the effects of HI on the lives of working adults generate far-reaching psychosocial consequences for the individual. The results further demonstrate that these consequences occur even at mild-moderate HI in a group of employees that have been fitted with HAs. This study shows that although employees with mild-moderate HI have been fitted with HAs, there is still a need for extensive services in aural rehabilitation for this population. This includes identifying the need of assistive listening devices, teaching the individual with HI about communication strategies and informing all stakeholders about the consequence of having a HI. The latter is especially important as colleagues showing support and employers making adjustments (technically or acoustically) are facilitating factors that would benefit both employees with HI and those with normal hearing. Future research identifying high-risk groups with HI in the labor market would also be of interest in clinical practice.

GENERAL DISCUSSION AND FUTURE DIRECTIONS

Main findings

The results from papers I-IV clearly demonstrate that noise has negative effects on employees with mild-moderate aided HI. In addition to generating significantly greater effort and disturbance, it is further reported from the participants that noise at work in combination with a HI has an impact on daily life. This includes a sense of exposure during work hours, physical and mental fatigue after work, and withdrawal from social situations in the work environment and leisure activities. However, it is important to state that none of the participants with HI performed significantly worse on the visual working tasks employed in this project compared to their normally-hearing peers. This demonstrates that employees with HI objectively perform the various employed working tasks at a level similar to a well-matched normally-hearing control group. Instead, the findings of this project indicate that working in a noisy environment with a HI occurs at the expense of this group reporting significantly worse results on subjective measurements, including greater effort and disturbance, and lower physical health status. Interviews with these participants further confirm that these effects are indeed mostly due to noise in the work environment which could have a negative impact both physically, mentally and socially during and after work hours.

Performance in the work-related tasks

No significant between-group differences were observed in any of the cognitive skills included in this project. This means that before the participants performed the different working tasks, they were all at a similar cognitive level, suggesting that performance in the working tasks would not differ significantly between-group. Even though the finding of non-significant differences in cognitive performance in the working tasks was somewhat expected, it cannot be denied that the measuring of cognitive performance has been important in the current research project as previous studies have clearly demonstrated that individuals with HI perform significantly lower in certain circumstances (Hygge et al, 1992; Lyxell et al, 2003; Larsby et al, 2005). In addition to different study samples, other reasons for the lack of difference in cognitive performance might be that different tasks, noise conditions and study designs have been employed in these studies. One could speculate that with different noise conditions and other types of visual or auditory only working tasks, or even a greater difficulty for the employed tasks, different results might have been revealed between-group.

Perceived effort and disturbance in noise

The Borg CR-10 scale was used to measure PE and PD in papers I-III. The results indicate that a significantly higher PE is reported by employees with HI in noisy work settings compared to a quiet setting. The same pattern of results was also observed in the group with normal hearing. This implies that the presence of noise does generate a higher effort compared to quiet, for both groups, regardless of hearing level. However, no group differences were observed in PE after performing the extraction of information task in traffic noise (paper II), whereas a significant difference ($p = 0.004$) was observed between-groups in the office condition (paper I). One possible explanation for this difference is that a Mann-Whitney U-test was employed to compare one condition (office noise) in paper I. In paper II, four conditions (quiet and traffic noise in the easy and difficult version of the extraction of information task) were compared to each other which in turn required more from the data (i.e. greater differences between-group) in order for it to be a significant interaction between ratings of PE and the two groups in the factorial ANOVA. The finding of the non-significant difference is not in line with previous studies conducted on this topic as studies have shown that people with HI usually do report a higher PE than normally-hearing controls when noise is present (Larsby et al, 2005; Zekveld et al, 2011). On the other hand, these studies have employed auditory tasks, and not visual tasks which have been used throughout the current project. There could also be a number of other possible explanations for the difference between our results and previous studies. Firstly, two healthy and well-matched groups with the main difference being the mild-moderate HI took part in these studies. Secondly, the present study recruited relatively young employees that were group matched on age and education, and no group differences were observed in cognitive skills before performing the extraction of information task in quiet and in noise, which might have contributed to the similar ratings in PE. Nevertheless, regardless of group differences, the results of paper II demonstrated that higher PE is generated when noise is present and this effect was observed for both study groups.

When comparing the results of PD with the control group, a significantly greater disturbance was reported by the group with HI in the traffic and daycare settings (i.e. the higher noise levels), and not in the office noise and quiet setting. Both groups rated the three noise conditions to be significantly more disturbing than the quiet condition, this finding being consistent with what previous research has shown in individuals with normal hearing (Schlittmeier et al, 2008; Ebissou, 2013). Similar effects of high level noise (60 dBA) have

also been observed in the hearing-impaired group in a study by Jahncke and Halin (2012) where the participants showed higher self-rated fatigue compared to the low level noise (30 dBA). There might be a couple of explanations for the similar findings in this project and their study. Firstly, the higher sensitivity to higher level of noise could be due to recruitment, meaning that the group with HI perceived the high level noises to be louder than the normally-hearing group. Secondly, HAs were worn by the participants in all working tasks which could have distorted incoming noise signals and consequently generated a higher disturbance for the group with HI. As the daycare and traffic noise were around moderate sound levels (73 dBA), one would believe that these two conditions were amplified to an even higher sound level for the group with HI and thus a higher PD was reported. In the current study sample, all participants were fitted with different HAs from different manufacturers which could have affected the present results. As stated in the methods section, before the inception of the study, all participants had their HAs checked by an audiologist, they were all frequent HA users and a majority of the participants were using open-fit HAs due to the mild-moderate HI. This means that regardless of manufacturer, the study sample was relatively homogenous in regards to HA use, HA model and that they were receiving the required amplification based on their individual audiograms.

Taken together, these findings demonstrate that working in a quiet setting or in lower noise levels are recommended for both employees with aided HI and normal hearing, even if the working tasks are non-auditory. Furthermore, the current results also demonstrate that a significantly higher PD is reported by the group with HI under higher noise levels (> 70 dBA). The effects of the high level noise were not observed in the group with normal hearing, who generally rated all three noise conditions equally similar. These results are further confirmed in paper IV, where a majority of the participants with HI stated that loud noise, either non-verbal or comprised of competing speech, could physically hurt their ears and complicate communication at work. Therefore, special attention should be paid to the noise levels of sound environments for individuals with HI in the labor market, both clinically and within occupational health services.

Are explicit processes involved when noise is present?

In paper II, statistically significant negative correlations were found between updating ability and PE in the work-related task in noise, but not in quiet, for both groups. This demonstrates that with lower ability to update new information, a greater PE in noise is experienced regardless of hearing ability. Furthermore, based upon the assumption that explicit processing

capacity is brought into play in noise, updating skills were thus involved in to a higher degree as the noise condition compared to quiet yielded a higher perceptual load. Interestingly, the current results showed that updating skill was only negatively correlated with PE in the easy task for people with normal hearing. By itself, one might think that a more difficult work-related task would generate a higher PE for the group with normal hearing. However, this might not be the case according to Lavie's perceptual load theory (Lavie, 1995, 2005). This theory postulates that distractor perception can be prevented when processing of task-relevant stimuli involves high perceptual load. In other words, when high perceptual load engages full capacity in relevant processing this would leave no spare capacity for perception of the noise. Conversely, in situations of low perceptual load, any capacity not taken up in perception of task-relevant stimuli would involuntarily "spill over" to the perception of task-relevant distractors. This means that the easy task left more room for processing of the noise for the group with normal hearing and explicit processes (such as updating) were therefore engaged in this condition. If this theory were to apply to employees with aided HI, similar patterns of the findings should have been observed between PE in the easy task in noise and updating, and not between the difficult task and updating observed in the results. There might be some explanations as to why there was a group difference in this finding and why the perceptual load theory does not apply to employees with aided HI. In the current project, all participants with HI always wore their HAs when performing the work-related tasks and this might have distorted incoming signals (i.e. traffic noise) which could have led to an even greater distraction (also observed in paper III) for people with HI as more cognitive resources are required to process the input. If this argument was true, disruption of task processing should have been observed between PE in the easy task in noise and updating, as the HAs were worn in both levels of difficulty. In the present study, a trending correlation was indeed observed in the results between the PE in the easy task in noise and updating for the group with HI. This means that participants with HI could still be distracted by the noise in the easy task due to HA, and that explicit processing capacity could still be involved in noise for this group even when performing an easy task. The current statistical significant correlations should however be interpreted with caution as the strength of the correlation was relatively small when judged against the standard criteria proposed by Cohen (1978).

Impact of working with a mild-moderate hearing impairment

In paper I, it was demonstrated that a lower physical health status was observed for the group with HI when compared to the control group, and no significant difference was observed

between the employees with HI and the normative population in HRQoL. This means that although employees with aided HI reports a good HRQoL, there could still be a risk for lower physical health status for this population. A mild self-perceived hearing handicap was further reported from this group. These findings are in line with previous studies where mild severity of hearing loss is somewhat associated with lower HRQoL and mild self-perceived hearing handicap (Ringdahl & Grimby, 2000; Dalton et al, 2003; Chia et al, 2007; Hogan et al, 2009). However, no other significant differences were observed between-group in the other subscales of the SF-36. These results are somewhat in contrast to the findings reported in paper IV, where it was observed that having a HI at work do generate far-reaching consequences for this population such as of sense of exposure, withdrawal and fatigue. One reason for the discrepancy between the results reported in paper I and IV is that the SF-36 questionnaire could lack the necessary sensitivity to identify the consequences of having a HI at work and, and one might argue about employing one generic HRQoL instrument in paper I. The SF-36 was chosen because it is a validated and frequently used instrument in Sweden, and the purpose of the paper I was to specifically compare HRQoL results with two other groups, and not to explore this group's conception of working with a HI using semi-structured interviews, which was the purpose of paper IV. It is true that the SF-36 is not specific to hearing but this is also the reason why data in paper I was supplemented with a hearing-specific measure using the HHIA, showing that the participants with HI did experience mild self-perceived hearing handicap (both emotionally and socially), which was later explored in-depth and confirmed in paper IV. Based on the interviews in paper IV, however, the impact of working with a HI did not seem to be "mild difficulties" this group experienced in everyday life as the results of the HHIA showed in paper I. Again, the discrepancy between these studies might be that one downside of using quantitative questionnaires is that it cannot provide a deeper understanding of the consequences this group might experience from having a HI, but rather indicating issues that should be explored in-depth in another context (i.e. paper IV).

In summary, the quantitative findings show that there is a risk for lower physical health status for employees with a mild-moderate HI even after undergoing aural rehabilitation, and that a mild self-perceived hearing handicap in everyday life is reported from them. When exploring these findings in-depth using qualitative interviews focusing on the impact of working with a HI, it is observed that these consequences affected them to a higher degree than the quantitative questionnaires showed. This includes a sense of exposure that could

generate negative emotions from feeling insecure to frustration, withdrawal from social situations, and physical and mental fatigue both at home and at work.

Clinical implications

The findings of papers I-IV demonstrate the consequences of working with a HI in noise can generate a greater PE, PD and even to some extent affect physical health status. These effects can in turn have an impact on this group negatively, both mentally and socially during and after work. In the findings of paper II, it is further demonstrated that the effects of noise are highly influenced by which task that is to be performed and that the chosen task relies on specific cognitive skills. Therefore, in clinical practice, it is important to identify the profession the individual has, the type of working tasks that the individual is performing on a daily basis (auditory or non-auditory), and what type of sound environment these tasks are being performed in. This finding indicates that a cognitive dimension within hearing health care is an important factor that should be taken into account.

In paper IV, participants who used additional listening equipment stressed that it was much easier for them to do certain tasks. For example, talking on the phone via streamer devices and having extra-large technical ear protectors that could both fit their HAs while also enhancing sounds and protecting their ears from loud noises were perceived as very helpful. In addition to the emphasis on assistive listening devices, acoustical adjustments were also perceived as a facilitating factor in the work environment. For example, some of the participants working in a school setting described that having linen table cloths, carpeting and drapery in the work environment improve room acoustics and decrease reverberation. Many of the participants also stated that these adjustments did not only benefit the individual with HI, but their normally-hearing peers as well. From a clinical perspective, these findings indicate that there is a need for extensive services for employees with HI even after a HA fitting. This thesis further emphasizes the importance of identifying the need for assistive listening devices, examining the room acoustics of the individual's work setting, providing the individual with information about communication strategies and the consequence of having a HI in order to facilitate communication at work. The latter is especially important as colleagues showing support and employers making adjustments at the workplace (technically or acoustically) are facilitating factors that would both benefit employees with HI and those with normal hearing. By itself, these findings might not be anything new in the field of aural rehabilitation. However, here we extend these findings and demonstrate that these services

are applicable and should include a relatively healthy and actively working group with aided HI, even if the degree of the hearing loss is considered as mild-moderate.

Methodological discussion

Generally, the tests included in this project were employed because a majority of them are well-established in the literature and this includes both psychoacoustic, cognitive and subjective measurements (e.g. Rönnberg et al, 1989; Magnusson, 1995; Sullivan et al, 1995; Sullivan & Karlsson, 1998; Borg, 2008). A phenomenographic approach was also used to analyze the data in the interview study. The reason for using this type of approach is that the quantitative data consistently showed a greater variation in the different outcome measures for the group with mild-moderate HI. In phenomenography, the focus is on capturing the variation of conceptions of certain phenomenon and was thus an appropriate approach to use in paper IV.

In the current project, only non-auditory tasks have been employed and one could speculate that with auditory tasks being included, a greater disadvantage for the group with HI would have been observed. As mentioned before, there was a discrepancy in significant differences between paper I and paper II, and also a lack of significance of the cognitive performances in paper III. However, the lack of significant differences in these outcome measures was not due to the lack of power. In paper III, an estimation of the required study sample was performed based on the visual working task used in paper I and II. Assuming that the results would show an effect size of 0.9 ($\alpha = 0.05$) between the two groups in noise, it was estimated that a minimum of 16 participants in each group were needed to reach statistical significance with a power greater than 0.8.

In paper I, the SF-36 profiles in the two study groups were compared to a normative population, selected from the Swedish normative database (Sullivan et al, 1995; Sullivan & Karlsson, 1998). For each of the 20 participants with hearing loss, 29-30 controls were randomly selected from the database matched on age and gender. The reason for including normative data from general population studies is because they provide a useful guide for interpretation of HRQoL scores in patients with different disease conditions. The normative population, unlike the two study groups, was not controlled for hearing loss, early retirement, sick leave, tinnitus, hyperacusis, psychiatric illnesses and other diseases/disabilities which could explain why slightly lower scores were observed for the norms. Ideally, the norm group should have been matched according to education as well. However, the matching becomes

more complicated with three variables and this was not possible in the current project due to amount of data required from this type of matching. Therefore, in order to partially compensate for confounding factors that may have affected the comparison, as many controls as possible were selected from the database (i.e. 29-30 controls) for each participant with HI.

In paper II, despite the multiple correlations, Bonferroni corrections were not applied as it was felt that the increase in the risk of a Type 2 error occurring outweighed the potential benefits of reducing the risk of a Type 1 error. Exact p-values were instead provided in order to enable the reader to evaluate whether applying a correction for multiple comparisons would have affected the outcome of the analyses. On the other hand, there are arguments as to why the statistical significant correlations between PE in noise and updating skill are valid: 1) the task is highly based upon updating skills and 2) no other statistical significant correlations emerged with the different cognitive tasks, and the involvement of updating was only observed in the noise conditions for both groups.

Interdisciplinary perspective

The results from papers I-III demonstrated that noise has negative effects on employees with mild-moderate aided HI including the perception of significantly greater effort and disturbance, and even to some extent a lower physical health status. Paper IV further corroborated these findings showing that this group reported that physical and mental fatigue were generated by noise at the workplace, which could also affect them socially and emotionally in the form of withdrawal and a sense of exposure. In critical realism, the identification of mechanisms on different levels and the integration of new knowledge are two central concepts. Four levels have been studied and identified in the current thesis, and it is also observed that many of these negative consequences could be generated by working with a HI in noisy sound environments at the workplace. This thesis hence shows that studying employees with aided HI has required a non-reductionist approach. In other words, HI at the workplace is not merely a psychoacoustic, cognitive, physiological or psychosocial phenomenon, but rather a complex phenomenon that should be studied using different methodologies. Table 4 illustrates the main findings of papers I-IV on four analytical levels and the possible mechanisms that could generate negative consequences for employees with aided HI in certain contexts at the workplace.

Table 4. The main findings of papers I-IV on different analytical levels and the possible mechanisms that could lead to negative consequences in certain contexts.

Level	Possible mechanisms	Example of context	Negative consequences
Psychosocial	Reduced speech recognition performance in noise due to hearing impairment	Communication in groups	Withdrawal and a sense of exposure
Physiological	Extra effort/concentration needed to do certain tasks in noise	Communication in groups	Physical fatigue and lower physical health status
Cognitive	Involvement of explicit processes (i.e. updating skills) in noise	Performance of various working tasks in noise	Greater perceived effort/mental fatigue
Psychoacoustic	Recruitment and the use of hearing aids	High level noise (> 70 dBA)	Greater perceived disturbance

A mixed methods design has been used in the current thesis, employing both psychoacoustic, subjective and cognitive measurements, and a qualitative approach. This seems appropriate as some of the findings in the quantitative part of the project were in agreement with the findings of the qualitative part. Moreover, in order to provide a more comprehensive view of the studied phenomenon, different methodologies have also been able to capture different findings on different levels. These findings could be an explanation as to why individuals with HI have an unfavorable position in the labor market such as poorer health, increased sick leaves, unemployment and early health-related retirement when compared to the population at large (Statistics Sweden, 2003). However, one should bear in mind that table 4 is a conceptual framework demonstrating the interdisciplinary perspective of the target population in the current thesis. In reality, different levels are entwined and a lot of mechanisms could be supporting or counteracting each other, and the outcome in a specific context is the result of a very complex interplay between different levels and mechanisms (Danermark & Gellerstedt, 2004b). Therefore, if this thesis had other aims or employed different methodology, it is important to note that different levels, mechanisms and outcomes might have been observed and identified.

Future directions

This thesis investigated the interaction between HI, cognitive skills, the effects of different occupational noises and working tasks in a group of employees with aided HI. The main findings show that there is a complex interaction between these four factors and that the consequences of working with a HI in noise could generate far-reaching psychosocial consequences for the individual even at a mild-moderate HI. However, the literature for this target group is still sparse and not much is known about hearing-impaired employees and their situation at work. For reasons yet unknown, this study group has consistently throughout the project shown a greater variation in different outcome measures compared to the group with normal hearing. Future research identifying high-risk groups with HI in the labor market would therefore be of interest. Furthermore, studies examining other target populations and comparing it with the current findings would also provide valuable knowledge. For example, these study populations could be employees with a severe-profound HI using HAs or cochlear implants, or even having additional disabilities such as individuals with deafblindness. At this stage, more research is also needed to unravel the complex area of research between factors such as cognitive processes, hearing and PE. Additional research focusing on including and comparing other types of cognitive tests, work-related noises and working tasks could provide a clearer explanation as to why the group with HI seemed to be more sensitive to noise (i.e. greater effort and disturbance perceived) while doing certain tasks when compared to those with normal hearing. Finally, one of the aims this project had was to develop tests and assessment methods that allow for analysis and assessment of perceived problems in clinical settings. In the paper III, however, no significant correlations were found between objective and subjective outcome measures. Based on the findings of this thesis, this indicates that one particular test cannot be recommended to demonstrate the effect different types of background noise may have on individuals. Future studies developing tests that can measure both a cognitive and subjective dimension, as an indicator and evaluation of people's perception of disturbance in a clinical setting, would be of value and importance.

CONCLUSIONS

- Employees with mild-moderate aided HI report a lower physical health status compared to their normally-hearing peers, and physical fatigue is experienced by the majority of the participants with HI after work.
- Employees with aided HI do not perform significantly worse on the cognitive tests or visual work-related tasks included in this project. However, greater perceived effort and disturbance are observed for employees with HI when noise is present.
- Moreover, even a mild-moderate aided HI can generate psychosocial consequences for this group such as a sense of exposure at work, and withdrawal from social activities at work and at home.
- In clinical practice, in addition to a HA-fitting, there is still a need for extensive services in aural rehabilitation for this population including the need for assistive listening devices, teaching the individual about communication strategies and informing stakeholders about the consequence of having a HI.
- Future research should identify high-risk groups with HI in the labor market. More research is also needed to unravel the complex area of research between factors such as cognitive processes, hearing and effort.

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