JYU DISSERTATIONS 221

Hannele Polku

Associations of Hearing Difficulties, Life-Space Mobility, Quality of Life and Depressive Symptoms Among Older Adults

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF SPORT AND
HEALTH SCIENCES

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ABSTRACT

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Difficulty in hearing is common among older adults and may complicate engagement in everyday life situations, thereby reducing quality of life. In this study, I examined cross-sectional and longitudinal associations between older adults' hearing difficulties and life-space mobility and, whether this association is modified by use of a hearing aid. Moreover, I studied the associations of older adults' quality of life with hearing difficulties and hearing sensitivity, and the association between life-space mobility and depressive symptoms. This study forms part of the "Life-Space Mobility in Old Age" (LISPE) -study with community-dwelling older adults aged 75 to 90 years. In total, 848 older adults took part in the baseline measurements, 816 in the first follow-up one year later and 761 in the second follow-up two years after the baseline. Additionally, a random sample of 169 persons drawn from the LISPE baseline cohort participated in a substudy, which included audiometric measurements. Information on perceived hearing difficulties and perceived benefit from hearing aid use, life-space mobility, quality of life and depressive symptoms were based on self-reports. Older adults who experienced more hearing difficulties in different everyday situations reported lower life-space mobility than those who reported no hearing difficulties. At the two-year follow-up, the presence of hearing difficulties compared to not having hearing difficulties doubled the risk for reporting life-space limited to nearby areas only. Participants who perceived hearing aid use as more beneficial reported higher life-space mobility than those who perceived hearing aid use as less beneficial. Perceived hearing difficulties in different daily situations were associated with poorer quality of life, whereas audiometrically measured hearing showed no association with quality of life. Lower life-space mobility correlated with a higher number of depressive symptoms. The results of the present study indicate that hearing difficulties typically experienced in old age are associated with poorer quality of life and less involvement in everyday life-situations, which in turn coincides with a higher number of depressive symptoms. Better understanding of these links may help in developing interventions to support positive life experiences among people with hearing difficulties, restricted life-space and depressive symptoms.

Keywords: impaired hearing, hearing aid, life-space mobility, quality of life, depression, old age

TIIVISTELMÄ (FINNISH ABSTRACT)

Polku, Hannele
Kuulovaikeuksien, elinpiirin, elämänlaadun ja masennusoireiden väliset yhteydet ikääntyneillä henkilöillä
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Kuulovaikeudet ovat yleisiä ikääntyneillä henkilöillä. Ne voivat vaikeuttaa suoriutumista monissa jokapäiväisissä tilanteissa ja heikentää näin elämänlaatua. Tämä väitöskirjatutkimus tarkastelee ikääntyneiden ihmisten kuulovaikeuksien, elinpiirin, elämänlaadun ja masennusoireiden välisiä yhteyksiä. Liikkumisaktiivisuus elinpiirissä kuvaa henkilön osallistumista arkipäivän tilanteisiin. Tutkimuksessa käytettiin kaksivuotisen "Life-Space Mobility in Old Age"(LISPE) -seurantatutkimuksen aineistoa. Ensimmäiseen mittaukseen osallistui 848 iältään 75—90 vuotiasta henkilöä, joista 816 osallistui seurantamittauksiin vuoden, ja 761 kahden vuoden päästä. Lisäksi 169 alkuperäisestä tutkimusjoukosta satunnaisesti valittua henkilöä osallistui tutkimukseen, jossa heille tehtiin audiometrinen kuulomittaus. Koettuja kuulovaikeuksia, kuulokojeen käytöstä koettua hyötyä, liikkumisaktiivisuutta elinpiirissä, elämänlaatua ja masennusoireita mitattiin itsearvioinneilla. Tulosten mukaan kuulovaikeuksia arjen eri tilanteissa kokevilla ikääntyneillä henkilöillä liikkumisaktiivisuus elinpiirissään oli vähäisempää verrattuna henkilöihin, jotka eivät kokeneet kuulovaikeuksia. Elinpiiri rajoittui pelkästään lähiympäristön alueelle lähes kaksi kertaa todennäköisemmin kuulonsa heikoksi kokevilla henkilöillä. Kuulokojeen käytöstä enemmän hyötyä kokevilla henkilöillä liikkumisaktiivisuus elinpiirissä oli korkeampi kuin niillä, jotka kokivat kuulokojeen käytöstä vähäisempää hyötyä. Koetut kuulovaikeudet olivat yhteydessä myös heikentyneeseen elämänlaatuun, kun taas audiometrisesti mitatun kuulon tarkkuudella ja koetulla elämänlaadulla ei ollut tilastollisesti merkitsevää yhteyttä. Vähentynyt liikkumisaktiivisuus elinpiirissä oli yhteydessä suurempaan masennusoireiden määrään. Tulokset osoittivat, että vanhuusiässä tyypillisesti koetuilla kuulovaikeuksilla on yhteys vähäisempään osallistumiseen ja aktiivisuuteen arjen toiminnoissa, sekä elämänlaadun heikentymiseen. Ymmärtämällä näitä yhteyksiä paremmin voidaan tunnistaa varhaisemmassa vaiheessa ne henkilöt, joilla on kohonnut riski psyykkisen ja fyysisen toimintakyvyn heikentymiseen tulevaisuudessa, mikä voi myös auttaa kohdistamaan toimintakykyä ylläpitäviä interventioita aikaisessa vaiheessa.

Asiasanat: kuulo, kuulokoje, elinpiiri, elämänlaatu, masennus, ikääntyneet

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Jyväskylä 29.5.2020
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FIGURES

TABLES

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, which will be referred to by their Roman numbers. The thesis also includes unpublished data.

I Polku H, Mikkola TM, Rantakokko M, Portegijs E, Törmäkangas T, Rantanen T, Viljanen A. 2015. Self-reported hearing difficulties and changes in life-space mobility among community-dwelling older adults: a two-year follow-up study. BMC Geriatrics 15(1): 1—7.

II Polku H, Mikkola TM, Gagné J-P, Rantakokko M, Portegijs E, Rantanen T, Viljanen A. 2018. Perceived benefit from hearing aid use and life-space mobility among community-dwelling older adults. Journal of Aging and Health 30(3): 408—420.

III Polku H, Mikkola TM, Rantakokko M, Portegijs E, Törmäkangas T, Rantanen T, Viljanen A. 2018. Hearing and quality of life among community-dwelling older adults. The Journals of Gerontology: Series B 73(3): 543—552.

IV Polku H, Mikkola TM, Portegijs E, Rantakokko M, Kokko K, Kauppinen M, Rantanen T, Viljanen A. 2015. Life-space mobility and dimensions of depressive symptoms among community-dwelling older adults. Aging and Mental Health 19(9): 781—789.

As the first author of the original publications and after giving due consideration to the comments from the co-authors, I have drafted the study design and research questions for the publications, prepared the data for statistical analysis, performed the statistical analysis with help from statisticians and assumed the main responsibility for writing the manuscripts. I actively participated in the data collection at the second follow-up of the "Life-Space Mobility in Old Age" (LISPE) study and related substudy "Hearing, cognition and well-being". These data were used in Studies I, II and III. LISPE baseline data were used in Study IV.

ABBREVIATIONS

ADL	Activities of daily living
ANCOVA	Analysis of covariance
ANOVA	One-way analysis of variance
APHAB	Abbreviated Profile of Hearing Aid Benefit - questionnaire
β	Standardized coefficient beta
BDI	Beck Depression Inventory
BEHL	Better ear hearing threshold level
CES-D	Centre for Epidemiological studies Depression Scale
CHL	Conductive hearing loss
CI	Confidence interval
dB	Decibel
DSM	Diagnostic and Statistical Manual of Mental Disorders
EU	European Union
GDS	Geriatric Depression Scale
GEE	Generalized estimating equations
HA	Hearing aid
HERE	Hearing in Real-Life Environments
HHIE	the Hearing Handicap Inventory for the Elderly
HL	Hearing level
IADL	Instrumental activities of daily living
ICD	International Classification of Diseases
IPA	Impact on Participation and Autonomy questionnaire
IQR	Interquartile range
kHz	Kilohertz
LISPE	Life-Space Mobility in Old Age
LSA	the University of Alabama at Birmingham Life-Space Assessment (LSA) -questionnaire
LSM	Life-space mobility
MMPI	Minnesota Multiphasic Personality Inventory
MMSE	the Mini-Mental State Examination
N	Number of participants
OR	Odds ratio
p	p-value, indicator of statistical significance
PCM	the Press-Competence Model
P-E	Person-environment
PTA	Pure-tone average
QoL	Quality of life
SD	Standard deviation
SE	Standard error
SNHL	Sensorineural hearing loss
SPPB	Short Physical Performance Battery
SSQ	the Speech, Spatial and Qualities of Hearing Scale

UAB	the University of Alabama at Birmingham
WHO	the World Health Organization
WHOQoL-Bref	World Health Organization Quality of Life Assessment short version
ZSDS	Zung's Self-Rating Depression Scale

CONTENTS

1 INTRODUCTION

According to World Health Organization (WHO) projections, 630 million people worldwide will be living with disabling hearing loss by the year 2030 (WHO 2018). Most of these hearing-impaired people will be over 60 years of age and the hearing-impaired population will continue to increase as the number of people reaching higher ages rises (Mathers, Smith & Concha 2000, Graydon et al. 2019). Globally, hearing loss is the fourth highest cause of disability (Brown et al. 2018, WHO 2018). In Finland, age-related hearing loss ranks eighth in the list of the top 10 causes of years lived with disability, and its prevalence increased by almost 21% during the period 2007-2017 (Institute for Health Metrics and Evaluation 2019).

Age-related hearing loss, presby(a)cusis, is the most common sensory impairment among older adults (Fook & Morgan 2000; Gratton & Vazquez 2003; Yueh & Shekelle 2007; Ciorba et al. 2012). In presbycusis, hearing loss begins gradually; first affecting the ability to hear high voices and then expands to the area of hearing the speech. Thus, hearing loss is not always noticed until it starts to hamper daily life (Davis et al. 2016). Use of a hearing aid (HA) may improve hearing performance and thus reduce these perceived negative consequences of hearing difficulties (Kochkin & Rogin 2000).

Disability refers to a situation where individual resources are insufficient to meet the demands of the environment (Nagi 1976). According to the ecological model of aging (Lawton & Nahemov 1973), individuals' functioning is strongly related to the balance between individuals' capacities, such as health, motor and sensory skills, and cognitive functioning, and environmental demands in both the physical and social contexts. This interaction is termed person-environment fit (P-E fit) (Lawton & Nahemow 1973). With increasing age, people became more vulnerable to imbalance in P-E fit (Lawton & Nahemow 1973; Wahl, Iwarsson & Oswald 2012). When a person's capacities are sufficient to cope with environmental demands, he/she has a possibility to maintain control over important aspects of everyday life, such as participating in valued activities (Wahl, Iwarsson & Oswald 2012). To function at an optimal level in different environments requires different personal competencies. For example, a person with mild hearing loss may not perceive difficulties in a silent environment; in a noisy environment, however, difficulties in hearing may hamper the person's functioning and thus become noticeable. Hence, the effect of hearing difficulties on older adults' everyday life depends not only on the person, but also on the interaction with the environment (Noble & Hetú 1994).

Many closely related concepts (such as "active", "healthy", "successful", or "optimal" aging) have been used to define "good aging" in the gerontological literature. However, so far, no widely accepted definition exists (Phelan & Larson 2002; Fernandes-Ballesteros et al. 2013; Nordvik et al. 2018). However, the above concepts all refer to a positive way of aging and to what is seen important for quality of life (QoL) in old age. In this study, QoL was investigated according to the WHO definition, which states that QoL comprises various aspects of an individual's daily life: physical and psychological health, environment and social relations (WHOQoL Group 1994). In previous studies conducted among older adults, one of the most commonly reported components of QoL is the maintenance of autonomy and independent functioning, meaning the maintenance of good physical, psychological, social and cognitive functioning, which allows people to remain active, independent and fully integrated in society as they grow old (Roos & Havens 1991; Strawbridge et al. 1996; Rowe & Kahn 1997; Depp & Jeste 2006; Wahl, Iwarsson & Oswald 2012; WHO 2012; WHO 2017). The ability to hear well is important for social interaction and participation in various daily activities and is also associated with better cognitive and physical functioning. Consequently, hearing difficulties can have noticeable effects on older adults' QoL (Hogan et al. 2009; Wallhagen 2010; Lin et al. 2013; Hyams, Hay-McCutcheon & Scogin 2018).

Individuals' physical and mental capacities form the basis for their activity, indicating what they are potentially capable of doing. However, these capacities do not reveal what an individual with a given level of capacity actually does in his/her everyday environment (Rowe & Kahn 1997). Older adults' everyday activity can be described by their life-space mobility (LSM). LSM refers to the spatial environment a person purposely moves through in daily life, the frequency of this activity and the need for assistance in its accomplishment (Baker, Bodner & Allman 2003). LSM indicates the level of actual mobility and independence a person has in moving around, and therefore also reflects the level of community engagement. LSM also describes how an individual uses his/her competencies to meet environmental demands in real-world situations. Thus, unlike traditional, performance-based mobility tests, it provides information on individuals' participation in everyday activities (Stalvey et al. 1999; Xue et al. 2008; Rantanen et al. 2012; De Silva et al. 2019). Shrinking life-space restricts participation in normal daily life situations (WHO 2001). This may mean giving up valued activities and lead to poor QoL (Cohen-Mansfield, Shmotkin & Hazan 2010). Reduced engagement with the environment also often coincides with depressive symptoms in old age (Choi & McDougall 2007; Fiske, Wetherell & Gatz 2009). It can also be assumed that reduced LSM is a sign of a more general disablement process in old age (Rantanen et al. 2012).

In this PhD thesis, I investigated how age-related changes in hearing relate to older adults' LSM and whether this association is modified by HA use. Additionally, I examined how hearing sensitivity and hearing difficulties in everyday life situations correlate with older adults' QoL and the association between LSM and depressive symptoms.

2 REVIEW OF THE LITERATURE

2.1 Theoretical background of the study

Conceptually, this study draws on the ecological model of aging (Figure 1), also known as the press-competence model (PCM), by Lawton and Nahemov (1973). This model provides a framework for viewing individuals' ability to interact with their environment. The model focuses on the fit between an individual's capacities and the demands (or press) of the environment (P-E fit). According to the PCM, the fit between an individual's capacities (such as health, sensory and motor skills and cognitive functioning), and the demands (or press) of the environment, is crucial for the individual's functioning. As posited by the model, every person has an optimal state of functioning, meaning a situation in which their capacities and environmental demands and opportunities are in balance and thus show an ideal P-E fit. In later life, individuals' capacities typically diminish and their ability to cope with environmental demands weakens. Thus, older adults are more predisposed to environmental press. In this case, to maintain optimal behaviour requires adaptations in competencies and/or the environment, for example using assistive devices (Lawton & Nahemov 1973; Wahl & Lang 2003; Thomése & van Groenou 2006; Wahl, Iwarsson & Oswald 2012).

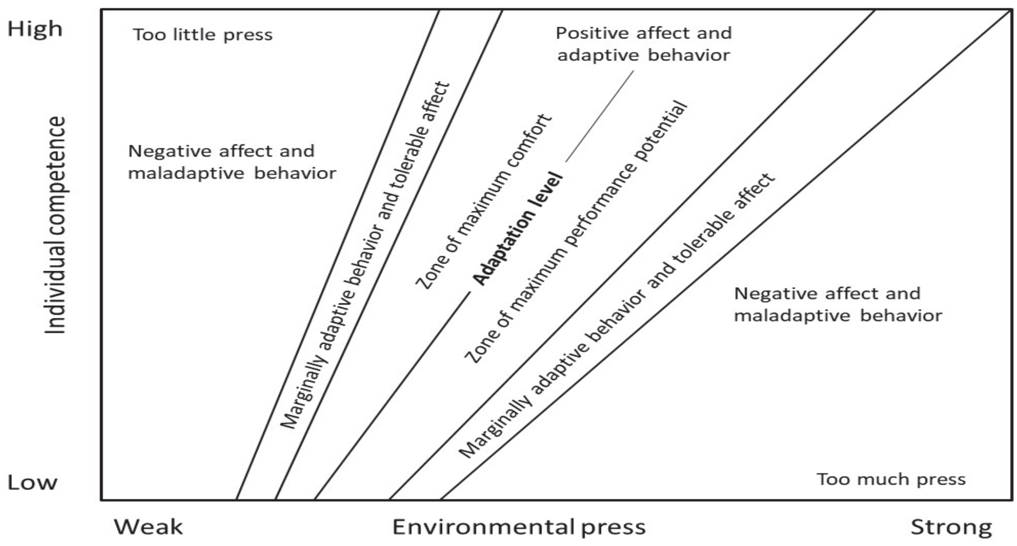

FIGURE 1 The ecological model of aging (modified from Lawton & Nahemow 1973). In the model, the Y-axis represents an individual's competencies and the X-axis indicates the amount of environmental press.

2.2 Hearing in older adults

The sense of hearing refers to the ability to obtain and interpret sound vibrations from the environment. The human auditory system consists of the outer ear, the middle ear and the inner ear. The hearing process requires that these components work together in order to convert sound waves into information the brain can interpret as sounds. Hearing loss occurs when one or more parts of the auditory system do not function normally (Musiek & Baran 2018, pp.1-19).

The hearing process starts from the outer ear, which comprises two parts: the pinna (or auricle) and the ear canal. The pinna forms most of the visible ear and it has an important role in capturing and concentrating sounds emanating from the environment. Sound waves enter the ear canal, which directs sounds from the outer ear into the middle ear. Sound waves cause the tympanic membrane (eardrum) in the middle ear to vibrate. These vibrations move through small interconnected bones (ossicles) to the cochlea in the inner ear and cause the fluid in the cochlea to move. In the cochlea, hair cells at one end transmit information on low pitch sounds and hair cells at the other end transmit information on high pitch sounds. Each sound frequency vibrates the membrane at one location and thus this mechanism enables different pitches within the sound to be heard. The amplitude of the vibration increases with volume of the sound, making it possible to hear loudness. Movement of the fluid in the cochlea bends the hair cells, creating neural signals that are then transmitted to the auditory nerve. The auditory nerve sends signals to the brain, where they are then interpreted as sounds (Musiek & Baran 2018, pp. 1-19). The vestibular system in the inner ear is a sensory system that provides the sense of balance and spatial orientation (Angelaki & Cullen 2008).

2.2.1 Assessing hearing in older adults

Auditory assessment

Auditory assessment of hearing sensitivity is commonly based on air-conducted pure-tone thresholds (Heinrich et al. 2019; Mener et al. 2020). In pure-tone audiometry, individual tones of different frequencies (usually from 0.125 to 8 kHz) are presented at different intensities (decibel, dB) to each ear in a soundproof room (Kutz, Mullin & Campbell 2012). The aim is to identify the faintest sound threshold at each frequency that a person can detect. Sound can be conducted to the inner ear either via air (air-conducted signals), using headphones, or via the cranial bones (bone-conducted signals). Pure-tone audiometry can be used to define the severity of hearing loss, and air- and bone-conducted hearing thresholds can be compared to identify whether a person has sensorineural, conductive or mixed hearing loss (Fook & Morgan 2000; Bainbridge & Wallhagen 2014). Pure-tone audiometry only measures the ability to hear tones, not the ability to understand words or speech, and therefore does not reflect individuals' real-life communication abilities. In speech audiometry, the purpose is to detect how many words, presented at different intensities, a person hears correctly (Fook & Morgan 2000; Bainbridge & Wallhagen 2014). Other auditory assessment tools include for example, tuning fork tests, such as Rinne's test and Weber's test (Crowley & Kaufman 1966; Burkey et al. 1998; Fook & Morgan 2000) and whispered voice-test (MacPhee, Crowther & McAlpine 1988; Pirozzo, Papinczak & Glasziou 2003).

The degree of hearing loss is usually defined based on the pure-tone average (PTA) of air-conduction audiometric hearing threshold level over frequencies 0.5-4 kilohertz (kHz) (Hannula 2011; Olusanya, Neumann & Saunders 2014). Both the WHO and European Union (EU) expert group recommend the use of better ear hearing threshold level (BEHL) over frequencies 0.5-4 kHz (Hannula 2011). The two main standardized classifications of hearing loss, the WHO classification and the EU classification, both classify hearing loss as mild, moderate, severe or profound, but use slightly different hearing threshold levels ($BEHL_{PTA\ 0.5\text{-}4\ kHz}$) (Roth, Hanebuth & Probst 2011). According to the WHO classification, the normal hearing threshold level is 25 dB hearing level (HL) or less (EU: 21 dB HL or less), mild loss 26-40 dB HL (EU: 21-39 dB HL), moderate loss 41-60 dB HL (EU: 40-69 dB HL), severe loss 61-80 dB HL (EU: 70-94 dB HL) and profound hearing loss 80 dB HL or above (EU: 95 dB HL or above) (Mathers, Smith & Concha 2000; Roth, Hanebuth & Probst 2011). Mild hearing loss increases listening efforts, especially in the presence of background noise, and soft speech may not be heard. Moderate hearing loss hampers interaction with other people and hearing conversational speech becomes demanding. When the PTAs are higher than 40 dB in the better ear, a person will, if amplification is not used, miss the majority of conversational speech sounds (Genther et al. 2015). In addition, severe hearing loss also affects sound quality and profound hearing loss means deafness (Kutz, Mullin & Campbell 2012).

Self-reported hearing difficulties

Although audiometric measures can be used to determine the severity of hearing loss and serve as objective measures of hearing ability, they do not automatically reflect how people perceive their hearing difficulties (Fook & Morgan 2000; Gopinath et al. 2012a). The subjective consequences of hearing loss, such as perceived communication and psychosocial difficulties related to hearing loss and effects on QoL, cannot be predicted from audiometric data alone (Hallberg, Hallberg & Kramer 2008; Kiely et al. 2012a; Weinstein 2015).

People perceive their hearing difficulties differently. According to some earlier studies, only a small proportion of people with audiometrically defined hearing loss report having hearing difficulties (Dalton et al. 2003; Agrawal, Platz & Niparko 2008; Solheim, Kvaerner & Falkenberg 2011), at least if hearing loss is mild. People with moderate or worse hearing loss are more likely to notice that their hearing has weakened (Feder et al. 2015). In contrast, some studies have found that some people with only mild audiometrically measured hearing loss experience significant hearing-related difficulties (Newman et al. 1997; Hannula et al. 2011). These conflicting findings support the view that self-reports of a person's ability to hear and cope with hearing difficulties in different daily situations are valuable.

Self-reported measures of perceived hearing difficulties can be obtained using interviews or questionnaires. Epidemiological studies have frequently used several structured questionnaires (Bentler & Kramer 2000). One of the most used questionnaires is the Hearing Handicap Inventory for the Elderly (HHIE), which evaluates the emotional, social and situational effects of hearing impairment (Ventry & Weinstein 1982). Another commonly used questionnaire is the Speech, Spatial and Qualities of Hearing Scale (SSQ), which is designed to evaluate how well a listener would manage in various everyday listening situations and the level of spatial hearing (Gatehouse & Noble 2004). Some questionnaires, such as the Abbreviated Profile of Hearing Aid Benefit (ABHAB) (Cox & Alexander 1995; Cox, Alexander & Grey 2003), have been specifically developed to assess the perceived effectiveness of hearing aid use.

The main focus in this PhD thesis is on self-reported hearing difficulties, defined as hearing-related problems that an individual perceives in his/her everyday life. As the presence of hearing difficulties was defined based on self-reported ability to hear in various everyday situations, it therefore reflects a functional limitation rather than biological loss of hearing acuity.

2.2.2 Age-related changes in hearing

Age-related hearing loss, presbycusis, is one of the commonest chronic health conditions among older adults, and hearing loss is the fourth leading contributor to years lived with a disability worldwide (Brown et al. 2018; WHO 2018). The prevalence of hearing loss increases dramatically as a function of age (Gates

& Mills 2005; Chia et al. 2007; Gopinath et al. 2011; Lin, Niparko & Ferrucci 2011; Roth, Hanebuth & Probst 2011; Kiely et al. 2012a). Consequently, as the life expectancy of populations rises, a considerable increase in the number of older adults with hearing loss in the Western world is expected (Lanzieri 2011; GBD 2017 Mortality Collaborators 2018; WHO 2018). According to WHO projections, 630 million people worldwide will be living with disabling hearing loss by the year 2030 and over 900 million by 2050, unless action is taken to improve hearing care (WHO 2018).

The prevalence of hearing loss among older adults differs depending on whether hearing measures are based on audiometric measurements or self-reports. For audiometric measurements, earlier studies have reported hearing loss (PTA $_{0.5\text{-}4\ kHz}$ >25 dB) prevalence rates ranging from 55% to 68% among adults aged 70 to 80 years and from 80% to 90% among adults aged 80 years or older (Lin et al. 2011b; Feder et al. 2015; Goman & Lin 2016). Hearing loss is more common among men than same-aged women (Hietanen et al. 2005, Lin et al. 2011b, Feder et al. 2015). For self-reported hearing difficulties, previous studies have reported prevalence rates ranging from 19% to 35% among older adults over 65 years of age (Chou 2008; Amieva et al. 2015), from 21% to 40% among people aged 70 years or older (Wiley et al. 2000; Mikkola et al. 2015a) and from 33% to 45% among older adults over 80 years of age (Wiley et al 2000; Hietanen et al. 2004). In a Nordic study (Hietanen et al. 2005), 41-57% of men and 28-37% of women aged 75 years had self-reported hearing difficulties.

Etiology of hearing impairment

Hearing loss is categorized into four types : sensorineural, conductive, mixed and neural hearing loss.

Sensorineural hearing loss (SNHL) is the most common type of hearing loss (Cruickshanks et al. 1998), accounting for more than 90% of all cases (Yueh et al. 2003). SNHL results from damaged or missing sensory cells (hair cells) in the inner ear (cochlea) or the cochlea nerve (Fook & Morgan 2000; Bance 2007; Yueh & Shekelle 2007). Both external and intrinsic factors may lead to SNHL. The hair cells may be abnormal at birth due to hereditary disorders or they may be damaged during the lifetime as a result of external causes. These external causes include for example, metabolic diseases, such as diabetes mellitus (Bainbridge, Cheng & Cowie 2010), systemic autoimmune diseases, like rheumatoid arthritis (Mathews & Kumar 2003), traumas, infections, ototoxic drugs (e.g., aminoglycosides, hydrocodone, methotrexate, loop diuretics) and chemicals (exposure to heavy metals), and noise exposure (Pyykkö et al. 2003; Tambs et al. 2003; Rizzi & Hirose 2007).

Presbycusis is the most common type of SNHL and it is also the most prevalent sensory impairment among older adults (Fook & Morgan 2000; Gratton & Vazquez 2003; Yueh & Shekelle 2007; Ciorba et al. 2012; Graydon et al. 2019). In presbycusis, hearing ability deteriorates progressively and bilaterally over the time. Presbycusis is a result of genetic susceptibility and lifetime exposure to environmental factors (i.e. noise, exposure to ototoxic drugs, chronic diseases), although it is not usually possible to determine the relative influence of these factors (Graydon et al. 2019). Typically, while this progressive weakening in hearing acuity starts already in early adulthood, at first affecting the ability to hear high frequencies, these changes do not become subjectively noticeable until later life (Yueh et al. 2003; Gates & Mills 2005; Schmiedt 2010). Thus, because the onset of hearing loss is insidious, many older adults are unaware of their hearing loss for a long time (Yueh et al. 2003). On average, among men, hearing loss at high frequencies (3-6 kHz, which are critical for understanding speech in noisy environments) begins during middle age. Women typically have rather well-preserved hearing at the higher frequencies up to age 65 to 70 years, after which it begins a steady decline (Li et al. 2014).

Common symptoms of presbycusis include difficulty in hearing speech (Arlinger 2003), particularly in competing contexts, such as sound-reverberating environments, or in the presence of background noise (Yueh et al. 2003; Gatehouse & Noble 2004). Normal speech is carried out mainly in the frequency range 0.5-4 kHz. As the ability to detect high frequency sounds decreases, it is difficult to hear high frequency consonants such as “k”, “t” and “sh”. The audibility of consonants is a critical component of speech understanding, and thus older adults with presbycusis often have difficulties understanding what is being said and, thus, can experience communication breakdowns (Fook & Morgan 2000; Arlinger 2003; Bainbridge & Wallhagen 2014). Difficulties in spatial hearing and other symptoms, such as vestibular problems (vertigo) and tinnitus, are also commonly reported with presbycusis (Fook & Morgan 2000; Arlinger 2003; Gates & Mills 2005). As the reason for hearing loss is structural changes in the inner ear, the damage cannot be reversed. Generally, presbycusis is treated with amplification devices, such as hearing aids or, in the case of severe or profound hearing loss, with cochlear implants (Fook & Morgan 2000; Yueh & Shekelle 2007). In addition, hearing may be supported by other methods and technologies, such as the maximization of communication skills (for example, instruction in how to utilize visual cues, such as lip reading) and use of environmental aids, such as signal alerting devices (flashing doorbells and fire alarms) and built-in amplifiers in telephones (Fook & Morgan 2000; Jopling 2015).

Conductive hearing loss (CHL) results from mechanical abnormalities of the middle or outer ear, including abnormalities of the tympanic membrane (Yueh et al. 2003; Yueh & Shekelle 2007; Kutz, Mullin & Campbell 2012). In CHL, the problem concerns the transmission of sound waves through the outer ear canal to the eardrum and the small bones (ossicles) of the middle ear (Fook & Morgan 2000; Yueh & Shekelle 2007). CHL typically occurs evenly over all frequencies. Typical causes of CHL include infection and inflammation in the outer ear (otitis externa) or middle ear (otitis media) (Yueh & Shekelle 2007; Graydon et al. 2019); “Glue ear” (fluid in the middle ear space prevents the normal movement of the ossicles and ear drum and stops sound from passing normally through to the inner ear); a build-up of cerumen (wax) in the outer ear and otosclerosis (stiffening of the ossicles prevents sound from passing normally through to the inner ear). CHL may also be genetic or induced by trauma (for example, a hole in the eardrum) (Yueh & Shekelle 2007). Because the reasons for hearing loss are mostly mechanical, treatment is often possible (e.g. fixing of the perforated eardrum or removal of cerumen) (Yueh et al. 2003).

Combined SNHL and CHL, termed mixed hearing loss, results from problems in both the inner and outer or middle ear. Neural hearing loss results from damage to the auditory nerve, with the result that sound is not organized in a way interpretable by the brain (Graydon et al. 2019).

2.2.3 Hearing aid use among older adults

A HA is a device designed to improve the hearing performance of a person with a hearing impairment by amplifying sounds. In Finland, the criterion for hearing rehabilitation is a BEHL equal to or greater than 30 dB over the frequencies 0.5-4kHz (Hannula & Mäki-Torkko 2013). Hearing aids are the primary clinical management intervention for people with hearing loss (Kochkin 2009). The precise number of HA users in Finland is unknown, but earlier studies have reported the prevalence of HA users at 75 years of age to be between 9% and 17% (Lupsakko, Kautiainen & Sulkava 2005; Salonen 2013).

According to previous studies, fewer than half of older adults with impaired hearing report using a HA (Gussekloo et al. 2003; Hartley et al. 2010; Lin et al. 2011b; Bainbridge & Ramachandran 2014) and many owners of HAs do not use them regularly (Salonen 2013). In some studies, women have shown a higher prevalence of regular HA use compared to men (Smeeth et al. 2002; Bertoli et al. 2009; Staehelin et al. 2011); however, the vast majority of studies have not found any gender influence on HA use (Cox, Alexander & Beyer 2003; Wong, Hickson & McPherson 2003; Lupsakko, Kautiainen & Sulkava 2005; Knudsen et al. 2010; Bainbridge & Ramachandran 2014).

Many factors may impact on the use of HAs (Ng & Loke 2015). Typically, people are more likely to use a HA if they have a moderate/severe hearing impairment (Meyer & Hickson 2012; Hickson et al. 2014; Ng & Loke 2015). However, hearing ability alone is not a sufficient motivator for individuals to seek help for their hearing loss. Various non-audiological elements also affect HA acceptance and use. Commonly reported reasons affecting HA use are related to the usefulness and comfort of the HA (Hickson, Clutterbuck, & Khan 2010; Staehelin et al. 2011). Perceived difficulties in everyday life are one of the main factors affecting HA use among older adults. People who often encounter hearing-related difficulties in their daily life are typically more active in their HA use than those with fewer problems (Cox, Alexander, & Beyer 2003; Duijvestijn et al. 2003; Helvik et al. 2008; Palmer et al. 2009; Knudsen et al. 2010; Laplante-Lévesque, Hickson & Worrall 2010; Meyer & Hickson 2012; Hickson et al. 2014; Ng & Loke 2015; Ridgway, Hickson & Lind 2015). People are less willing to use a HA if its benefit is perceived as poor (i.e. not effective in noisy situations or in the presence of background noise, or not suitable for the type of hearing loss), or if it is found uncomfortable and difficult to handle. Situational factors may also affect the use of HA if the HA is needed only occasionally or if it works only in limited settings (Lupsakko, Kautiainen & Sulkava 2005; Hickson 2006;

Vuorialho, Karinen & Sorri 2006; Bertoli et al. 2009; Hartley et al. 2010; Gopinath et al. 2011; Staehelin et al. 2011; McCormack & Fortnum 2013; Hickson et al. 2014). People may also consider that their hearing problem is not severe enough to merit a HA, and hence the perceived benefit of a HA may be poor; especially if it is recommended too early (Kochkin 2000; Gussekloo et al. 2003; Lupsakko, Kautiainen & Sulkava 2005; Bertoli et al. 2009). Attitudes towards HA use, such as perceived stigma associated with wearing a HA (Hickson 2006; Meister et al. 2008; Meyer & Hickson 2012; Hickson et al. 2014; Ng & Loke 2015), previous experience with a HA (Cox, Alexander & Beyer 2003; Knudsen et al. 2010) and financial considerations (costs of batteries and repairs) (Kochkin 2000; Lupsakko, Kautiainen & Sulkava 2005; Hartley et al. 2010), may all influence HA use. Difficulties in handling and using a HA may also be related to deficits in cognitive performance (Lupsakko, Kautiainen & Sulkava 2005).

Benefits of hearing aid use
HA use may have positive effects on older adults' QoL by reducing the psychological, emotional and social effects of hearing loss (Kochkin & Rogin 2000; Yueh et al. 2001; Joore et al. 2003; McArdle et al. 2005; Chisolm et al. 2007; Gopinath et al. 2012b; Cox, Johnson & Xu 2014). HA may support everyday speech understanding and support participation in activities involving other people (Mulrow et al. 1990; Kochkin & Rogin 2000; Yueh et al. 2001; Cox, Johnson & Xu 2014). HA use may also alleviate negative feelings, such as depression, anxiety, frustration, insecurity and discontentment (Kochkin & Rogin 2000; Chisolm et al. 2007; Gopinath et al. 2009; Acar et al. 2011; Boi et al. 2012; Gopinath et al. 2012b; Mener et al. 2013). Some studies have also found an association between HA use and better cognitive performance (Dawes et al. 2015b; Desjardins 2016; Qian et al. 2016). However, the findings are somewhat contradictory and not all studies have demonstrated that HAs significantly promote cognitive function (van Hooren et al. 2005; Lin et al. 2013).

2.3 Indicators of healthy aging

Terms such as "healthy aging", "successful aging", "optimal aging" and "active aging" are common in many research protocols and policy documents. However, there is no clear agreement on how to define "healthy aging" or how to measure it (Depp & Jeste 2006; Montross et al. 2006). Furthermore, it has been debated whether healthy aging should be examined objectively, based on measurements determined by researchers, or subjectively from the older adult's own perspective (Depp & Jeste 2006; Montross et al. 2006; Michel & Sadana 2017). Older adults often adapt to age-related changes in health and functional ability and may therefore perceive themselves as aging "healthily" even when they have a disability or chronic disease (Strawbridge, Wallhagen & Cohen 2002; Montross et al. 2006; Michel & Sadana 2017). In 2003, the "Healthy Aging" project was initiated under the EU Public Health Programme, and involved ten countries, the WHO, the European Older People's Platform (AGE) and Euro-Health-Net. The project defined healthy aging as follows: "Healthy aging is the process of optimizing opportunities for physical, social and mental health to enable older people to take an active part in society without discrimination and to enjoy an independent and good quality of life"(Swedish Institute of Public Health 2006). In line with this, the WHO (2015) used the following definition: "Healthy aging is more than just the absence of disease; it is the process of developing and maintaining the functional ability that enables well-being in older age".

Following these definitions, this study utilized information on older adults' LSM, QoL and depressive symptoms as indicators of healthy aging. Life-space mobility reflects older adults' daily activity and engagement with the society. Perceived QoL reflects an individual's satisfaction with different aspects of daily life, including physical health, psychological health, social relationships and environment. The presence of depressive symptoms is considered a sign of lowered mental health.

2.3.1 Life-space mobility

Older adults' real-world functioning and participation can be described through LSM. LSM refers to the size of the spatial area in which a person deliberately moves in everyday life, the frequency of moving and the need for assistance in moving. LSM does not solely measure individuals' ability to walk but includes other forms of mobility, such as using public transportation or driving a car. Compensatory strategies, for example the use of assistive devices or help from another person, can significantly affect LSM (Stalvey et al. 1999; Baker, Bodner & Allman 2003; Xue et al. 2008). At its most limited, a person can be totally dependent on other people's assistance and life-space can be restricted to a bedroom, while a person with optimal mobility is able to travel safely and reliably when, where, and how he or she wishes to go (Satariano et al. 2012).

The first studies on the life-space of older adults, mainly those living in health care institutions, appeared in the gerontological literature during the 1980s and early 1990s (Ward & Kilburn 1983; May, Nayak & Isaacs 1985; Tinetti & Ginter 1990). Later studies have examined the LSM of community-dwelling older adults (Baker, Bodner & Allman 2003; Peel et al. 2005; Barnes et al. 2007; Snih et al. 2012). In Finland, LSM among community-dwelling older adults was first studied in the LISPE -study (Rantanen et. al 2012). The LISPE data were also used in this study.

In accordance with the PCM model of Lawton and Nahemow (1973), LSM can be seen as a measure that reflects the balance between an individual's resources (e.g. physiological and psychological capacity) and the demands of that individual's real-life situation, or environment (Baker, Bodner & Allman 2003; Xue et al. 2008). LSM describes the individual's actual mobility in his/her everyday environment. Thereby it provides a broader picture of a person's engagement with the community than the traditional assessment of mobility limitations and disabilities, which reflect a person's potential capacity to perform the specific activities but not the real-life extent of mobility and participation in those activities (Baker, Bodner & Allman 2003; Peel et al. 2005; Allman, Sawyer & Roseman 2006; Barnes et al. 2007; Wilkie et al. 2007; Xue et al. 2008; Sawyer & Allman 2010).

Typically, LSM decreases as people age (Hendrickson & Mann 2005). The ability to move outside of the home requires good functional abilities and hence a decline in LSM often indicates a weakening in older adults' resources, which in turn is a sign of the more general disablement process in old age (Kono et al. 2004; Xue et al. 2008; Rantanen et al. 2012; Hashidate et al. 2013). In addition to higher age, female gender (Barnes et al. 2007; Snih et al. 2012), mobility limitations (Wilkie et al. 2007), higher levels of depressive symptoms (Snih et al. 2012), difficulties in activities of daily living (Peel et al. 2005; Portegijs et al. 2016) and impairment of cognitive skills (Barnes et al. 2007; Crowe et al. 2008; Silberschmidt et al. 2017) are concomitant with poorer life-space mobility. In contrast, good physical health and decent cognitive skills and active social participation are related to higher LSM in old age (Barnes et al. 2007; Sartori et al. 2012; Snih et al. 2012). Higher LSM is also associated with better QoL among older adults (Baker, Bodner & Allman 2003; Rantakokko et al. 2013).

Apart from factors related to the individual, environmental factors may also affect older adults' LSM. Perceived barriers and the perceived insecurity of an outdoor environment may reduce participation in activities outside the home and, thus, decrease LSM (Rantakokko et al. 2015). However, older adults may be able to maintain their LSM by using compensatory strategies, such as mobility devices or hearing aids, which help them to cope with different kinds of environmental challenges. Older adults' LSM may also change owing to behavioral adaptation. People can reduce their participation in less important activities and focus their energy on more necessary functions, such as running daily errands (Rush, Watts & Stanbury 2011).

Assessment of life-space mobility

Life-space mobility is usually assessed via questionnaires, which are either interviewer administered or, based on the self-reports.

In 1990, Tinetti and colleagues developed the Nursing Home Life-Space Diameter -questionnaire (Tinetti & Ginter 1990), which was mainly designed for life-space assessment in an institutionalized environment. Later, Stalvey and colleagues (1999) focused on examining life space in community-dwelling older adults and designed the original Life-Space Questionnaire. This original questionnaire focuses on person´s movement across nine life-space zones during the previous three days.

Nowadays, the most common method for assessing LSM is the University of Alabama at Birmingham (UAB) Study of Aging Life-Space Assessment (LSA) (Baker, Bodner & Allman 2003). The LSA questions establish individual´s movement to specific life-space levels ranging from within one´s dwelling to beyond one´s town during the 4 weeks preceding the assessment. For each life-space level, frequency of movement and use of assistance (from equipment or persons) are also assessed (Baker, Bodner & Allman 2003), which was not included in the original Life-Space Questionnaire (Stalvey et al. 1999). Scoring of the LSA is based on the assumption that those persons who are able to get to a certain life-space level by themselves are the most independent, using only equipment represent a mid-level of independence and that requiring the help of another person represents dependence (Baker, Bodner & Allman 2003). LSA-questionnaire was use also in the present study.

During the last few years, also technological solutions (such as accelerometers and GPS-technology) have been used in life-space assessments alongside with questionnaires (Hirsch et al. 2014; Portegijs et al. 2015; Takemoto et al. 2015).

2.3.2 Quality of life

In the literature, the term 'quality of life' (QoL) has a wide array of characterizations and no universally accepted definition (Nordvik et al. 2018). However, QoL is recognized as a multidimensional entity that comprises both objective and subjective features. According to the WHO, QoL is "an individual's perception of their position in life in the context of the culture and value systems in which they live, and in relation to their goals, expectations, standards and concerns" (WHOQoL Group 1994). Thus, QoL is more than the absence of illnesses and impairments; it also includes factors related to mental wellbeing, social relationships and participation, autonomy and independence, and environmental mastery (Ryff 1995, Bowling & Gabriel 2007; Netuveli et al. 2006; Levasseur, Desrosiers & St-Cyr Tribble 2008; Kalfoss 2010; Arnold 2014). Depending, for example, on the age of the individual, the importance of each domain will be differently emphasized.

For many older adults, social roles and activities, also those enjoyed alone, are an important source of pleasure and enjoyment, and participation in these activities enhances people's sense of self-worth (Bowling & Gabriel 2007). Furthermore, older adults also consider good physical and mental health, favorable home and neighborhood characteristics, good financial circumstances and independence to be important attributes of QoL (Netuveli et al. 2006; Bowling & Gabriel 2007). Good sensory function and the ability to move around are also commonly mentioned determinants of QoL (Fisher et al. 2009; Kalfoss & Halvorsrud 2009). Physical, mental and social problems, such as mobility limitations, difficulties in everyday activities, limiting longstanding illness, depressive symptoms, and poor perceived financial situation reduce QoL among older adults (Netuveli et al. 2006).

Assessment of Quality of Life

Quality of life can be defined and assessed in various ways depending on the population of interest, resources, and on the context in which it is used (Logsdon et al. 2002; Arnold 2014). Several generic QoL questionnaires, which are designed to cover many different QoL domains in individuals' life, such as physical, psychological and social aspects, are available. These questionnaires include, for example, the WHO Quality of Life-questionnaire (WHOQoL Group 1994) and the Short-Form 36 Health Survey (SF-36) (Ware, Kosinski & Keller 1994; Ware 2000). The Euro-QoL instrument (EQ-5D) is also commonly used (Nordvik et al. 2018). In addition, many disease-specific QoL questionnaires have also been developed to measure the physical, psychological and social effects of disability or disease on an individual's QoL and function (Wilson & Cleary 1995; Stika & Hays 2016). For example, the HHIE is designed to assess the effects of hearing impairment on the emotional and social adjustment of older adults (Ventry & Weinstein 1982).

QoL is typically assessed using questionnaires or personal interviews. Many QoL issues are highly subjective and thus best collected via self-reports. Sometimes the evaluation of QoL (particularly in older adults) can be based on proxy ratings (for example, if a person him-/herself is cognitively severely impaired) or by observations of behaviors and events believed to be essential for individuals' QoL. However, an element of uncertainty is always present as to whether these measures reflect the individual's, the proxy's or the researcher's view about what factors are important for QoL (Logsdon et al. 2002). In this thesis, QoL was assessed with the short version of the WHO Quality of Life Assessment scale (WHOQoL-Bref)(WHOQoL Group 1994), which is described in detail in the methods section.

2.3.3 Depressive symptoms in old age

Depression is the most common mental health disorder in later life (Sivertsen et al. 2015). Major depression, also known as clinical depression, is a mental disorder characterized by episodes of persistent feelings of sadness and hopelessness and loss of interest in previously enjoyed activities. Several of the following symptoms are also common in depression: reduced energy, a change in appetite, sleep disturbances, indecisiveness, slowness of thought or action, reduced concentration and restlessness, lowered self-esteem and excessive self-criticism and feelings of worthlessness and thoughts of self-harm or death. As well as emotional problems, physical symptoms such as chronic pain may also be present. Symptoms may range from mild to severe and, to be diagnosed as depression, they must have been present for at least two consecutive weeks (Diagnostic and Statistical Manual for Mental Disorders, DSM-V). Sub-clinical or sub-threshold depression refers to a situation where an individual has depressive symptoms but not of sufficient severity or persistence to meet the criteria for major depression (Ji 2012). Sub-clinical states are usually seen as a prodromal version of the disorder (Ji 2012). Depression differs from the grieving process, which is an appropriate emotional response to the experience of losses, such as loss of a spouse (DSM-V). The reported prevalence of depressive symptoms among older adults vary depending on whether the focus is major or sub-clinical depression. Among community-dwelling older adults, about 8-16% have depressive symptoms, while only 1-5% of the population have major depression (Mulsant & Ganguli 1999; Blazer 2003; Hasin et al. 2005; Djernes 2006).

Among specific populations, such as institutionalized older adults, these percentages are substantially higher (Blazer 2003; Djernes 2006; Helvik et al. 2012).

Older adults often express depressive symptoms in different ways than younger age groups (Fiske, Wetherell & Gatz 2009; Sözeri-Varma 2012; Schaakxs et al. 2017). Affective symptoms, such as sadness, may not be prominent, but older adults may mention other symptoms such as somatic discomfort (i.e. sleeplessness, pain), absence of positive affect and lack of interest. Cognitive difficulties, such as subjective memory problems and slower cognitive processing are also frequently encountered (Chen et al. 2000; Fiske, Wetherell & Gatz 2009; Ready et al. 2011; Sözeri-Varma 2012). Individual variability in depressive symptoms is also common among older adults (Chen et al. 2000; Mora et al. 2012): while two individuals may report a similar total level of depressive symptoms, they may differ in the patterns of particular symptoms (Cole et al. 2000).

Etiology

In old age, the risk of depressive symptoms often increases as a result of other factors related to aging (Blazer 2003; Blazer & Hybels 2005; Vink et al. 2009). Among older adults, medical and psychiatric co-morbidity and poor functional status are common factors underlying depressive symptoms (Bruce 2001; Lenze et al. 2001; Blazer & Hybels 2005). Depressive symptoms often coexist with chronic conditions, such as cardiac- and cerebrovascular diseases, neurological conditions, diabetes mellitus, or cancer (Heikkinen & Kauppinen 2004; Blazer & Hybels 2005; Djernes 2006; Moussavi et al. 2007; Fiske, Wetherell & Gatz 2009; Chang-Quan et al. 2010; Huang et al. 2010; Richardson et al. 2012). Sometimes symptoms may arise as a result of medications used to treat physical conditions (e.g., beta-blockers and corticosteroids) (Alexopoulos 2005; Djernes 2006; James et al. 2014; Judd et al. 2014). Endocrine changes, such as hypersecretion of corticotropin-releasing factor (Arborelius et al. 1999; Binder & Nemeroff 2010) and neurotransmitter dysfunctions (particularly serotonin and norepinephrine), are also commonly found among depressed older adults (Nemeroff 2001, Nutt 2007). A history of depression earlier in life is one of the main predictors of depressive disorders and depressive symptoms in old age (Djernes 2006). Mobility limitations are strongly associated with depressive symptoms (Lampinen & Heikkinen 2003; Hirvensalo et al. 2007) and weakening of sensory functions, such as vision (Huang et al. 2010; Bookwala & Lawson 2011; Popescu et al. 2012) and hearing (Huang et al. 2010; Boi et al. 2012; Ciorba et al. 2012) may also have negative effects on mood. The co-occurrence of depressive symptoms and cognitive decline is likewise widely reported (Ballard et al. 2000; Modrego & Ferrández 2004; Djernes 2006; Potter & Steffens 2007; Panza et al. 2010; Rosenberg et al. 2010). Self-reported health is also related to depressive symptoms, with those who perceive their health to be poor typically reporting more depressive symptoms (Han 2002; Heikkinen & Kauppinen 2004; Djernes 2006; Chang-Quan et al. 2010; Richardson et al. 2012). This association is likely to be bi-directional.

Older women typically show more depressive symptoms than men (Hybels, Blazer & Pieper 2001; Samuelsson et al. 2005; Fauth et al. 2012). On average, women live longer than men and are therefore more likely to experience age-related changes that are risk factors for depressive symptoms, such as functional disability and widowhood (Samuelson et al. 2005). Living alone, being unmarried or divorced are also associated with higher rates of depressive symptoms in older adults, possibly due to poorer chances for social interaction and support (Hybels, Blazer & Pieper 2001; Voils et al. 2007; Weyerer et al. 2008). Loneliness, social isolation, and lack or loss of positive relationships and support increase the likelihood of experiencing depressive symptoms (Bruce 2002; Heikkinen & Kauppinen 2004; Djernes 2006; Fiske, Wetherell & Gatz 2009; Richardson et al. 2012). In addition, poor financial situation is a risk factor for depressive symptoms (Heikkinen & Kauppinen 2004; Samuelson et al. 2005).

Psychological risk factors include personality traits, lack of emotional control and self-efficacy, and cognitive distortions (Blazer & Hybels 2005). Late-life depressive symptoms are common among older adults with high levels of neuroticism (Kendler, Kuhn & Prescott 2004). Cognitive distortions, such as a tendency to rumination and exaggerating adverse outcomes of life events, may also increase the risk for depressive symptoms (Blazer & Hybels 2005). Older adults with higher levels of mastery (Jang et al. 2002) and self-efficacy (Blazer 2002) have lower levels of depressive symptoms.

Methods for assessing depressive symptoms in older adults

Clinical evaluation of depression is based on the DSM-V and International Classification of Diseases (ICD-10) criteria. In epidemiological studies, depressive symptoms are normally studied by using different self-report questionnaires. These are not intended to diagnose clinical depression but ascertain depressive symptoms in the study population. Among older adults, frequently used questionnaires include the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff 1977), the Beck Depression Inventory (BDI) (Beck et al. 1961), Geriatric Depression Scale (GDS) (Yesavage et al. 1983; Segulin & Deponte 2007) and the Zung Self-Rating Depression Scale (ZSDS) (Zung 1965).

In this study, the focus was on self-reported depressive symptoms, which were evaluated using the CES-D scale. The CES-D scale contains sections of the following scales: the BDI, ZSDS, and the Minnesota Multiphasic Personality Inventory (MMPI). The CES-D scale includes four different dimensions of depression: depressed affect, somatic symptoms, positive affect and interpersonal problems. The CES-D cut-off score indicating a clinically significant level of depressive symptoms in community samples is 16 or more (Radloff 1977). The BDI is primarily intended to measure the intensity of depressive symptoms but has also commonly been used in screening for depression, as, for example, in the Finnish Health 2000 study. The GDS is specifically designed to detect depression in older adults and has been found to be well suited for the screening of depressive symptoms (Friedman, Heisel & Delavan 2005). The ZSDS was developed to evaluate depression among patients admitted to psychiatric care and also for non-institutionalized older adults (Zung, Richards & Short 1965). The ZSDS was originally developed to monitor treatment effectiveness, but it has also been used in research and in general medical practice (Magruder-Habib, Zung & Feussner 1990).

2.4 Relationships between hearing difficulties, mobility, depressive symptoms and quality of life in old age

Hearing ability notably affects an individual's capacity to manage various daily activities, and hence difficulties in hearing give rise to number of problems. Good hearing ability forms the basis for interaction with other people and thus is essential for effective communication. Older adults with hearing loss often report difficulty in recognizing speech and easily experience conversational breakdown, which makes it much more problematic for them to function successfully in a society where verbal communication is central (Heine & Browning 2002; Arlinger 2003; Dalton et al. 2003; Ciorba et al. 2012). Several studies have provided evidence from both cross-sectional and longitudinal studies that uncorrected hearing loss and perceived hearing-related difficulties in daily life are associated with social isolation and reduced social activity (Kramer et al. 2002; Gopinath et al. 2012a; Mick, Kawachi & Lin 2014; Mikkola et al. 2015b; Mikkola et al. 2016) poorer QoL (Arlinger 2003; Dalton et al. 2003; Chia et al. 2007; Hogan et al. 2009; Ciorba et al. 2012; Gopinath et al. 2012b; Nofrdvik et al. 2018), and increased risk for depressive symptoms (Cacciatore et al. 1999; Kramer et al. 2002; Gopinath et al. 2009; Saito et al. 2010; Gopinath et al. 2012a; Cosh et al. 2018; Lawrence et al. 2019).

Other kinds of hearing-related disabilities concern mobility and physical functioning. Walking difficulties (Viljanen et al. 2009a; Chen et al. 2014), poorer postural balance and higher risk for falls (Viljanen et al. 2009b; Kamil et al. 2016) as well as fear of falling (Viljanen et al. 2012) are more common among older adults with hearing loss compared to their normal hearing peers. They also report lower levels of physical activity (Gispen et al. 2014) and experience more difficulties in physical functioning and in performing activities of daily living (ADL) and instrumental activities of daily living (IADL) functions (Strawbridge et al. 2000; Gopinath et al. 2012c; Lasisi & Gureje 2013; Liljas et al. 2015; Mikkola et al. 2015a). Some studies have also reported an association between hearing loss and increased risk for developing frailty among older adults (Kamil et al. 2016; Liljas et al. 2017) and between hearing loss and poorer cognitive performance (Lin et al. 2004; Tay et al. 2006; Wallhagen, Strawbridge & Shema 2008; Lin et al. 2011a; Kiely et al. 2012b; Lin et al. 2013; Limongi et al. 2015; Taljaard et al. 2016; Thomson et al. 2017; Alattar et al. 2020). Hearing loss is also associated with poorer self-reported health, increased disease burden (McKee, Stransky & Reichard 2018) and increased mortality risk (Karpa et al. 2010, Genther et al. 2015).

Because hearing loss can have a significant effect on an individual's capability and desire to participate in everyday activities, it can also have negative effect on older adults' LSM. People who move more frequently outside their homes, and thus have higher LSM, also maintain their functional ability better (Kono et al. 2004). Moving outside the home also provides more opportunities to engage with society and participate in various valued activities, such as running daily errands, hobbies and social interaction with others (Kono et al. 2004; Barnes et al. 2007; Kono et al. 2007; Jacobs et al. 2008). As individuals reduce their moving outdoors, their LSM also declines, which has a negative effect on person's QoL (Rantakokko et al. 2016).

To the best of my knowledge, little is known about the association between hearing difficulties and LSM. Moreover, the association between HA use and LSM has not been studied before. Allman and colleagues (2004) investigated the predictors of LSM change. In their study, hearing difficulties were included in the analyses along with several other diseases, geriatric syndromes, neuropsychological factors and health behaviors. The authors found a statistically significant correlation between hearing difficulties and decline in LSM. However, the association was no longer significant when adjusted for all the other potential significant predictors for LSM change.

Several previous studies have reported an association between hearing difficulties and poorer QoL among older adults (Arlinger 2003; Dalton et al. 2003; Chia et al. 2007; Hogan et al. 2009; Ciorba et al. 2012; Gopinath et al. 2012b). However, unlike the present study, these studies either did not identify specific aspects of perceived hearing difficulties in everyday life (e.g. hearing speech, hearing-related socioemotional problems and spatial hearing) or differentiated between the different domains of QoL (Gatehouse & Noble 2004; Hallberg, Hallberg & Kramer 2008). Hence, the present study provides new knowledge on the influence of different aspects of perceived hearing difficulty and audiometrically assessed hearing on different domains of QoL among older adults.

The association between LSM and depressive symptoms has also been reported in earlier studies (Baker, Bodner & Allman 2003; Peel et al. 2005; Allman, Sawyer & Roseman 2006; Snih et al. 2012), although the possible associations of LSM with the different dimensions of depressive symptoms have not previously been investigated. Furthermore, as far as I know, knowledge on possible factors mediating the associations between LSM and depressive symptoms is nonexisting.

2.5 Study concepts

In the present study, I define hearing difficulties as hearing-related problems perceived by individuals in their everyday lives. Hearing sensitivity refers to the uncorrected PTA air-conduction thresholds over frequencies of 0.5-4 kHz (Heinrich et al. 2019; Merten et al. 2020). The use of HA is considered as a compensatory strategy which may alleviate the negative consequences of hearing loss.

LSM refers to the extent to which individuals move in their environment, including the frequency of travel within a specific time and possible assistance needed for that travel (Peel et al. 2005; Rantanen et al. 2012), and thus reflects older adults' daily activity.

Perceived QoL refers to individuals' satisfaction with various aspects of their daily lives. Depressive symptoms are considered as a sign of lowered mental health.

3 AIMS OF THE STUDY

The purpose of this study was to examine associations between older adults' hearing difficulties and LSM and whether this association is modified by HA use. A further aim was to study the possible associations between older adults' QoL, hearing sensitivity and hearing difficulties in everyday life situations, and the association between life-space mobility and depressive symptoms.

The analytical framework of this study is illustrated in Figure 2. I hypothesized that hearing difficulties hamper the individual's ability to manage in everyday life situations, which in turn is associated with lower LSM. I assumed that use of a HA would alleviate hearing-related problems and be associated with higher LSM. I also hypothesized that the perception of hearing difficulties in daily life situations weakens QoL and that lower LSM is associated with a higher number of depressive symptoms.

The specific research questions were:

1. Do perceived hearing difficulties predict a change in life-space mobility in older adults during a two-year follow-up? (Study I)
2. Does hearing aid use alleviate the effects of hearing difficulties on older adults' life-space mobility? (Study II)
3. Are hearing sensitivity and perceived hearing difficulties in everyday life situations associated with quality of life in old age? (Study III)
4. Does life-space mobility correlate with depressive symptoms in old age? (Study IV)

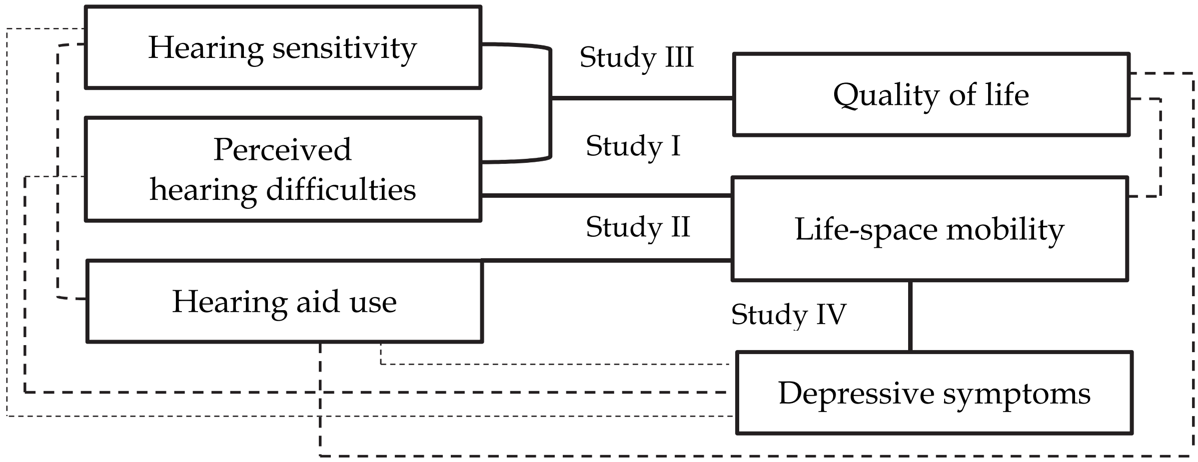

FIGURE 2 The analytical framework of the study. Solid lines indicate the associations studied. Dashed lines indicate that an association is assumed to exist between the variables but was not examined in this study.

4 DATA AND METHODS

4.1 Study design and participants

The data for this study form part of the data collected for the research project LISPE, conducted at the University of Jyväskylä. LISPE was a two-year prospective cohort study of community-dwelling older adults (Rantanen et al. 2012). A random sample of men and women aged 75—90 years living in the municipalities of Jyväskylä and Muurame (N=2550) was obtained from the Finnish National Register. Potential participants were first contacted by a letter informing them about the study protocol, after which they were contacted via telephone to enquire about their willingness to participate and to screen them for eligibility. To be eligible for the study, persons willing to participate needed to be community-dwelling and able to communicate (i.e. able to understand the questions and provide answers to them). Of the initial sample of 2 550 people, 2 269 were reached by telephone. Of these, 1 111 persons declined to participate and 304 were not eligible. In all, 854 persons were interviewed in their homes by trained interviewers between January and June 2012. An additional four participants were excluded due to communication problems during the home interview and the data on two persons were lost due to a technical problem. Thus, 848 eligible persons participated in the baseline home-interviews during spring 2012. The first follow-up (F1) of the LISPE study was conducted one year and the second follow-up (F2) two years after the baseline home interviews. Of the 848 participants at the baseline, 816 participated in F1 and 761 participated in the F2. F1 interview was conducted via telephone and F2 consisted of a telephone interview and a postal questionnaire. Participants unable to answer the questions over the phone due to hearing problems were offered the possibility to take part in a face-to-face interview in their homes (F1 n=2, F2 n=3) or to answer the study questions via a postal questionnaire (F1 n=14, F2 n=10).

For the substudy “Hearing, cognition and well-being”, a random sample of 230 participants was drawn from the original LISPE baseline cohort in January 2014. Of these 14 were not eligible to participate. During the F2 telephone call in the LISPE study, the interviewer informed eligible participants about the substudy and 169 people agreed to participate (Figure 3). Measurements were conducted in the participants' homes during spring 2014. The substudy sample did not differ from the original LISPE study sample (n=848) in age, sex, years of education, number of chronic conditions, cognitive functioning (measured with Mini-Mental State Examination, MMSE) (Folstein, Folstein & McHugh 1975) or, lower extremity functioning (measured with the Short Physical Performance Battery, SPPB) (Guralnik et al. 1994) (p values >0.127).

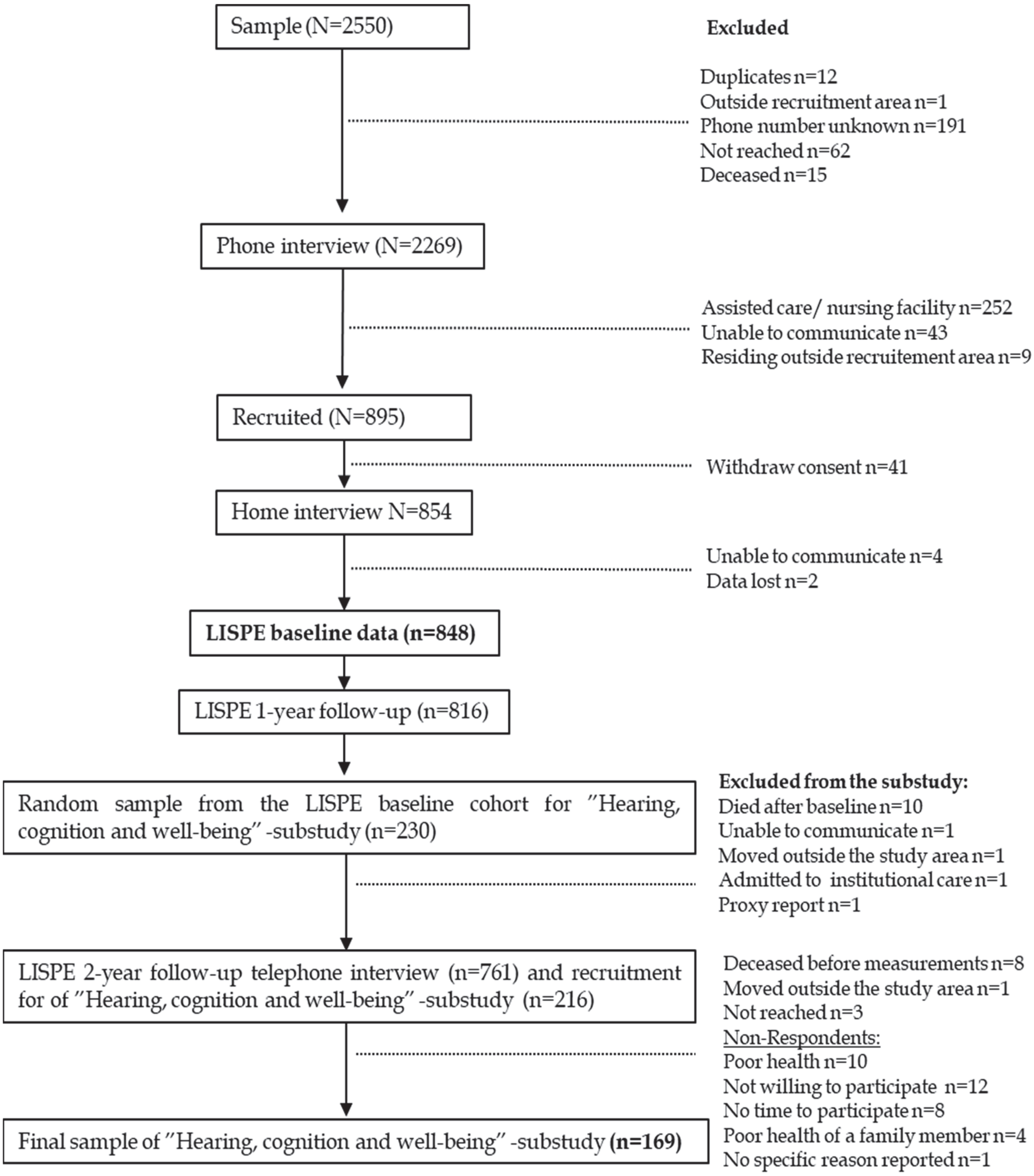

FIGURE 3 Flow chart of the study.

The LISPE baseline data were used in the cross-sectional analyses of Study IV. The LISPE baseline data and F2 data were used in the longitudinal analyses of Study I. The data obtained from the F2 were used in the cross-sectional analyses in Studies II and III. The audiometric data obtained from the "Hearing, cognition and well-being" -substudy were also used in Study III.

4.2 Ethics

The LISPE study and its substudy were approved by the Ethical Committee of the University of Jyväskylä, Finland and the study was conducted according to the guidelines for good scientific and clinical practice laid down by the Declaration of Helsinki. Participants were informed about the research before the baseline measurements and before the substudy and they gave their written informed consent. Participation was voluntary and participants had the right to withdraw from the study at any stage. The privacy and security of the data were ensured in all phases of the research. Permission for data use must be applied for by contacting the study´s principal investigator and is contingent on a relevant research plan. The data are stored on the server of the University of Jyväskylä behind a password. The data analyzed for this PhD thesis were pseudonymized. Postal questionnaires are stored without personal identification in a secure place at the Faculty of Sport and Health Sciences in the University of Jyväskylä.

4.3 Measurements

Table 1 presents a summary of the variables and the assessment methods used in this study.

TABLE 1 Summary of the study variables.

Variables	Study	Methods
Hearing		
Perceived hearing difficulties	I,II,III	Self-reported (baseline home interview in Study I, postal questionnaire in Study II, Hearing in Real-Life Environments (HERE) postal questionnaire in Study III)
Hearing sensitivity	III	Pure-tone screening audiometry (Oscilla USB-330)
Perceived benefit from hearing aid use	II	Self-reported (HERE postal questionnaire)
Life-Space Mobility (composite score)	I,II,IV	University of Alabama at Birmingham Study of Aging Life-Space Assessment.
Quality of Life	III	World Health Organization Quality of Life Assessment short version (WHOQoL-Bref)
Depressive symptoms	IV	Centre for Epidemiological Studies Depression Scale (CES-D)
Covariates		
Age	I-IV	National registers
Sex	I-IV	National registers
Financial situation	IV	Self-reported
Education (years)	I-IV	Self-reported
Living arrangement (alone vs. with another person)	IV	Self-reported
Number of chronic conditions	I-IV	Self-reported
Cognitive functioning	I-IV	Mini Mental State Examination (MMSE)
Depressive symptoms	II	Centre for Epidemiological Studies Depression Scale (CES-D)
Perceived difficulties in walking 500 meters	IV	Self-reported
Sense of autonomy in participation outdoors	IV	Impact on Participation and Autonomy questionnaire (IPA)

4.3.1 Hearing

4.3.1.1 Perceived hearing difficulties

At baseline, perceived hearing difficulties were examined during the home interview with the following three questions: ”Do you have difficulties hearing when having a conversation with several people simultaneously?”; “Do you have difficulties hearing when conversing with another person in the presence of noise?”; and “Do you have difficulties hearing where a particular sound (i.e. phone ringing, sound of a car) is coming from?”. The participants were asked to estimate their level of difficulty when using a HA if they had one. The response options for all three questions were: no difficulty (0 points), some difficulty (1 point), and major difficulty (2 points). For the analysis, scores were summed, and the resulting scale was divided into three categories: no hearing difficulties (score 0), mild hearing difficulties (score 1-2), and major hearing difficulties (3 or higher). The rationale for this categorization was that having major hearing difficulties should involve some difficulty in all three situations or major difficulty in at least one situation plus some difficulty in another situation (Wallhagen et al. 2001). These data were used in the analyses of Study I.

In Study III, the data on perceived hearing difficulties were drawn from the two-year follow-up of the LISPE study. Perceived hearing ability was assessed using a new, 16-item postal questionnaire titled Hearing in Real-Life Environments (HERE), which was developed as a part of the substudy “Hearing, cognition and well-being”(Polku et al. 2018; Heinrich et al. 2019). The HERE questionnaire was designed to assess perceived hearing difficulties with and without a HA in a variety of real-life environments. The items used in the questionnaire were modified from items in the APHAB (Cox & Alexander 1995), the SSQ (Gatehouse & Noble 2004) and the HHIE (Ventry & Weinstein 1982). Participants were asked to assess their hearing in everyday situations by choosing on a scale from 0 to 10 the number that best corresponded to their perceived hearing ability. Higher scores indicated poorer performance/more difficulties. Participants who owned a HA gave two answers to each question: one assessing their hearing with, and the other without, their HA. The best hearing performance for each item with or without a HA, whichever was better, was used in the analysis. This was considered the best indicator of perceived hearing performance in everyday life, as some people may use HAs only in situations where they perceive a benefit from doing so. In a recent study, Heinrich et al. (2019) conducted a psychometric evaluation of the HERE questionnaire and found the questionnaire to be valid, reliable and stable. The HERE questionnaire is described in detail in the results section.

4.3.1.2 Hearing sensitivity

Hearing sensitivity was assessed in the “Hearing, cognition and well-being” substudy in the participants’ homes. Pure-tone screening audiometry (Oscilla USB-330), using Peltor noise-reducing headphones with a noise reduction rating of 21 dB, was used to measure pure-tone air-conduction hearing thresholds for both ears separately. The automatic Hughson-Westlake protocol was used at frequencies 0.125, 0.25, 0.5, 1, 2, 4 and 8 kHz. The frequency was first set to 1 kHz and a tone automatically presented at an intensity of 30 dB. If the participant gave no response, the intensity was increased by 5 dB each time the tone was presented. For each response the sound intensity was decreased by 10 dB and, conversely, when there was no answer, increased by 5 dB. The maximum intensity was 90 dB. In determining when to proceed to the next frequency in order to ascertain the lowest sound intensity detectable by the participant, the test uses the 2 out of 3 method of answering. The audiometry data were automatically stored on a personal computer. HAs were not worn during the hearing examination. In the analysis for Study III, the BEHL was used and defined as the PTA over the frequencies of 0.5-4 kHz.

4.3.1.3 Perceived benefit from hearing aid use

Perceived benefit from HA use was examined at the two-year follow-up of the LISPE -study. In the postal questionnaire the participants were asked “How is your hearing?”, which was one item in the HERE questionnaire. Participants evaluated their hearing by selecting on a scale from 0 to 10 the number that best corresponded to their perceived hearing ability. Higher scores indicated poorer performance. Participants who reported having a HA gave two answers: one assessing their hearing with, and the other without, their HA (Figure 4). Perceived benefit from HA use was quantified by subtracting the aided hearing score from the unaided hearing score, a greater difference indicating greater perceived benefit. The median value of the perceived benefit from HA use was three and, based on this, three groups were formed: more HA benefit (difference of 3 or more points between non-aided and aided hearing ability), less HA benefit (difference less than 3 points) and a no-HA group (participants without a HA). In addition, HA users were asked whether they used their HA daily (yes/no), whether they have a HA in one ear or both ears and, in an open-ended question, to estimate how many hours per day on average they used their HA. These data were used in Study II.

How is your hearing?

A. Without hearing aid

very good … very poor

0 1 2 3 4 5 6 7 8 9 10

B. With hearing aid

very good … very poor

0 1 2 3 4 5 6 7 8 9 10

FIGURE 4 Assessment of perceived hearing ability and perceived benefit from hearing aid use.

4.3.2 Life-Space Mobility

Life-space mobility was measured using the University of Alabama at Birmingham (UAB) Study of Life-Space Assessment (LSA) questionnaire (Baker, Bodner & Allman 2003), translated into Finnish (Rantanen et al. 2012). The LSA is based on self-reports and contains 15 items. It measures mobility through the different life-space levels in which a person reports having moved either by walking or using other forms of transportation, such as driving a car or using public transport, during the four weeks preceding the assessment. The LSA includes following life-space levels: bedroom (score 0), other rooms in the home (score 1), areas outside the home (e.g., porch, deck or patio; score 2), neighborhood (outside own yard or apartment building; score 3), town (places outside neighborhood, but within the hometown; score 4); and beyond town (score 5). For each of these life-space levels, frequency of movement was assessed by asking how many days a week participants attained each level: daily (score 4), 4-6 times per week (score 3), 1-3 times per week (score 2), less than once a week (score 1). Participants also reported whether they needed help from another person or from assistive devices (score 2 if independent, i.e., no assistance from equipment or persons; 1.5 if equipment was used; or 1 if personal assistance was reported). For the analyses, a LSM composite score, which reflects the distance, frequency and level of independence of mobility, was calculated. Values were computed for each life-space level by multiplying the level score, the degree of independence and the frequency score. The level-specific values were summed to create a composite score ranging from 0 to 120, with higher levels representing greater LSM (Baker, Bodner & Allman 2003). A score of <60 on the life-space assessment represents restricted life-space (Peel et al. 2005; Allman, Sawyer & Roseman 2006). The reliability and validity of the questionnaire, as well as its responsiveness to change, have been established (Baker, Bodner & Allman 2003; Peel et al. 2005; Sawyer & Allman 2010). In a test-retest study in a Finnish context it was found to be fairly good, although the scores showed somewhat more variation in the winter than spring (Portegijs et al. 2014a). At the LISPE study baseline, the LSA was conducted in face-to-face interviews, and at the first and second follow-ups via telephone interviews. Data on life-space mobility were used in Studies I, II and IV.

4.3.3 Quality of life

QoL was assessed with the 26-item World Health Organization Quality of Life Assessment short version (WHOQoL-Bref) (WHOQoL Group 1994). The scale is scored in four domains, i.e. physical health, psychological health, social relationships and environment, and a total score calculated. The physical health domain includes 7 items on the following aspects: mobility, ability to carry out daily activities, energy, pain, need for medication or other treatment, sleep, and working capacity. The psychological health domain includes 6 items which concern level of positive and negative feelings, self-esteem, body image, cognition and spirituality. Social relationships include 3 items focusing on individual's satisfaction with personal relationships, their sex life and social support. The environment domain of QoL consists of 8 items, which reflect the individual's satisfaction with the physical environment, satisfaction with home environment, physical safety and security, financial resources, opportunities to obtain health care and social services, information, opportunities to participate in leisure activities and possibilities to use public transportation (WHOQoL Group 1994; Skevington, Lotfy & O'Connell 2004). In addition, a total QoL score for all the domains combined was calculated. The total score ranges from 0 to 130, higher scores indicating better QoL. The WHOQoL-Bref has been found to be reliable and valid among diverse populations, including both healthy people and people with specific diseases or health conditions (Skevington, Lotfy & O´Connell 2004; Skevington & McCrate 2012). The psychometric properties of the questionnaire are good also among older adults (von Steinbüchel, Lischetzke, Gurny et al. 2006; Kalfoss, Low & Molzahn 2008; Lucas-Carrasco, Laidlaw & Power 2011). The WHOQoL-Bref domain scores have good discriminant validity, content validity, internal consistency and test-retest reliability (WHOQoL Group 1994; Skevington, Lotfy & O'Connell 2004). At baseline, the QoL was examined in a face-to-face interview and via a postal questionnaire at the two-year follow-up. The cross-sectional data from the two-year follow-up were used in Study III.

4.3.4 Depressive symptoms

Depressive symptoms were assessed with the 20-item CES-D scale (Radloff 1977). The CES-D scale is based on a self-report of depressive symptoms. The participants were asked to rate the frequency of each symptom during the previous week. Each item is scored from 0 to 3, with higher scores indicating more depressive symptoms (total score range 0-60). The cut-off score on the CES-D total score indicating a clinically significant level of depressive symptoms in community samples is 16 or more (Radloff 1977). To examine different dimensions of depressive symptoms, scores for the four CES-D dimensions were computed. The dimensions and their respective items were the following: depressed affect (having the blues, feeling depressed, life a failure, feeling fearful, feeling lonely, crying spells, feeling sad; range 0—21), somatic symptoms (being bothered, poor appetite, trouble concentrating, everything was an effort, restless sleep, talked less than usual, couldn´t get going; range 0—21), positive affect (feeling as good as others, hopeful about the future, feeling happy, enjoying life; range 0—12), and interpersonal problems (people were unfriendly, people dislike me; range 0-6). Higher scores always represented a higher level of the dimension in question. The CES-D has been widely used in epidemiologic studies and its validity and reliability have been demonstrated in heterogeneous samples (Beekman et al. 1997). The baseline data, which were collected in the face-to-face interview, were used in Study IV.

4.3.5 Covariates and descriptive variables

In the LISPE study baseline, the age and sex of the participants were derived from the National Population Register (Studies I-IV). Years of education were asked with the question “How many years of education have you had in total? (Studies I-IV). In addition, the participants rated their financial situation as 1) very good, 2) good, 3) moderate, 4) poor or 5) very poor. For the analyses, the answers were categorized as 1) very poor or poor, 2) moderate or, 3) very good or good) (Study IV). Participants were also asked whether they lived alone or with another person (Study IV). Self-reported physician-diagnosed chronic conditions (such as rheumatoid arthritis, diabetes, cancer, glaucoma, cardiac, circulatory and neurological diseases) were obtained from a list of 22 chronic conditions and with an open-ended question (Studies I -IV). Cognitive functioning was assessed using the Mini-Mental State Examination (MMSE) (Folstein, Folstein & McHugh, 1975) (Studies I-IV). Walking difficulties, reflecting an advanced mobility limitation, were studied by asking the participants if they had difficulties in walking 500 meters. The response options were 1) able to manage without difficulty, 2) able to manage with some difficulty, 3) able to manage with great deal of difficulty, 4) able to manage only with help from another person, and 5) unable to manage even with help. For the analyses, perceived difficulties in walking was dichotomized as “no walking difficulties” (1) and “walking difficulties” (2-5) (Study IV). Sense of autonomy in participation outdoors was measured using the domain “autonomy outdoors” from the IPA -questionnaire (Cardol et al. 1999). Participants were asked to rate their perceived opportunities to 1) visit relatives and friends, 2) make trips and travel, 3) spend leisure time, 4) meet other people, and 5) live life the way they want. The response categories ranged from 0 (very good) to 4 (very poor). A sum score (range 0—20) was calculated, higher scores indicating more restrictions in perceived autonomy (Study IV).

4.4 Statistical analyses

The descriptive measures were computed using mean values and standard deviations (SD) (Studies II, III) or medians and interquartile ranges (IQR) (Studies I and IV) for continuous variables and, percentages for categorical variables (Studies I-IV). The Mann-Whitney U-test (Study IV) and Kruskall-Wallis test (Study I) were used for comparing means of non-normally distributed continuous variables. Pearson’s chi-squared test was used for comparing proportions of categorical variables (Study I, II). Associations between the study variables were examined using correlation coefficients (Study III, IV). One-way analysis of variance (ANOVA) was used in Study II for continuous variables to compare characteristics between the HA use groups. Analysis of covariance (ANCOVA) was used to test the association between perceived benefit from HA use and

LSM (Study II). A value of $p<.05$ was chosen as the level of statistical significance. Analyses were performed using IBM SPSS version 22.0 (SPSS Inc. Chicago, IL).

Generalized estimating equations (GEE) (Liang & Zeger 1986) were used to test the significance of the association of self-reported hearing difficulties with changes in the LSM composite score over the two-year follow-up (Study I). The time-interaction effects for the one- and two-year follow-ups and main effects of self-reported hearing difficulties on LSM were estimated. Age and sex were included in all models and the analysis was further adjusted for variables with a significant effect ($p<.05$) on the parameters (i.e. cognitive functioning, rheumatoid arthritis, diabetes, as well as cardiac, circulatory and neurological diseases). Parameter estimates for the GEE models were obtained from IBM SPSS version 22.0. 95% Confidence intervals (CI) for the estimated marginal means were computed in the R programming environment, version 3.1.1.

Logistic regression models were used to investigate whether self-reported hearing difficulties at baseline were associated with higher odds for life-space restriction at baseline and at the two-year follow-up (Study I). For analyses, the LSM score was dichotomized by using a cut-off score of 60, which represents restricted life-space (Peel et al. 2005; Allman, Sawyer & Roseman 2006). In Study I, odds ratios (ORs) for life-space restriction at the two-year follow-up were calculated only for participants who had unrestricted life-space at baseline. Age and sex were included in the crude model. In addition, cognitive functioning, rheumatoid arthritis, diabetes and cardiac, circulatory, and neurological diseases had also a significant effect ($p<.05$) on the parameters and were used as covariates in the adjusted models.

Logistic regression models were also used to examine cross-sectional association between perceived benefit from HA use and life-space restriction. Data were from the two-year follow-up of the LISPE study. These models are based on the additional analyses which were conducted for this thesis and were not published in the original article (Study II). Of the potential covariates, only age and perceived hearing ability without a HA differed statistically significantly between the HA groups and were thus included in the analysis. Logistic regression analyses were performed using IBM SPSS version 22.0 (SPSS Inc. Chicago, IL).

Linear regression analysis was used to assess the strength of the association between quality of life (QoL) and perceived hearing difficulties and, between QoL and hearing sensitivity measured in the substudy (Study III). The association between perceived hearing difficulties and QoL was analyzed by conducting cross-sectional analyses on the data obtained from the two-year follow-up of the LISPE study. Data from the "Hearing, cognition and well-being" -substudy were used to examine the association between audiometrically measured hearing and QoL. Only covariates showing a significant association with both the predictor (i.e. hearing) and the outcome variable (i.e. QoL) were included in the analysis. Of the potential covariates, only age was associated with audiometrically measured hearing threshold (BEHL $_{PTA\ 0.5\text{-}4kHz}$) and QoL, while age, sex and cardiac diseases were associated with both QoL and self-reported hearing difficulties. The influence of HA use on the results was tested by conducting the analysis separately for HA users and non-users. The results remained largely unchanged, and thus HA users and non-users were included in the same model.

Linear regression analysis was also used to investigate the association between LSM and depressive symptoms at the baseline (Study IV). An interaction of sex and LSM on depressive symptoms was found ($p<.001$) and therefore men and women were analyzed separately. The significance of the effects in the gender-specific models was tested using the standard single parameter Wald tests, and gender-differences in regression coefficients were tested using the likelihood ratio test for a single parameter. CIs are based on the inversion of the Wald-test for the given parameter. The selection of potential confounders and mediating factors was based on the findings of previous studies on factors associated with LSM and depressive symptoms. Only variables with a statistically significant association with both depressive symptoms and LSM were chosen for the analyses, as they could influence the association between LSM and depressive symptoms. The base model was adjusted for age, financial situation and cohabitation (i.e., living alone or with another person). The second model was additionally adjusted for walking limitation and number of chronic conditions; finally, sense of autonomy in participation outdoors was added into the model. Linear regression analyses were accomplished using IBM SPSS 20.0 (IBM Corp., Armonk, NY, USA) (Study III) and MPlus version 7 (Muthén & Muthén 2012)(Study IV). Statistical significance was set at $p<.05$ for all linear analyses.

Factor analysis was used for the purposes of Study III. The structure of the 16-item scale on perceived hearing difficulties (HERE questionnaire) was tested using the oblique geomin-rotation of the factor solution. Estimation was based on the maximum likelihood method with the assumption that missing data were missing at random, thereby also permitting inclusion of partial response patterns. Participants were excluded from the analysis only when scores were missing for all items (n=4). Factor scores were computed using the exploratory structural equation modelling approach. A three-factor structure was found, reflecting different aspects of perceived hearing difficulties (Socioemotional effects, Speech hearing and Spatial hearing). The factor analysis was performed in Mplus using the oblique geomin-rotation of the factor solution (version 7) (Muthén & Muthén 2012). Subscale Cronbach alpha coefficients were computed in IBM SPSS version 22.0 (SPSS Inc. Chicago, IL).

5 RESULTS

5.1 Hearing and life-space mobility (Study I)

Participant characteristics categorized according to self-reported difficulty in hearing at the LISPE study baseline are shown in Table 2.

TABLE 2 Participant characteristics categorized by self-reported difficulty in hearing at baseline.

	No hearing difficulties (n=276)	Mild hearing difficulties (n=381)	Major hearing difficulties (n=187)	
	Median (IQR)	**Median (IQR)**	**Median (IQR)**	**p[a]**
Age	79.0 (6.0)	80.0 (8.0)	81.0 (8.0)	<.001
Education in years	9.0 (5.0)	9.0 (6.0)	8.0 (5.0)	.224
Cognitive functioning (MMSE)	27.0 (3.0)	27.0 (3.0)	26.0 (4.0)	<.001
	n (%)	**n (%)**	**n (%)**	**p[b]**
Women	175 (63)	226 (59)	122 (65)	.328
Hearing aid owner	4 (1.5)	38 (10)	71 (38)	<.001
Cardiac diseases	88 (32)	166 (44)	102 (55)	<.001
Circulatory diseases	160 (58)	265 (70)	128 (68)	.005
Diabetes	44 (16)	68 (18)	37 (20)	.562
Neurological diseases	19 (7)	26 (7)	15 (8)	.859
Rheumatoid arthritis	11 (4)	19 (5)	15 (8)	.153

Notes:
MMSE= Mini-Mental State Examination
IQR= Interquartile range
a = Kruskal-Wallis H-test
b = Chi-Square test

Data for perceived hearing difficulties were available for 844 participants. At baseline, 33% of the participants reported not having hearing difficulties, 45% reported mild hearing difficulties and 22% reported major hearing difficulties. Having a HA was reported by 13.5% of the participants. LSM data were available for all 848 participants at baseline, 806 participants at the one-year follow-up and 757 participants at the two-year follow up. In the total sample, the mean LSM score was 64.0 (SD 20.6) at baseline and 61.4 (SD 22.1) at the two-year follow-up. The median age was highest in the group with major hearing difficulties and this group had lower median MMSE -score compared to other groups. The group with major hearing difficulties also had the largest proportion of participants who reported having cardiac diseases (Table 2).

Table 3 shows the estimated marginal means for LSM by categories of self-reported hearing over the 2-year follow-up. At baseline, after adjustment for sex and age, participants with major hearing difficulties had a significantly lower LSM score compared to those without hearing difficulties (mean 62 vs. 68, $p<.001$) or to participants with mild hearing difficulties (62 vs. 65, $p=.022$). LSM scores did not statistically significantly differ between the group with mild hearing difficulties and those without hearing difficulties ($p=.141$). At the 2-year follow-up, participants without hearing difficulties had higher LSM score compared to those with either major (65 vs. 59, $p=.001$) or mild hearing difficulties (65 vs. 60, $p=.002$) (Table 3, Model 1).

After further adjustments for cognitive functioning and chronic conditions, participants who reported major hearing difficulties had a lower LSM score at baseline than participants without hearing difficulties (mean 54 vs. 57, $p=.040$). The difference in LSM scores between persons with mild hearing difficulty and those with major hearing difficulty was statistically non-significant (56 vs. 54, respectively; $p=.106$). At the 2-year follow-up, the LSM score had declined in all three hearing categories (main effect of time $p<.001$) at a similar rate (group x time $p=.164$) and hearing had a statistically significant effect on the LSM score (main effect of group $p=.049$). However, participants without hearing difficulties had a higher LSM score than those with either mild (55 vs. 51, respectively, $p=.012$) or major hearing difficulties (55 vs. 51, $p=.037$), whereas no difference in LSM scores ($p=.544$) were observed between the participants with mild and those with major hearing difficulties (Table 3, Model 2). The LSM score substantially attenuated in all hearing groups after cognitive functioning and chronic conditions were included in the model, suggesting that these factors influence LSM.

TABLE 3 Estimated marginal means for life-space mobility by categories of self-reported hearing over the two-year follow-up.

	Model 1[a]								
	Baseline			1-year follow-up			2 -year follow-up		
	Mean	**SE**	**95%CI**	**Mean**	**SE**	**95%CI**	**Mean**	**SE**	**95%CI**
No hearing difficulties	68	1.14	65-70	66	1.16	64-68	65	1.23	63-68
Mild hearing difficulties	65	0.93	64-67	63	1.08	61-65	60	1.09	58-62
Major hearing difficulties	62	1.37	59-64	60	1.35	57-63	59	1.41	56-62
	Model 2[b]								
No hearing difficulties	57	1.96	53-61	56	1.93	52-60	55	1.97	51-59
Mild hearing difficulties	56	1.75	53-60	54	1.86	50-58	51	1.87	47-54
Major hearing difficulties	54	1.95	50-58	52	1.96	48-56	51	2.00	47-55

Notes:
a= adjusted for age and sex
b= adjusted for age, sex, cognitive functioning (MMSE) and chronic conditions (diabetes, cardiac, circulatory and neurological diseases and rheumatoid arthritis)

At baseline, participants with major hearing difficulties had significantly higher odds for restricted life-space (LSM score <60) compared to those without hearing difficulties. Among the participants with unrestricted life-space at baseline (LSM score $\geq$ 60), those who also reported having mild or major hearing difficulties at baseline had approximately twofold higher odds for life-space restriction at the two-year follow-up compared to those without hearing difficulties (Table 4). While further adjustments for cognitive functioning and chronic conditions did not materially change the results, the odds ratio became borderline significant for those with major hearing difficulties (Table 4, Model 2[b]). Participants with major hearing difficulties were older, their cognitive functioning was poorer, and they had higher percentage of cardiac diseases compared to other groups (Table 2). It is likely that these factors affected LSM score and thus the observed association between hearing difficulties and life-space attenuated.

TABLE 4 Odds for restricted life-space by categories of self-reported hearing difficulties at baseline and for incidence of life-space restriction at the two-year follow-up.

			Baseline (N=844)					
			Model 1[a]			Model 2[b]		
Baseline hearing difficulties	**n**	**Life-space restriction %**	**OR**	**95%CI**	**p**	**OR**	**95%CI**	**p**
No hearing difficulties	276	31	1			1		
Mild hearing difficulty	381	41	1.5	1.0-2.1	.033	1.4	0.9-2.0	.107
Major hearing difficulty	187	55	2.1	1.4-3.2	<.001	1.8	1.2-2.8	.007
			Two-year follow-up (N=465)					
			Model 1[a]			**Model 2[b]**		
	n	**Life-space restriction %**	**OR**	**95%CI**	**p**	**OR**	**95%CI**	**p**
No hearing difficulties	177	16	1			1		
Mild hearing difficulty	210	27	1.8	1.1-3.1	.025	1.8	1.0-3.2	.035
Major hearing difficulty	78	30	2.1	1.1-4.0	.031	2.0	1.0-3.9	.057

Notes:
Group without hearing difficulties at baseline is the reference group. Odds ratios for restricted life-space (=LSM score <60) during the two-year follow-up were calculated only for participants with unrestricted life-space at baseline.
a = adjusted for sex and age
b = adjusted for sex, age, cognitive functioning (MMSE), rheumatoid arthritis, diabetes, cardiac, circulatory and neurological diseases. Information on cognitive functioning and chronic conditions were based on baseline data.

5.2 Hearing aid use and life-space mobility (Study II)

Table 5 presents the sample characteristics by perceived benefit from HA use reported at the 2-year follow-up of the LISPE study. The postal questionnaire, which included data on HA use, was returned by 712 participants. Of those participants, 127 reported having a HA and information on the perceived benefit from HA use was available for 118 participants. These participants were included in the analyses along with those without a HA (n=584), and thus the final sample comprised 702 participants. LSM data were available for 699 of these participants. As these data were missing for less than 1% of the sample, missing values were not imputed.

TABLE 5 Participant characteristics categorized by hearing aid use at the two-year follow-up (N=702).

	No hearing aid (n=584) Mean (SD)	**Less hearing aid benefit (n=41) Mean (SD)**	**More hearing aid benefit (n=77) Mean (SD)**	**p[a]**
Age	81.3 (4.0)	83.3 (4.3)	83.9 (4.4)	<.001
Education in years	9.7 (4.2)	9.4 (4.2)	9.7 (4.4)	.872
Cognitive functioning (MMSE score, range 0-30)	26.0 (2.7)	25.5 (3.2)	26.2 (2.3)	.820
Perceived hearing ability without a hearing aid (range 0-10)[c]	2.9 (2.3)	5.8 (1.9)	7.3 (1.7)	<.001
Perceived hearing ability with a hearing aid (range 0-10)[c]	-	5.4(2.4)	2.7(1.4)	<.001
	n (%)	**n (%)**	**n (%)**	**p[b]**
Women	366 (63)	25 (61)	50 (65)	.899
Cardiac diseases	233 (40)	22 (54)	34 (44)	.191
Circulatory diseases	378 (65)	30 (73)	34 (56)	.146
Diabetes	101 (17)	7 (17)	15 (20)	.891
Neurological diseases	34 (6)	3 (7)	7 (9)	.517
Rheumatoid arthritis	30 (5)	1 (2)	3 (4)	.679

Notes:
SD = standard deviation
MMSE= Mini-Mental State Examination
a = one-way ANOVA
b = Chi-Square test
c = Higher scores indicate poorer performance

Among the participants who perceived more benefit from HA use, 81% reported using their HA daily and on average for 9 hours/day. Among those who perceived less benefit from HA use, 49% reported daily use and for an average of 6 hours/day. Five participants (4%of HA users) reported having a HA in both ears (binaural fitting). Distributions of the self-reported unaided and aided hearing scores by categories of HA use are shown in Figure 5.

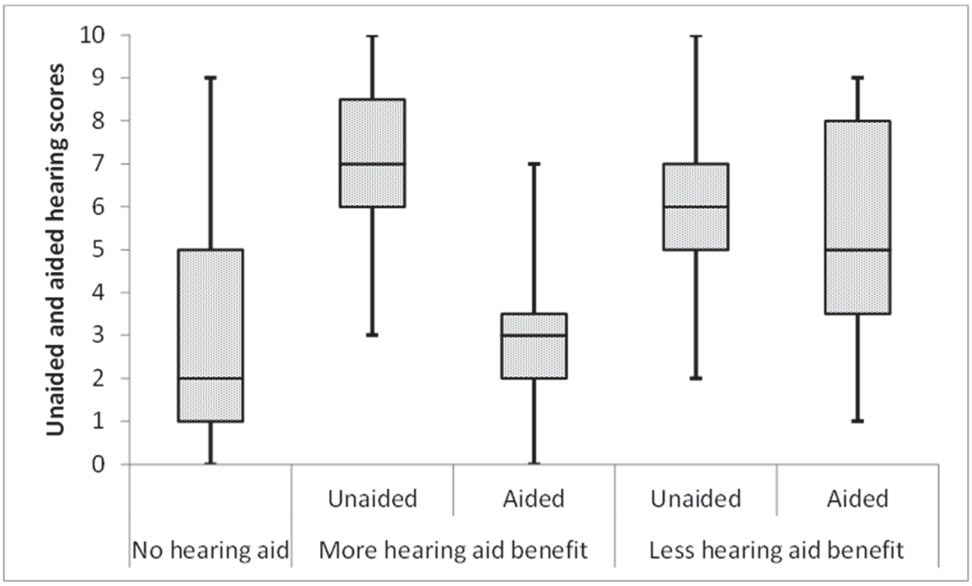

FIGURE 5 Distributions of the self-reported unaided and aided hearing scores by categories of HA use. Higher scores indicate poorer hearing performance.

Figure 6 displays the estimated marginal means for LSM by categories of HA use. The analysis showed that participants who perceived more benefit from HA use had a significantly higher LSM score than those who perceived less benefit from using a HA (mean 65, 95%CI 60—70 vs. 55, 95%CI 49—61, respectively, mean difference 10.1, 95%CI for difference 0.8—19.4, p=.028). LSM scores did not significantly differ between participants who perceived more benefit from use of a HA and HA non-users (63, 95%CI 61—65; mean difference 2.1, 95%CI for difference -4.8—8.9, p=1.0). The difference between HA non-users and participants who perceived less benefit from HA use was borderline significant (mean difference 8.0, 95%CI for difference -0.03—16.1, p=.051) (Model 2 in Figure 6).

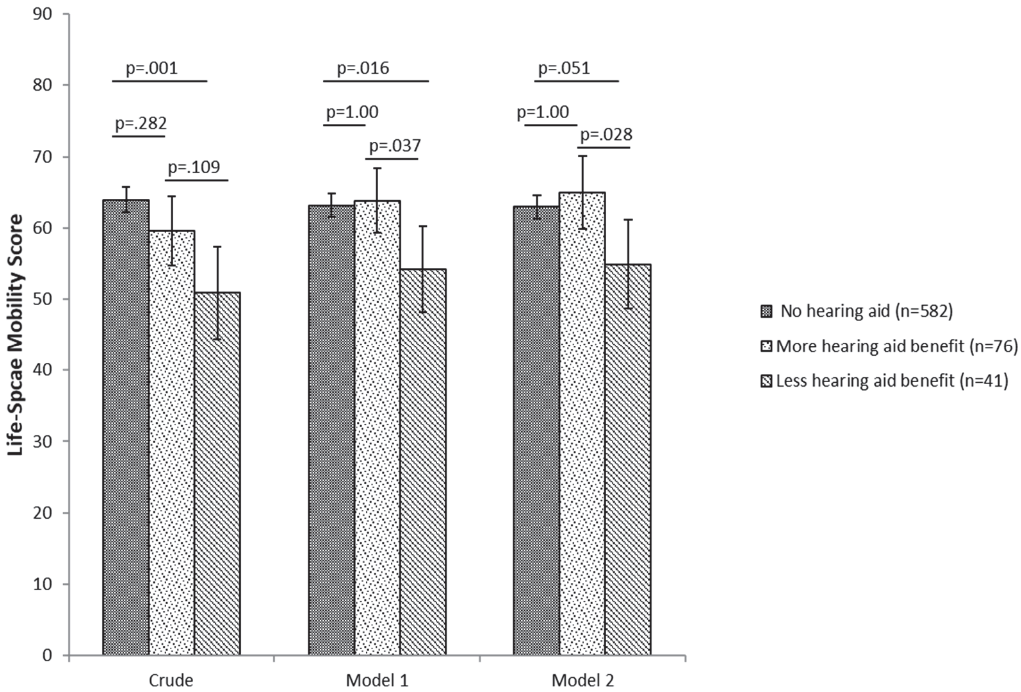

FIGURE 6 Estimated marginal means and 95%CIs for life-space mobility by categories of HA use. Crude model and adjusted scores. Model 1 is adjusted for age and Model 2 is adjusted for age and perceived hearing ability without a hearing aid.

Participants who perceived less benefit from a HA had higher odds for restricted life-space compared to HA non-users; this association remained significant after adjustment for age and perceived hearing ability without a hearing aid. Participants who perceived more benefit from a HA did not significantly differ from HA non-users (Table 6; previously unpublished data).

TABLE 6 Odds for restricted life-space (life-space mobility score <60) by categories of hearing aid use (N=699).

		Model 1[a]			Model 2[b]		
Hearing aid use	**Life-space restriction %**	**OR**	**95%CI**	**p**	**OR**	**95%CI**	**p**
Non-users (n=582)	40	1			1		
Less hearing aid benefit (n=41)	68	3.3	1.7-6.4	.001	2.4	1.1-5.1	.023
More hearing aid benefit (n=76)	47	1.4	0.8-2.2	.205	0.8	0.4-1.4	.384

Notes:
Group without a hearing aid is the reference group.
a = crude model
b = adjusted for age and perceived hearing ability without a hearing aid

5.3 Hearing and quality of life (Study III)

In Study III, perceived hearing difficulties were examined with the HERE scale. The exploratory factor analysis for the scale yielded three dimensions reflecting different aspects of perceived hearing difficulties, i.e., *socioemotional effects, speech hearing and spatial hearing*. The factor loadings on each item in the questionnaire for each factor are shown in Table 7.

TABLE 7 Hearing in Real-Life Environments (HERE) scale. Geomin-rotated exploratory factor analysis loadings, communality estimates and subscale Cronbach alphas for hearing scale items. Communalities represent the share of item variance explained by the factor solution.

	Factor			
	1	**2**	**3**	
Item	**Socioemotional effects (α=0.93)**	**Speech hearing (α=0.96)**	**Spatial hearing (α=0.89)**	**Communality**
My hearing difficulties hamper my social life (for example meeting friends or acquaintances, participating in leisure-time activities or different gatherings).	**0.81**	0.08	0.04	0.66
I feel left out when I am with a group of people because of my hearing difficulties.	**0.90**	0.01	0.01	0.81
Hearing problems cause me to feel frustrated.	**0.94**	-0.01	-0.03	0.89
Hearing problems cause me to feel embarrassed.	**0.85**	-0.01	-0.08	0.73
I need help from other people because of my hearing difficulty.	**0.59**	0.23	0.00	0.40
How is your hearing.	-0.10	**0.91**	0.00	0.83
When I am having a conversation with another person at my home, I find it difficult to hear his/her speech.	-0.01	**0.90**	-0.09	0.82
I have to ask the person I´m talking to repeat what he/she is saying when having a conversation in a quiet room.	0.06	**0.84**	-0.12	0.73
It is difficult for me to follow what another person in saying when other people are simultaneously talking around us.	-0.02	**0.85**	0.11	0.73
It is difficult for me to follow what performers are saying at the theatre, in a concert or some other similar situation.	0.05	**0.81**	0.11	0.67

It is difficult for me to follow speech in places where you can hear an echo (e.g. priest's sermon in church).		-0.00	**0.82**	0.14	0.70
I have to strain to hear when listening to something or someone.		0.10	**0.84**	-0.01	0.71
I can estimate from a sound the direction from which the sound is coming (e.g. dog barking or sound of a car).		0.47	0.04	**0.51**	0.48
I can estimate from the sound how far away the sound source is (e.g. dog barking or sound of a car).		0.46	-0.00	**0.63**	0.60
I can estimate from the sound whether the sound source is coming towards me or going away from me (e.g. a barking dog or a car).		0.59	-0.01	**0.47**	0.54
I find traffic noises uncomfortably loud.		0.35	0.28	0.13	0.22
Factor correlations	1	1.0			
	2	0.74	1.0		
	3	0.37	0.51	1.0	

Note: Boldface values are significant at 5% level

Table 8 presents the characteristics of the total sample and substudy sample at the 2-year follow-up. Among the substudy participants, the mean BEHL ($_{PTA\ 0.5\text{-}4\ kHz}$) was 39 dB (SD 14.4, range 10—83 dB). BEHL ($_{PTA\ 0.5\text{-}4\ kHz}$) correlated moderately with all three dimensions of perceived hearing difficulties (Speech hearing r=.471, p<.001; Socioemotional effects r=.423, p<.001; and Spatial hearing r=.299, p<.001).

TABLE 8 Sample characteristics of the total sample and substudy sample at the two-year follow-up.

	Total sample		Substudy sample	
	n	**Mean (SD)**	**n**	**Mean (SD)**
Age	712	81.7 (4.2)	161	82.2 (4.2)
Education in years	712	9.8 (4.2)	158	9.6 (4.3)
Cognitive functioning (MMSE score, range 0-30)	712	26.4 (2.6)	161	26.1 (2.5)
Quality of life				
Total score (range 0-130)	706	95.0 (13.8)	160	94.1 (13.6)
Physical domain (range 0-100)	706	64.0 (18.6)	161	62.8 (17.9)
Psychological domain (range 0-100)	706	64.4 (14.3)	161	64.3 (14.1)
Social domain (range 0-100)	705	64.4 (18.7)	160	63.5 (17.2)
Environmental domain (range 0-100)	706	72.8 (15.3)	160	71.3 (16.0)
Self-reported hearing [a]				
Speech hearing (range 0-10)	653	2.8 (2.1)	157	2.7 (2.1)
Socioemotional effects (range 0-10)	667	1.4 (1.7)	160	1.3 (1.7)
Spatial hearing (range 0-10)	668	2.4 (2.1)	159	2.1 (1.9)
BEHL ($_{PTA0.5\text{-}4kHz}$), dB			168	38.8 (14.4)
		n (%)		**n (%)**
Women	712	445 (63)	161	100 (62)
Hearing aid owners	711	127 (18)	161	30 (19)
Diabetes	712	124 (17)	161	25 (16)
Cardiac diseases	712	292 (41)	161	72 (45)
Circulatory diseases	712	457 (64)	161	101 (63)
Neurological diseases	712	45 (6)	161	10 (6)

Notes:
IQR = Interquartile range
SD = standard deviation
MMSE = Mini-Mental State Examination
BEHL = Better ear hearing threshold level
PTA =pure tone average 0.5-4kHz
dB = decibel
a = Mean scores of the items in each factor. Higher scores indicate poorer performance/more difficulties

Associations between the dimensions of perceived hearing difficulties and QoL as well as between measured HL (BEHL $_{PTA\ 0.5\text{-}4kHz}$) and QoL are shown in Table 9. Higher scores in any dimension of perceived hearing difficulties were significantly associated with poorer QoL in each QoL domain. No significant associations were found between measured HL (BEHL $_{PTA\ 0.5\text{-}4kHz}$) and any of the QoL domains.

The influence of HA use on the results was tested by conducting the analysis separately for HA users and non-users (data not shown). This did not essentially change the results and therefore HA users and non-users were included in the same model.

TABLE 9 Associations between dimensions of perceived hearing difficulties and quality of life (QoL) in the total sample at the two-year follow-up (N=706), and between measured uncorrected hearing threshold level ($BEHL_{PTA\ 0.5\text{-}4kHz}$) and QoL in the substudy sample (N=161). Linear regression analysis.

		Model 1[a]			**Model 2[b]**		
		β	**SE**	**p**	**β**	**SE**	**p**
QoL domain	**Dimension of hearing difficulty**						
Total score							
	Speech hearing	-.259	.51	<.001	-.226	.50	<.001
	Socioemotional	-.296	.52	<.001	-.269	.50	<.001
	Spatial hearing	-.181	.58	<.001	-.151	.56	<.001
	$BEHL_{(PTA\ 0.5\text{-}4\ kHz)}$	-.004	.08	.958	.084[c]	.08	.325
Physical							
	Speech hearing	-.260	.70	<.001	-.222	.67	<.001
	Socioemotional	-.275	.70	<.001	-.243	.67	<.001
	Spatial hearing	-.178	.79	<.001	-.144	.75	<.001
	$BEHL_{(PTA\ 0.5\text{-}4\ kHz)}$	.022	.10	.784	.119[c]	.11	.164
Psychological							
	Speech hearing	-.218	.54	<.001	-.199	.54	<.001
	Socioemotional	-.269	.54	<.001	-.252	.54	<.001
	Spatial hearing	-.180	.60	<.001	-.162	.60	<.001
	$BEHL_{(PTA\ 0.5\text{-}4\ kHz)}$	.057	.08	.475	.141[c]	.08	.099
Social							
	Speech hearing	-.134	.72	<.001	-.115	.72	.001
	Socioemotional	-.173	.72	<.001	-.157	.72	<.001
	Spatial hearing	-.114	.70	.002	-.098	.80	.009
	$BEHL_{(PTA\ 0.5\text{-}4\ kHz)}$	-.089	.10	.266	-.031[c]	.10	.717
Environmental							
	Speech hearing	-.192	.58	<.001	-.171	.58	<.001
	Socioemotional	-.235	.58	<.001	-.219	.58	<.001
	Spatial hearing	-.102	.65	.007	-.082	.65	.028
	$BEHL_{(PTA\ 0.5\text{-}4\ kHz)}$	.025	.09	.750	.089[c]	.10	.306

Notes:
β = Standardized coefficient beta
SE = the standard errors of the coefficients
QoL= Quality of life
BEHL = Better ear hearing threshold level
PTA = pure tone average 0.5-4kHz
a = Crude model
b = adjusted for sex, age and cardiac diseases
c = adjusted for age only

5.4 Life-space mobility and depressive symptoms (Study IV)

Table 10 summarizes the characteristics of the participants categorized according to sex.

TABLE 10 Characteristics of the participants by sex at baseline (N=848).

	Women (n=526)			Men (n=322)			
	Mean	**Median**	**IQR**	**Mean**	**Median**	**IQR**	**p[a]**
Age	80.3	80.0	8.0	79.5	79.0	7.0	.005
Education in years	9.2	8.0	5.0	10.3	9.0	5.0	.005
MMSE score (range 0-30)	26.2	27.0	3.0	26.2	27.0	3.0	.630
IPA total score (range 0-20)	6.4	6.0	5.0	5.7	5.0	3.0	.005
Number of chronic conditions	4.5	4.0	3.0	3.9	4.0	3.0	<.001
LSM-score (range 0-120)	59.9	60.0	28.4	71.3	72.0	26.0	<.001
CES-D total score (range 0-60)	10.4	9.0	9.5	8.2	8.0	9.0	<.001
Depressed affect (range 0-21)	2.6	2.0	4.0	1.6	1.0	3.0	<.001
Somatic symptoms (range 0-21)	3.8	3.0	3.0	3.1	3.0	4.0	<.001
Positive affect (range 0-12)	8.3	9.0	5.0	8.8	9.0	4.0	.032
Interpersonal problems (range 0-6)	0.3	.00	0.0	0.3	.00	0.0	.665
	n	**%**		**n**	**%**		**p[b]**
Living alone	367	70		85	26		<.001
Walking difficulty, 500m	158	30		59	18		<.001
Perceived financial situation							.005
Good or very good	248	47		179	56		
Moderate	261	50		139	43		
Poor or very poor	17	3		2	0.6		

Notes:
IQR = Interquartile range
LSM-score = Life-Space mobility score
CES-D = Centre for Epidemiological Studies Depression Scale
MMSE = Mini-Mental State Examination
IPA = Autonomy outdoors from the Impact on Participation and Autonomy questionnaire.
a = Mann-Whitney U-test, comparison between women and men
b = Chi-Square test, comparison between women and men

Associations between LSM and different dimensions of depressive symptoms were examined by utilizing the baseline measurements of the LISPE study. LSM data were available for all 848 participants and data on depressive symptoms (CES-D) for 843 participants (CES-D scores were missing for 0,6% of the total sample). A significant interaction of sex and life-space was found ($p<.001$), suggesting that the effect of LSM on depressive symptoms varied as a function of sex. Therefore, men and women were analysed separately. In total, 21% of the women and 12% of the men had a CES-D total score of 16 points or higher, scores which are considered to indicate a clinically significant level of depressive symptoms in community samples. The bivariate correlation between the LSM score and total CES-D score was -.297 ($p<.001$) for women and -.170 ($p=.002$) for men.

Linear regression analyses were conducted to search for potential factors mediating the association between LSM and the different dimensions of depressive symptoms (Table 11). The results were interpreted according to the following two guidelines: 1) fixed demographic characteristics are presumed to precede depressive symptoms; and 2) variables which are considered as possible mediating factors (i.e., sense of autonomy in participation outdoors, walking difficulties, and chronic conditions) are presumed to precede the current level of depressive symptoms. However, it is acknowledged that some of these variables may have been affected by prior depressive symptoms (Hays et al. 1998).

The results showed that when walking difficulties and number of chronic conditions were included in the model, the association between LSM and depressed affect was substantially attenuated for both men and women. For men, the association between LSM and somatic symptoms was also substantially attenuated (Table 11, model 2). These results indicate that these associations are at least partially mediated by perceived walking difficulties and co-morbidity. The association with positive affect was mitigated for both sexes after adding sense of autonomy in participation outdoors into the regression model (model 3). Among women, the association between LSM and interpersonal problems was also partially explained by sense of autonomy in participation outdoors. The association between LSM and somatic symptoms showed the most significant variation by sex and was stronger among women than men (Table 11, model 1). Among men, the association was mainly related to walking difficulties and number of chronic conditions (model 2), while among women, the association was mostly mediated by sense of autonomy outdoors (model 3). Although the 95% CIs for somatic symptoms in model 3 overlap (-0.143, 0.106 for men, -0.277, -0.028 for women), the effect was significant among women. This indicates that the association between LSM and somatic symptoms is not wholly mediated by walking difficulties, chronic conditions or sense of autonomy in participation outdoors.

TABLE 11 Associations between life-space mobility score and the different dimensions of depressive symptoms among men (n=313) and women (n=509) at baseline and comparison of regression coefficients between men and women.

	Model 1[a]			**Model 2[b]**			**Model 3[c]**		
	β	**SE**	**p**	**β**	**SE**	**p**	**β**	**SE**	**p**
CES-D total score			.16			.34			.91
Women	-.236***	.043		-.168**	.048		-.048	.049	
Men	-.183**	.060		-.127*	.063		-.051	.062	
Depressed affect			.79			.70			.25
Women	-.110*	.046		-.047	.052		.047	.053	
Men	-.140*	.061		-.110	.064		-.046	.064	
Somatic symp-toms			**.01**			**.05**			.13
Women	-.289***	.043		-.202***	.049		-.128*	.051	
Men	-.125*	.060		-.068	.063		-.019	.064	
Positive Affect			.98			.80			.63
Women	.179***	.045		.150**	.050		.026	.050	
Men	.201**	.060		.149*	.063		.070	.062	
Interpersonal Problems			.08			.09			.29
Women	-.095*	.047		-.113*	.052		-.062	.055	
Men	.032	.062		.023	.066		.027	.067	

Notes:
β = Standardized coefficient beta
SE = the standard errors of the coefficients
CES-D = Centre for Epidemiological Studies Depression Scale
p = comparison of regression coefficients between men and women. Bold type face indicates a statistically significant difference in regression coefficients between men and women at the 0.05 level of significance based on the likelihood ratio test.
a = adjusted for age, living alone and perceived financial situation
b = adjusted for model 1, walking difficulty (500m walk) and number of chronic conditions
c = adjusted for model 2 and autonomy in participation outdoors
*p< .05. **p< .01. ***p< .001

6 DISCUSSION

This study examined potential associations between older adults' hearing difficulties and LSM and whether such associations are modified by HA use. Relationships between older adults' QoL, hearing sensitivity and hearing difficulties in everyday life situations were also studied, as were the potential associations between LSM and depressive symptoms.

The results of the study indicate that hearing difficulties may contribute to restrictions in LSM among older adults. However, perceiving HA use to be beneficial was associated with higher LSM. Perceived hearing difficulties in daily life, but not audiometrically measured hearing sensitivity, were also associated with QoL. Lower life-space mobility was associated with a higher number of depressive symptoms. These findings are discussed in light of the press-competence model (PCM) proposed by Lawton and Nahemov (1973), which was the conceptual framework of this study.

6.1 Hearing, hearing aid use and life-space mobility

The results of this PhD thesis suggest that hearing problems may contribute to restrictions in LSM over time among older adults. Compared to older adults with hearing difficulties, those with no hearing difficulties had higher LSM at baseline and this difference remained over the 2-year follow up period. During the 2-year follow-up, those with hearing difficulties were almost twice as likely as those without hearing difficulties to limit their life-space to nearby areas only. Among the older adults without perceived hearing difficulties, life-space remained more often unrestricted. The findings indicate that perceived benefit of HA use also affect LSM. Persons who perceived more benefit from HA use were comparable with HA non-users in their LSM. Participants who perceived less benefit from a HA had lower LSM and a higher probability for restricted life-space.

To my knowledge, only one previous study has reported on the association between hearing difficulties and LSM (Allman et al. 2004). The present research seems to be, however, the first effort to investigate the effects of HA use on LSM. In the 18-months follow-up study, Allman and colleagues (2004) examined the predictors of LSM change and hearing difficulties were included in the analyses along with several other diseases, geriatric syndromes, neuropsychological factors and health behaviors. In their study, a statistically significant correlation between hearing difficulties and decline in LSM was found. However, this association was no longer significant when all the other potential significant predictors for LSM change were included into analyses, suggesting that the significance and relative importance of hearing difficulties on LSM may be lesser. However, the sample sizes and the methodologies used to measure hearing differ between their study and the present study, and thus comparison between these results is difficult. Compared to the present study, however, the sample used in the study of Allman and colleagues (2004) contained significantly fewer people classified as having hearing problems and therefore may have lacked the statistical power needed to reveal the association.

The maintenance of mobility is central for older adults, as it enables an active lifestyle and independent living (Webber, Porter & Menec 2010). LSM reflects individuals' everyday activity by considering their real-life mobility and frequency of participation in activities outside the home. Participation in out-of-home activities requires that the person's capacities are consistent with environmental demands, as theorized by the concept of person-environment fit in the press-competence model. Hearing difficulties can disturb this balance by hampering participation in everyday activities and possibly lead to decreased LSM.

Although the precise nature of the link between hearing difficulties and LSM has not been clarified, several plausible explanations can be advanced for this association. Meeting other people is one of the commonest reasons for older adults going outside the home (Gardner 2014) and thus socially active people are also more likely to have larger life space than those with less social interactions (Barnes et al. 2007; Byles et al. 2015). Perceived communication problems and related negative feelings are the most obvious consequences of hearing loss and may lead to a reluctance to be active and engage in social activities outside the home (Wallhagen et al. 2001; Crews & Campbell 2004; Gagné, Southall & Jennings 2011; Gopinath et al. 2012a; Liljas et al. 2015; Mikkola et al. 2015b). Consecutively, individual's LSM may become poorer, which may also accelerate further declines (Pichora-Fuller, Mick & Reed 2015). Changes in LSM may also reflect adaptations that older adults make in response to impaired hearing (Allman, Sawyer & Roseman 2006). For example, a person may participate less often in situations where they experience hearing difficulties (Mikkola et al. 2015b), reflecting a behavioral adaptation resulting from a decline in personal competence and increased difficulties in manage environmental demands.

Hearing loss can also affect LSM by having consequences beyond communication. Epidemiological and experimental studies have consistently shown that hearing loss is associated with difficulties in walking and postural balance, as well as with higher risk for falls and fear of falling and for poorer overall physical functioning (Crews & Campbell 2004; Viljanen et al. 2009a; Viljanen et al. 2009b; Lin & Ferrucci 2012; Viljanen et al. 2012; Chen et al. 2014; Chen et al. 2015; Agmon, Lavie & Doumas 2017). Receiving insufficient environmental acoustic information may also threaten safe mobility and cause feelings of insecurity, for example, by impairing spatial orientation and hampering the observation of environmental threats, e.g. the sounds of motor vehicles, while moving (Ashmead, David & Northington 1995; Arlinger 2003; Gates & Mills 2005; Solheim, Kvaerner & Falkenberg 2011). The avoidance of challenging acoustic environments may lead to negative cycle where restrictions on LSM cause further decline in physical ability and social relationships. Furthermore, hearing loss in old age is often associated with deficits in other sensory as well as cognitive functions, and the cumulative effect of these deficits may further hamper the management of daily activities (Campos, Ramkhalawansingh & Pichora-Fuller 2018).

Unrestricted life-space is defined as a "person's ability to get out of one's neighborhood independently" (Peel et al. 2005; Allman, Sawyer & Roseman 2006). Reporting restricted life-space, in turn, is associated with a reduced sense of autonomy and may reflect abandonment of valued activities and engagement with society (Sawyer & Allman 2010; Portegijs et al. 2014b). Present study suggests that older adults with hearing difficulties may reach this critical threshold for restricted life-space sooner than those without hearing difficulties. In old age, as posited by the PCM (Lawton & Nahemov 1973), compensatory strategies, such as the use of assistive devices, become more important to sustain a given level of functioning. HA use may ease hearing-related problems and facilitate participation in out-of-home situations, thereby supporting LSM. Thus, in accordance with the press-competence model, the perceived benefit from HA use may be related to individuals' ability to use a HA to compensate for the loss of resources in coping with environmental demands. The perceived benefit of HA use may vary across different contexts, as listening situations differ in their auditory demands (Wong, Hickson & McPherson 2003; Williger & Lang 2014). The misfit between the capacities of a hearing-impaired person and the demands of the environment is likely to be greater in activities requiring a lot of communication than in solitary activities (Chang, Ho & Chou 2009). If communication difficulties increase the risk for withdrawal from social situations, then supporting communication by using HAs could alleviate the risk (Kochkin and Rogin 2000). Williger and Lang (2015) examined the use of HAs in everyday life among older adults aged 55 to 88 years. They found that participants who reported greater satisfaction with HAs also reported more diverse listening situations. They concluded that HAs might be proactively used to master situation-specific demands and that HA use and satisfaction depend on the extent to which the HAs helps them to manage effectively in everyday life (Williger & Lang 2015). This is in line with the findings of this thesis showing an association between perceived benefit from HA use and LSM.

According to previous studies, most HA users have moderate or severe hearing impairment (Meyer & Hickson 2012) and are more likely to experience greater benefit from its use than those with mild hearing impairment (Knudsen et al. 2010; Williger & Lang 2014). In line with this, the participants in the present study who perceived more benefit from HA use more often perceived their hearing poorer without a HA compared to those who perceived less benefit from HA use. This would seem reasonable, since people with mild hearing impairment are probably less likely to experience negative consequences, such as severe communication difficulties (Gopinath et al. 2011). Hence, they may also be less likely to use a HA or perceive less gain from using a HA.

HAs can strengthen individuals´ competencies and, hence, help to maintain LSM by supporting active participation in everyday activities. As the present study indicated, the perception that little or no benefit is gained from using a HA increases the risk for life-space restriction. However, despite its potential benefits, unwillingness to use a HA may also be related to perceived disadvantages, such as perceived stigma attached to being seen wearing a HA or to finding it difficult to handle (Williger & Lang 2014). Therefore, people also need to evaluate whether using a HA brings more benefits than disadvantages (Meyer & Hickson 2012; Hickson et al. 2014) and try to "maximize gains and minimize losses related to hearing aid use" (Williger & Lang 2014).

6.2 Hearing and quality of life

It has been reported that, in the general population, QoL declines after age 75, particularly among older adults with hearing impairment (Hogan et al. 2009). Ciorba et al. (2012) reported that only 39% of people with hearing loss, compared to 68% of those without hearing loss, perceived their QoL to be excellent.

In the present study, participants assessed how much their perceived hearing difficulties affected their ability to cope in real-life environments. According to the PCM (Lawton & Nahemow 1973), this assessment can be considered to reflect the balance between individual competencies and environmental demands. In an optimal situation, older adults can choose freely when and in what kind of daily activities they want to participate. Poor hearing, however, impedes an individual´s competence to manage diverse listening situations, and may therefore hamper participation in everyday activities and have a negative effect on QoL (Gatehouse & Noble 2004, Hallberg, Hallberg & Kramer 2008, Hogan et al. 2009, Wallhagen 2010). These results are in line with the findings of several earlier studies showing that hearing loss and hearing-related difficulties are associated with poorer QoL among older adults (Strawbridge et al. 2000; Kramer et al. 2002; Arlinger 2003; Dalton et al. 2003; Chia et al. 2007; Hogan et al. 2009; Solheim, Kvaener & Falkenberg 2011; Gopinath et al. 2012b; Lasisi & Gureje 2013; Zhang et al. 2016; Nordvik et al. 2018). However, the present study provides more detailed information on the associations between different dimensions of perceived hearing difficulties in daily life situations and QoL domains than has previously been reported.

According to the WHO definition, QoL is related to four important domains in an individual's life: physical health, psychological health, environment and social relations (WHOQoL Group 1994; Skevington, Lotfy & O'Connell 2004). Self-esteem, enjoyment and meaningfulness of life, and individuals´ satisfaction with their personal relationships are among the main components of the psychological and social domains of QoL. Hearing difficulties commonly cause communication failures, feelings of embarrassment and exclusion and withdrawal from social activities (Arlinger 2003; Gopinath et al. 2012a; Mikkola et al. 2015b) and may thus lead to poorer QoL in these domains. Poor hearing is also associated with poorer ADL and IADL functional status (Dalton et al. 2003) and difficulties in lower limb performance and mobility (Mikkola et al. 2015a). These associations, in turn, may explain the association with poorer QoL in the physical domain, which includes items such as mobility and the ability to manage daily activities. In the present study, the associations between spatial hearing and the QoL domains were rather modest. However, difficulties in spatial hearing may exacerbate feelings of insecurity while moving around (Arlinger 2003; Gates & Mills 2005) and thereby impair QoL.

Previous findings on the association between audiometrically assessed hearing and QoL have been conflicting. Some studies have reported an association between the severity of hearing loss and poorer QoL (Dalton et al. 2003; Chia et al. 2007; Davis et al. 2016), while other studies have found no such association (Teixeira et al. 2008; Gopinath et al. 2012b; Hogan et al. 2015). In the present study, no significant association was observed between audiometrically assessed hearing and the QoL domains. This finding is reasonable, as hearing deficit audiometrically detected in optimal circumstances largely reflects peripheral sensory functioning, which is only one component of hearing performance. Real-life situations, however, require more challenging hearing processes in different environments, such as speech understanding in a noisy environment (Gatehouse & Noble 2004). Therefore, audiometrically measured hearing loss does not automatically capture how people perceive their hearing ability and how hearing difficulties affect their daily life (Gopinath et al. 2012a).

Based on the PCM (Lawton & Nahemov 1973), the fit between individuals' competencies and the demands of the environment may explain why significant hearing-related difficulties are experienced by some older adults, including those with mild audiometrically measured hearing loss (Newman et al. 1997; Hannula et al. 2011; Hogan et al. 2015) and not by others, including individuals with audiometrically detectable hearing loss (Agrawal, Platz & Niparko 2008; Chang, Ho & Chou 2009). For example, Chang et al. (2009) reported only a moderate association between hearing impairment (pure-tone audiometry) and self-perceived handicap. In their study, only about 21% of participants with moderate to profound hearing impairment ($\geq$ 41 dB HL) perceived themselves as hearing handicapped. A person with audiometrically detectable hearing loss may perceive good QoL, if he/she is able to cope with environmental demands, for example by using a HA as a compensatory strategy or by avoiding situations that challenge hearing (Wiley et al. 2000). In other cases, such as where a person finds that hearing difficulties complicate participation in valued everyday life situations, even mild hearing loss may have a negative effect on QoL (Hogan et al. 2015). Poor hearing may have a different effect on individuals who favor engagement in activities that require good hearing ability (i.e. lots of interpersonal contacts), than on those who prefer more individual activities (Scherer & Frisina 1998; Strawbridge et al. 2000). Thus, QoL may be more closely associated with perceived hearing ability in the community than with audiometrically measured hearing (Chia et al. 2007). However, it should be kept in mind that the participants of the present study were relatively old at baseline and probably already had some degree of age-related hearing loss. The negative effects of hearing loss on QoL may, therefore, have emerged before the start of this study. People in different age groups typically assess their hearing ability differently, and older adults may be less likely to report hearing-related activity limitations compared to younger people (Li et al. 2014). Older adults may consider hearing loss and related difficulties as a normal and unavoidable consequence of aging and thus do not report them (Wallhagen 2010). Moreover, as the progression in age-related hearing loss is gradual and communication difficulties are typically noticed only when hearing loss has reached a moderate level (Gates & Mills 2005; Davis et al. 2016), hearing difficulties may not become evident in everyday life until later (Strawbridge et al. 2000). Therefore, self-reports may sometimes underestimate the prevalence of audiometrically determined hearing impairment (Bainbridge & Wallhagen 2014).

This study did not examine the effect of HA use on older adults' QoL. However, other studies have reported better perceived health-related QoL among HA users than non-users, although ratings were poorer than those of the general population (Hogan et al. 2009). Previous studies have also consistently indicated that HAs reduce perceived hearing handicap (Yueh et al. 2001; Tolson, Swan & Knussen 2002; Gopinath et al. 2012b). However, findings on the impact of HAs on mental and physical health, cognitive function and social engagement remain somewhat inconsistent. Some studies have reported that using a HA does not affect social activities, satisfaction with social relationships, well-being and cognitive functioning (Tesch-Römer 1997; Dawes et al. 2015a), while others have suggested that HAs could potentially reverse the adverse effects of hearing loss on older adults' QoL (Kochkin & Rogin 2000; Yueh et al. 2001; Humes et al. 2002; Chisolm et al. 2007; Ciorba et al. 2012; Gopinath et al. 2012b; Cox, Johnson & Xu 2014; Davis et al. 2016; Hyams, Hay-McCutcheon & Scogin 2018).

6.3 Life-space mobility and depressive symptoms

Depression is the most common mental health disorder in later life (Sivertsen et al. 2015). In the present study, older adults' lower LSM was associated with a higher number of depressive symptoms. This result concurs with earlier findings (Stalvey et al. 1999; Baker, Bodner & Allman 2003; Peel et al. 2005; Allman, Sawyer & Roseman 2006; Cohen-Mansfield, Shmotkin & Hazan 2010; Snih et al. 2012). However, knowledge on possible mediating factors between LSM and depressive symptoms has been limited. A novel finding in the present study was that the associations between LSM and the different dimensions of depressive symptoms were not direct but mediated by walking difficulties, chronic conditions and sense of autonomy in participation outdoors and that these associations differed between men and women. It has been suggested that reduced engagement with the environment is one of the main reasons for increased depressive symptoms in old age, regardless of whether the underlying risks are due to psychological, biological or social factors (Fiske, Wetherell & Gatz 2009). This view emphasizes the importance of LSM on older adults' mental health.

Depressive symptoms form a multidimensional entity (Watson & Clark 1997; Hays et al. 1998; Schroevers et al. 2000; Johnson et al. 2008) that was examined in this study by using a CES-D scale (Radloff 1977) comprising the dimensions of depressed affect, somatic symptoms, positive affect and interpersonal problems. Functional capacity is one of the most important factors affecting the number of depressive symptoms in older adults (Lampinen & Heikkinen 2003; Taylor & Lynch 2004; Greenglass, Fiksenbaum & Eaton 2006). Decline in functional capacity and the development of mobility limitations changes the relationship between the individual and the environment. A person's ability to move in his or her environment may become compromised (Rantakokko et al. 2010), thus increasing the risk for life-space restrictions. Therefore, the finding that walking difficulties and chronic conditions mediated the association between LSM and depressed affect and somatic symptoms, is reasonable. This finding is also in line with earlier studies reporting a strong correlation between physical limitations and depressive symptoms (Hays et al. 1998; Fonda & Herzog 2001).

Limitations in LSM may present a threat to a person's sense of autonomy (Penninx et al. 1998; Stalvey et al. 1999; Wilkie et al. 2006; Portegijs et al. 2014b). Sense of autonomy in outdoor activities is optimal when a people perceive themselves able to decide where, when and how to move in their environment (Cardol et al. 1999; Wilkie et al. 2006). In the present study, higher LSM was associated with more positive affect and the association was mediated by a greater sense of autonomy in participation outdoors. This seems reasonable as the ability to move independently from one place to another provides opportunities to engage in meaningful activities outside the home, an outcome which also supports wellbeing (Schwanen & Ziegler 2011). It is also known that people who perceive greater control over their lives have fewer depressive symptoms, even in cases where they might have physical impairments (Jang et al. 2002). In the present study, the association between LSM and somatic symptoms among women was more closely related to the perception of autonomy outdoors than to mobility limitations or diseases. An earlier study reported similar sex differences, finding a highly significant association between physical health and depressive symptoms in men, but not in women (Beekman et al. 1995). Hence, sense of autonomy and independence in daily life may have more influence than physical limitations on older women's depressive symptoms.

In the present study, a modest trend indicating an association between LSM and interpersonal problems was observed, but only among women. This is not surprising, as the majority of older adults living alone are women, and thus their interaction with other people may strongly rely on social contacts outside the home. It is known that these contacts more strongly affect mental health in older women than in older men (Glaesmer et al. 2011). Having higher LSM enables higher frequency of participation in social activities as well as a greater number of social networks, while reduced LSM leads to fewer opportunities for community participation (Hays et al. 1998, Barnes et al. 2007). Social relationships can provide emotional support and affection as well as the opportunity to obtain concrete support in everyday situations (Fukukawa et al. 2004), thus acting as a protective factor in stressful life situations and reducing the risk for depressive symptoms (Copeland et al. 1999; Glass et al. 2006).

Presumably, not only decline in LSM increase the likelihood of depressive symptoms, but also vice versa. Older adults with depressive symptoms may be less enthusiastic about moving outside their home and consequently experience reduced LSM (Penninx et al. 1998; Rosqvist et al. 2009; Cohen-Mansfield, Shmotkin & Hazan 2010). Therefore, it is likely that the association between poorer LSM and depressive symptoms is bidirectional in that each increases the probability of the other, potentially leading to a vicious circle (Greenglass, Fiksenbaum & Eaton 2006; Cohen-Mansfield, Shmotkin & Hazan 2010).

6.4 Methodological considerations

The present study is based on data from the LISPE -study. The LISPE -study was originally designed to investigate the interactions between home and neighborhood characteristics and older adults' health, functioning, LSM and QoL, and consequently rich data were collected on relevant topics (Rantanen et al. 2012). The LISPE -study investigated a large population-based sample of community-dwelling older adults. Although the participants were rather well functioning, the sample also included people with health problems and participants with and without hearing difficulties. The data were collected from a population-based cohort rather than from a cohort with hearing loss or any other specific health-related problem. It is thus reasonable to assume that the associations observed here likely represent those prevalent among the similar-aged general population in Finland. The participants were interviewed by trained interviewers face-to-face in their homes at baseline and via telephone at the follow-ups thereby ensuring that the data were of good quality. Face-to-face interviews also allowed persons with poorer health to participate as they did not have to be able to move outside their home. The reliability and validity of the questionnaires used in the LISPE -study have been shown to be good (Davidson, Feldman & Crawford 1994; WHOQoL Group 1994; Beekman et al. 1997; Lewinsohn et al. 1997; Baker, Bodner & Allman 2003; Skevington, Lotfy & O´Connell 2004; Sawyer & Allman 2010). Moreover, the new questionnaire, HERE, developed as part of the "Hearing, cognition and well-being" -substudy, has recently been tested and found to be valid, reliable and stable (Heinrich et al. 2019). In the HERE-questionnaire, multiple questions were used to assess perceived hearing difficulties in situations that persons with age-related hearing loss find typically challenging. Participants also evaluated the perceived degree of their hearing difficulties. This approach may provide a broader picture of the extent of hearing difficulties than would be gained by using a single question. Therefore, it can be concluded that the presence of hearing difficulties was appropriately assessed in this study.

Perceived hearing difficulties and perceived benefit from HA use, QoL, depressive symptoms and LSM were all self-reported, and thus may be subject to reporting bias. Some participants may have interpreted questions or filled out questionnaires incorrectly, for example via exaggeration or underestimation in their answers. There is also the possibility of endogenous associations, meaning that self-evaluations are shaped by a confounder such as personality traits or general health pessimism (Podsakoff et al. 2003). However, self-reports of hearing are commonly used in epidemiological studies and are relevant since they make use of information about the difficulties older adults perceive in their everyday situations (Kiely et al. 2012a). Previous studies support the validity of self-reported measures of hearing difficulties and HA benefit (Kramer et al. 1996; Reuben et al. 1998; Strawbridge et al. 2000; Wallhagen et al. 2001; Weinstein 2015). Moreover, subjective experiences, such as QoL, can be evaluated only via self-reports. Depression self-assessment indicators have been estimated to provide excessively high prevalence rates. Nevertheless, it should be noted that the self-assessment scales are not intended to diagnose clinical depression but to demonstrate depressive symptoms in the population (Angst & Merikangas 1997), which was also the aim in this study. Therefore, the CES-D scale was an appropriate tool for assessing depressive symptoms in this PhD thesis.

The use of the WHOQoL-Bref questionnaire (WHOQoL Group 1994) in Study III may have partly affected the associations observed between hearing and QoL. The WHOQoL-Bref is a generic QoL outcome measure, which measures many aspects of QoL and can be used over a wide variety of diseases. Disease-specific QoL questionnaires, in turn, are designed to directly measure the specific consequences of a disease (e.g., hearing-specific questionnaires, such as HHIE) (Nordvik et al. 2018). Generic, versus disease-specific QoL measures may show different results. When examining the effect of hearing loss, generic QoL measures typically show a small-to-medium effect on QoL, while hearing-specific instruments show stronger effects (Chisolm et al. 2007; Bainbridge & Wallhagen 2014). It should be acknowledged that the WHOQoL-Bref and HERE questionnaires are not overlapping, even if some of the items used in HERE to assess the socioemotional effects of perceived hearing difficulties appear similar to some of the items in the social domain of the WHOQoL-Bref scale. The WHOQoL-Bref identifies how people feel and how satisfied they are in general, while HERE focuses specifically on the effects of perceived hearing difficulties.

Because studies II, III and IV were cross-sectional in design, the direction or causality of the associations observed between the variables of interest cannot be established. Therefore, future studies are needed to examine causal pathways. Moreover, although the aim was to control for the effects of potential confounders, the possibility of residual confounding variables induced by unmeasured factors cannot be ruled out.

It should also be noticed that the participants of this study were in the age range 75 to 90 years at baseline, which is a life stage when people are increasingly vulnerable to decline in LSM due to underlying changes in their health, and in their sensory and physical functions (Allman et al. 2004; Jacobs et al. 2012). As hearing decline is usually a gradual process, it is likely that majority of the participants already had at least mild hearing impairment before entering the study and consequently, the influence of hearing difficulties on LSM and QoL was already present. Hence, the longitudinal findings presented in the Study I may be an underestimation. Clearer changes in LSM might have been observed with a longer follow-up starting from middle age. Further studies are needed to confirm the associations reported in this study. Moreover, some persons were excluded from the study because they were not able to communicate due to hearing problems during the initial telephone screening or home interview. Therefore, the number of persons with the severest hearing loss was under-represented in this study. Similarly, it is likely that older adults with the most depressive symptoms were less willing to participate. It can be that the associations observed between hearing, depressive symptoms and LSM might have been stronger had all these persons participated.

Some factors concerning perceived benefits of HA use may have affected the results of Study II. In the study sample, there were significantly fewer HA users than non-users. This may have affected the statistical power of the study. Audiological equipment was not available to quantify hearing status and no information was collected concerning the types of HAs participants had, or the appropriateness of the HA they had been fitted with. Only 4% of HA users reported having a HA in both ears and therefore it was not possible to compare participants who were fitted with one HA (monaural fitting) and those fitted with two HAs (binaural fitting). It should be borne in mind that some participants were only occasional users of their HA, which may have reduced the impact of HA on LSM. On the other hand, people may use their HA only in situations in which they perceive a benefit from so doing, and thus the number of hours of HA use alone does not necessarily reflect HA benefit. Future investigations of the effects of HA use on LSM should consider the role of these variables.

In Study III, the audiometric measurements were conducted solely with pure tone audiometry. The method measures the ability to hear tones, but not the ability to understand words or speech. In future studies, an additional, more direct test for assessing difficulties in hearing speech (for example Hearing in Noise Test) could provide more detailed information on the association between measured hearing and QoL. The audiometric measurements were conducted in the participants' homes instead of in standardized conditions. This may partially have affected the results, although background noise was minimized and measured prior to testing and headphones, which can filter out external voice, were used. The advantage of performing home-measurements is that it enables persons with poorer health to take part.

This study was conducted in a Finnish context and the study participants were all of Finnish ethnic origin. Therefore, generalizations to other ethnic groups and cultural contexts may be limited. According to an OECD report (2017), Finland performs well across the different wellbeing dimensions when compared with other OECD countries; for example, life satisfaction receives one of the highest ratings in Finland, and public health services, some gratis and others at a small fee, are available to all citizens. Audiological services, such as HA fitting, are supplied free of charge by community-owned primary health care (hospitals, national health services, etc.) and are thus easily available (Mäki-Torkko 2001; Sorri et al. 2001). These services have the potential to improve older adults' QoL by decreasing the negative effects of hearing difficulties.

6.5 Implications and future directions

This study yielded new knowledge on the associations between older adults' hearing difficulties, life-space mobility, quality of life and depressive symptoms. Understanding the functional consequences of hearing difficulties accompanying advanced age is important given that in Finland, as in other Western countries, more and more people are reaching very high ages, with the result that age-related hearing problems are becoming more prevalent (Mäki-Torkko 2001). Hearing difficulties are often seen as an inevitable consequence of aging and their impact therefore easily dismissed. However, the findings of this study suggest that, along with audiometric measurements, health care practitioners should also consider the implications of hearing problems for people's ability to manage in everyday life. By understanding how hearing associates with older adults' LSM may help to identify persons who are not yet disabled, but who are at high risk for mobility decline in the near future. Identification of these persons at earlier stages may help to target timely interventions and thus promote older adults' QoL and ability to live actively in community; thereby diminishing the likelihood of subsequent losses in functional capacity. This is in line with the WHO Strategy and Action Plan for Healthy Aging in Europe 2012-2020, which states that allowing older adults to remain active, autonomous and participate fully in the society supports both their quality of life and the sustainability of health and welfare systems in Europe (WHO 2012).

According to the PCM by Lawton and Nahemow (1973), optimal fit between an individual and the environment takes place when person's capacities are consistent with environmental opportunities and demands. Individuals' functioning can be facilitated by modifying contextual factors via removing barriers and/or by strategies compensating for the negative consequences of hearing loss. Further attention should be paid to the balance between individual resources and environmental demands in older adults who have hearing difficulties. It is important to identify the environmental changes that need to be made to support individuals' capabilities. More specifically, on the issue of hearing acuity, it would be worth knowing more precisely how certain acoustic characteristics of the environment, such as environmental noise, affect older adults' possibilities and willingness to maintain active participation in real-world situations in their daily lives. Hearing-friendly environments in different life-space areas could support older adults' out-of-home activity.

Self-perceived restrictions in participation strongly predict the acceptance and use of hearing aids (Palmer et al. 2009; Knudsen et al. 2010; Laplante-Lévesque, Hickson & Worrall 2010; Meyer & Hickson 2012; Hickson et al. 2014; Ng & Loke 2015; Ridgway, Hickson & Lind 2015). Assistive devices can reduce person-environment misfit and thus support more active participation in society. The results of this study indicate that perceiving HA use as beneficial is associated with higher LSM. While HA use may not grant increased participation in everyday activities, the present findings suggest that, by supporting higher LSM, audiological rehabilitation could reduce the negative effects of hearing loss. Further longitudinal studies are needed to establish the causality and pathways underlying these associations.

It would also be important to explore similarities and differences in the associations between hearing difficulties and QoL in different cultural contexts. Although age-related impairment in hearing is universal, QoL is culturally constructed and therefore the variables that most influence QoL may not be identical in different across cultures.

Decline in LSM associates with decline in QoL (Rantakokko et al. 2016) and this study showed that lower LSM is also related to a higher risk for depressive symptoms. These findings emphasize the importance of ensuring opportunities for out-of-home activity to support older adults´ QoL and mental health. Attention to older adults' LSM may help to identify persons at elevated risk for depressive symptoms, even before they fulfil the diagnostic criteria for a major depressive disorder. The notion that the association between LSM and depressive symptoms may partly be mediated through separate underlying factors may help to identify the factors that are important to bear in mind when developing tools for the prevention and treatment of depressive symptoms among older adults. As the relationship between restricted LSM and depressive symptoms is presumably reciprocal, more research is needed to examine the temporal order and potential causality of these phenomena.

Promoting older adults' everyday activity and QoL requires a holistic approach. It needs to be acknowledged that "living well" in old age is affected by various factors that also interact with each other. While it is not possible to influence all these factors at the same time, change in one factor may also affect the others. Therefore, paying attention to older adults' hearing difficulties and finding solutions to alleviate these may be one way to support QoL, active life and engagement with society in old age.

7 MAIN FINDINGS AND CONCLUSIONS

The main findings and conclusions can be summarized as follows:

1. Perceived hearing difficulties in everyday life situations were associated with lower LSM among older adults. Those who reported no hearing difficulties had higher LSM at both baseline and at the 2-year follow-up compared to those with hearing difficulties. Perceived hearing difficulties also increased the odds for life-space restriction to nearby areas.

2. Perceived benefit from HA use affected older adults' LSM. Persons who perceived more benefit from HA use were comparable with HA non-users in their LSM, while perceiving less benefit from a HA was associated with lower LSM and higher probabilities for restricted life-space.

3. Perceived hearing difficulties in various everyday life situations, but not audiometrically assessed hearing loss, were associated with perceived QoL among older adults.

4. Lower LSM was associated with a higher number of depressive symptoms.

YHTEENVETO (FINNISH SUMMARY)

Kuulovaikeuksien, elinpiirin, elämänlaadun ja masennusoireiden väliset yhteydet ikääntyneillä henkilöillä

Tämä väitöskirjatutkimus tarkastelee ikääntyneiden ihmisten kuulovaikeuksien, elinpiirin, elämänlaadun ja masennusoireiden välisiä yhteyksiä. Kuulovaikeudet ovat hyvin yleisiä ikääntyneillä henkilöillä. Tutkimusten mukaan yli puolella 70 vuotta täyttäneistä henkilöistä on kuulovaikeuksia ja eliniän odotteen kasvaessa myös kuulovaikeuksia kokevien määrä lisääntyy, joten aihe koskettaa suurinta osaa ikääntyneestä väestöstä. Liikkumisaktiivisuus elinpiirissä kuvaa henkilön osallistumista arkipäivän tilanteisiin. Laaja elinpiiri tarjoaa enemmän mahdollisuuksia aktiiviseen toimintaan, itsenäisyyteen ja osallistumiseen yhteiskunnassa.

Tutkimuksen tulokset osoittivat, että vanhuusiässä koetut kuulovaikeudet olivat yhteydessä vähentyneeseen liikkumisaktiivisuuteen elinpiirissä, eli vähentyneeseen aktiivisuuteen ja osallistumiseen arjen toiminnoissa. Iäkkäät henkilöt, jotka kokivat kuulovaikeuksia arjen eri tilanteissa, liikkuivat elinpiirissään vähemmän kuin henkilöt, jotka eivät kokeneet kuulovaikeuksia. Kahden vuoden seurannan aikana tutkittavien elinpiiri rajoittui pelkästään lähiympäristön alueelle lähes kaksi kertaa todennäköisemmin kuulonsa heikoksi kokevilla henkilöillä, kun taas henkilöillä, jotka eivät kokeneet kuulovaikeuksia, elinpiiri säilyi useammin rajoittumattomana. Tutkimus osoitti myös, että kuulolaitteen käytöstä koettu hyöty oli yhteydessä ikääntyneiden henkilöiden liikkumisaktiivisuuteen elinpiirissään. Kuulokojeen käytöstä enemmän hyötyä kokevilla henkilöillä liikkumisaktiivisuus elinpiirissä oli vastaavalla tasolla kuin henkilöillä, jotka eivät käyttäneet kuulokojetta. Vähäisempi kojeesta koettu hyöty oli yhteydessä vähäisempään liikkumisaktiivisuuteen elinpiirissä ja lisäsi todennäköisyyttä elinpiirin rajoittumiseen.

Henkilön kokemat kuulovaikeudet jokapäiväisen elämän eri tilanteissa olivat yhteydessä myös heikentyneeseen elämänlaatuun. Tutkimuksessa elämänlaatua arvioitiin WHOQoL-Bref-mittarilla, joka sisältää fyysisen, psyykkisen, sosiaalisen ja ympäristöön liittyvän koetun elämänlaadun. Audiometrisesti mitatulla kuulon tarkkuudella ei ollut yhteyttä ikääntyneiden henkilöiden arvioimaan elämänlaatuun.

Ikääntyneiden henkilöiden vähentynyt liikkumisaktiivisuus elinpiirissä oli yhteydessä myös suurempaan masennusoireiden määrään. Aktiivinen liikkuminen elinpiirissä tarjoaa yksilölle enemmän mahdollisuuksia itsenäisyyteen ja osallistumiseen yhteiskunnassa, kun taas osallistumisen vähentyminen voi johtaa yksinäisyyteen, elämänlaadun heikentymiseen sekä masennusoireiden lisääntymiseen.

Tulosten perusteella voidaan päätellä, että vanhuusiässä tyypillisesti koetuilla kuulovaikeuksilla on yhteys vähäisempään osallistumiseen ja aktiivisuuteen arjen toiminnoissa, sekä heikentyneeseen elämänlaatuun. Vähäisempi liikkumisaktiivisuus elinpiirissä on yhteydessä psyykkiseen terveyteen vaikuttaviin tekijöihin, kuten masennusoireisiin. Asianmukaisilla apuvälineillä, kuten henkilölle sopivan kuulolaitteen käytön avulla, voidaan mahdollisesti lievittää kuulon heikentymisen aiheuttamia vaikeuksia ja tukea ikääntyneiden henkilöiden aktiivista osallistumista yhteiskuntaan. Yhteiskunnallisella tasolla tämä väitöskirjatutkimus edistää ikääntyneiden henkilöiden hyvinvointia ja autonomiaa tuomalla uutta tietoa tekijöistä, jotka voivat johtaa elinpiirin kaventumiseen, sekä elämänlaadun ja itsenäisen selviytymisen heikentymiseen. Nämä ovat keskeisiä teemoja väestön eliniänodotteen noustessa.

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ORIGINAL PAPERS

I

SELF-REPORTED HEARING DIFFICULTIES AND CHANGES IN LIFE-SPACE MOBILITY AMONG COMMUNITY-DWELLING OLDER ADULTS: A TWO-YEAR FOLLOW-UP STUDY

by

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RESEARCH ARTICLE

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Self-reported hearing difficulties and changes in life-space mobility among community-dwelling older adults: a Two-year follow-Up study

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Abstract

Background: Life-space mobility reflects individuals' actual mobility and engagement with society. Difficulty in hearing is common among older adults and can complicate participation in everyday activities, thus restricting life-space mobility. The aim of this study was to examine whether self-reported hearing predicts changes in life-space mobility among older adults.

Methods: We conducted a prospective cohort study of community-dwelling older adults aged 75–90 years ($n = 848$). At-home face-to-face interviews at baseline and telephone follow-up were used. Participants responded to standardized questions on perceived hearing at baseline. Life-space mobility (the University of Alabama at Birmingham Life-Space Assessment, LSA, range 0–120) was assessed at baseline and one and two years thereafter. Generalized estimating equations were used to analyze the effect of hearing difficulties on changes in LSA scores.

Results: At baseline, participants with major hearing difficulties had a significantly lower life-space mobility score than those without hearing difficulties (mean 54, 95 % CI 50–58 vs. 57, 95 % CI 53–61, $p = .040$). Over the 2-year follow-up, the life-space mobility score declined in all hearing categories in a similar rate (main effect of time $p < .001$, group x time $p = .164$). Participants with mild or major hearing difficulties at baseline had significantly higher odds for restricted life-space (LSA score < 60) at two years (OR 1.8, 95 % CI 1.0–3.2 and 2.0, 95 % CI 1.0–3.9, respectively) compared to those without hearing difficulties. The analyses were adjusted for chronic conditions, age, sex and cognitive functioning.

Conclusions: People with major hearing difficulties had lower life-space mobility scores at baseline but did not exhibit accelerated decline over the follow-up compared to those without hearing difficulties. Life-space mobility describes older people's possibilities for participating in out-of-home activities and access to community amenities, which are important building blocks of quality of life in old age. Early recognition of hearing difficulties may help prevent life-space restriction.

Keywords: Hearing, Life-space, Aging, Cohort, Longitudinal study

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Background

Difficulty in hearing is common among older adults [1]. The prevalence of hearing difficulties rises markedly with increasing age [2–4], affecting about two-thirds of people aged 70 years [5] and 90 % of adults aged 80 or above [2]. Most often older adults' hearing difficulties result from degenerative changes in cochlear structure and the auditory pathway [6], although other factors such as exposure to noise, ototoxic drugs and a number of medical conditions, such as diabetes, may induce deterioration in hearing [7].

Previous studies have suggested that hearing difficulties can complicate engagement in everyday life situations; especially those requiring communication with other people [8, 9]. Difficulty in following conversations is one of the most common worries among older adults [10], especially in challenging listening conditions such as in the presence of background noise or sound-reverberating environments [11]. It has also been shown that older people with hearing difficulty experience more walking difficulties [12, 13], poorer postural balance, higher risk for falls [14] and fear of falling [15], than those without hearing impairment, factors which may also compromise possibilities for participation in everyday activities.

Life-space mobility reflects the size of the spatial area a person moves through in daily life, the frequency of moving and the need for assistance [16, 17]. While the assessment of mobility limitations or disabilities reflect a person's potential capacity to perform the particular activities [18, 19], it does not reflect actual participation in activities in question [20, 21]. Life-space mobility, in turn, reflects what people *actually* do, as it describes total mobility, thereby providing us with a broad picture of a person's engagement with the community [16, 20, 22, 23]. Life-space mobility is a measure of the balance between an individual's resources (e.g. physiological and psychological capacity) and the demands of the environment in the context of a person's real-life situation [16, 19].

We are aware of only one earlier study that has investigated the association between hearing problems and life-space mobility. After adjustment for potential confounders, Allman et al. found that hearing difficulty did not predict decline in life-space mobility in a 18-month follow-up [24].

The aim of our study was to examine whether self-reported hearing is associated cross-sectionally with life-space mobility among 75 to 90-year-old community-dwelling older adults and, whether self-reported hearing difficulties at baseline predict changes in life-space mobility at follow-up one and two years later.

Methods

Study design and participants

This study is part of the "Life-space mobility in old age" (LISPE) project, which is a prospective cohort study of community-dwelling older adults. A more detailed description of the study design has been published earlier [25]. Briefly, for this study, a random sample of 2550 community-dwelling 75 to 90-year-old residents of the Finnish municipalities of Jyväskylä and Muurame was drawn from the national population register. Individuals were contacted by letter and over the phone to enquire about their willingness, and assess their suitability, to take part in the study. The inclusion criteria were community-dwelling in the study area, and able to communicate. After screening, a total of 848 eligible people agreed to participate and were interviewed in their homes during spring 2012. Of them, 816 participated in the one-year follow-up and 761 participated in the two-year follow-up. During the two-year period, 41 participants died, 15 moved into institutional care, and 12 were excluded due to loss of the ability to communicate. Other reasons for attrition were moving outside the study area ($n = 6$), poor health ($n = 5$), not willing to continue ($n = 6$), and not reached ($n = 2$). The LISPE project was approved by the Ethical Committee of the University of Jyväskylä. Participants were informed about the project and signed a written informed consent.

Measurements

Hearing

Hearing at baseline was assessed by asking the following three questions:" Do you have difficulties hearing when having a conversation with several people simultaneously?", "Do you have difficulty hearing when conversing with another person in the presence of noise?", and "Do you have difficulties hearing where a particular sound (i.e. phone ringing, sound of a car) is coming from?". The participants were asked to estimate their level of difficulty when using a hearing aid if they had one. The response categories were 1) No difficulty (0 points), 2) Sometimes, some difficulty (1 point), and 3) Yes, major difficulty (2 points). Scores were summed and the resulting scale was divided into three categories: no hearing difficulties (score 0), mild hearing difficulties (score 1–2), and major hearing difficulties (3 or higher). The reason for this categorization was that having major hearing difficulties should involve some difficulty in all three situations or major difficulty in at least one situation plus some difficulty in another situation [26].

Life-space mobility

Life-space mobility was measured using the University of Alabama at Birmingham Life-Space Assessment (LSA) questionnaire [16] at baseline and in both follow-ups. The LSA is based on self-report and comprises 15 items measuring mobility through different life-space levels (bedroom, other rooms in the home, outside home, neighborhood, town, beyond town) in terms of distance, frequency and independence during the 4 weeks preceding the assessment. In this study we used the life-space mobility score [16] ranging from 0 to 120 (higher scores indicate better life-space mobility). A score of <60 on the life-space assessment represents restricted life-space [18, 23]. The reliability and validity of the questionnaire has been found to be acceptable [16, 20, 27].

Potential confounders

Factors previously found to be potential risk factors for life-space mobility decline and hearing difficulties were considered potential confounders [7, 13, 16, 22, 28–31]. *Basic demographic and socioeconomic indicators* of the study subjects included age, sex and number of years of education. *Self-reported physician diagnosed chronic conditions* were obtained from a list of 22 chronic conditions and with an open-ended question. Chronic conditions that could theoretically be linked to hearing difficulties and life-space mobility, namely diabetes, rheumatoid arthritis, cardiac, circulatory and neurological diseases were chosen as potential covariates. *Cognitive functioning* was assessed using the Mini- Mental State Examination (MMSE) [32].

Statistical analyses

The Kruskal-Wallis test was used for continuous variables and chi-square tests for categorical variables to compare the baseline characteristics between the hearing groups. Characteristics of the participants are described using medians and interquartile ranges (IQR) or percentages. In the two-year follow-up, generalized estimating equations (GEE) models were used to test the significance of the association of self-reported hearing difficulties on changes in life-space mobility over time. In addition, logistic regression models were used to investigate whether self-reported hearing difficulties at baseline were associated with higher odds for life-space restriction at baseline and at the second follow-up. In the logistic regression analyses, the life-space mobility score was dichotomized by using a cut-off score of 60. Odds ratios for life-space restriction at the second follow-up were calculated only for those participants who had unrestricted life-space at baseline. Age and sex were included in all models. In addition, cognitive functioning, diabetes and cardiac, circulatory, and neurological diseases had also a significant effect ($p < .05$) on the parameters and were used as covariates in the adjusted models. Education did not have a significant effect in the model and was therefore excluded from the final model.

Life-space mobility data were available for all 848 participants at baseline, 806 participants at the one-year follow-up and 757 participants at the two-year follow up. Data for hearing difficulties at baseline were available for 844 participants. As hearing data were missing for less than 1 % of the participants, missing values were not imputed.

Parameter estimates for the GEE models [33] were obtained from IBM SPSS Statistics for Windows software, version 22.0.0.1. Confidence intervals for the estimated marginal means were computed in the R programming environment, version 3.1.1.

Results

Baseline results

The median age of all the participants ($n = 848$) was 80.0 years at baseline (interquartile range 8.0, mean 80, SD 4.3) and 62 % of the participants were women. At baseline, the median life-space mobility score in the total sample was 64.0 (IQR 30.4, mean 63.9, SD 20.6), ranging from 8 to 120. In the total sample, 33 % reported no hearing difficulties, 45 % reported mild hearing difficulties and 22 % reported major hearing difficulties, while having a hearing aid was reported by 13.5 %. Baseline characteristics of the participants categorized according to self-reported difficulty in hearing are presented in Table 1. There were no differences in distribution of hearing difficulties at the baseline between those participants who were followed and those who were lost during the follow-up.

Participants with major hearing difficulties had a significantly lower life-space mobility score at baseline (mean 62, 95 % CI 59–64) compared to participants without hearing difficulties (68, 95 % CI 65–70, $p < .001$) or with mild hearing difficulties (65, 95 % CI 64–67, $p = .022$). Participants with mild hearing difficulties did not statistically significantly differ from those without hearing difficulties in their life-space mobility score ($p = .141$). After further adjustment for cognitive functioning (MMSE), diabetes, cardiac, circulatory and neurological diseases and rheumatoid arthritis, the statistically significant difference in life-space mobility score between persons with mild hearing difficulty and those with major hearing difficulty became non-significant (56, 95 % CI 53–60 vs. 54, 95 % CI 50–58, $p = .106$), while between participants without hearing difficulties (57, 95 % CI 53–61) and those with major hearing difficulty the difference remained significant ($p = .040$).

At baseline, participants with mild hearing difficulty had 1.5 (95 % CI 1.0-2.1), and those with major hearing difficulty 2.1(95 % CI 1.4–3.2) times higher odds for restricted life-space compared to those without hearing difficulties. After further adjustment for the covariates, the participants with mild hearing difficulty no longer differed significantly from those without hearing difficulties (Table 2).

Follow-up results

At the two-year follow-up the median life-space mobility score of all the participants was 63 (mean 61.4, SD 22.1, IQR 35).

Table 1 Baseline characteristics of the participants categorized according to self-reported difficulty in hearing

	No hearing difficulties (*n* = 276)		Mild hearing difficulties (*n* = 381)		Major hearing difficulties (*n* = 187)		
	Median	IQR	Median	IQR	Median	IQR	p[a]
Age	79.0	6.0	80.0	8.0	81.0	8.0	<.001
Education in years	9.0	5.0	9.0	6.0	8.0	5.0	.224
MMSE score	27.0	3.0	27.0	3.0	26.0	4.0	<.001
	%	(n)	%	(n)	%	(n)	p[b]
Women	63.4	175	59.3	226	65.2	122	.328
Hearing aid owner	1.5	4	10.0	38	38.2	71	<.001
Cardiac diseases	31.9	88	43.6	166	54.5	102	<.001
Circulatory diseases	58.0	160	69.6	265	68.4	128	.005
Diabetes	15.9	44	17.8	68	19.8	37	.562
Neurological diseases	6.9	19	6.8	26	8.0	15	.859
Rheumatoid arthritis	4.0	11	5.0	19	8.0	15	.153

[a]Kruskal-Wallis H-test
[b]Chi-Square test

Over the 2-year follow-up, the life-space mobility score declined in all the hearing categories (main effect of time $p < .001$) and at a similar rate (group x time $p = .164$) (Fig. 1). Hearing had a significant effect on the life-space mobility score over the two-year follow-up (main effect of group $p = .049$). During the two-year follow-up, the difference in life-space mobility score remained significant ($p = .001$) between the participants without hearing difficulties and those with major hearing difficulties. At the end of the follow-up, participants without hearing difficulties had a higher life-space mobility score (Mean 65, 95 % CI 63–68) than those with either mild (60, 95 % CI 58–62, $p = .002$) or major hearing difficulties (59, 95 % CI 56–62, $p = .001$). Participants with mild hearing difficulties and those with major hearing difficulties did not differ in their life-space mobility score at two-years ($p = .544$). Further adjustments for cognitive functioning, rheumatoid arthritis, diabetes, cardiac, circulatory or neurological diseases did not essentially change the differences between hearing categories, as life-space mobility score remained significantly higher among participants without hearing difficulties (55, 95 % CI 51–59) compared to those with mild (51, 95 % CI 47–55, $p = .012$) or major (51, 95 % CI 47–55, $p = .037$) hearing difficulties.

Among the participants with unrestricted life-space at baseline (LSA-score > 60, $n = 465$), those with mild or

Table 2 The odds for restricted life-space by categories of self-reported hearing difficulties at baseline and odds for incident of life-space restriction at second follow-up

		Baseline (n = 844)						
			Model 1[a]			Model 2[b]		
Baseline hearing difficulties	n	Life-space restriction %	OR	95 % CI	p	OR	95 % CI	p
No hearing difficulties	276	30.9	1			1		
Mild hearing difficulty	381	41.2	1.5	1.0-2.1	.033	1.4	0.9-2.0	.107
Major hearing difficulty	187	54.5	2.1	1.4-3.2	<.001	1.8	1.2-2.8	.007
		Two-year follow-up (n = 465)						
			Model 1[a]			Model 2[b]		
	n	Life-space restriction %	OR	95 % CI	p	OR	95 % CI	p
No hearing difficulties	177	16.4	1			1		
Mild hearing difficulty	210	27.1	1.8	1.1-3.1	.025	1.8	1.0-3.2	.035
Major hearing difficulty	78	29.5	2.1	1.1-4.0	.031	2.0	1.0-3.9	.057

Group without hearing difficulties at baseline is the reference group. Odds ratios for restricted life-space (=life-space mobility score <60) during the two-year follow-up were calculated only for those participants who had unrestricted life-space at baseline
[a]adjusted for sex and age
[b]adjusted for sex, age, cognitive functioning (MMSE),rheumatoid arthritis, diabetes, cardiac, circulatory and neurological diseases

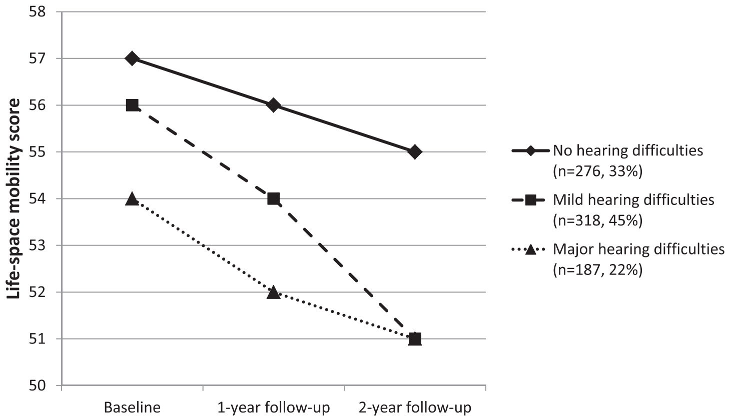

Fig. 1 Estimated marginal means for life-space mobility by categories of self-reported hearing over a two-year follow-up. Fully adjusted model

major hearing difficulties at baseline had significantly higher odds for life-space restriction at the second follow-up compared to those without hearing difficulties. While further adjustments did not materially change these results, the odds ratio became borderline significant (p = .057) for those with major hearing difficulty (Table 2).

Discussion

Our results showed that hearing difficulties were associated with poorer life-space mobility in community-dwelling older adults. Life-space mobility declined steadily in all the hearing categories over the two-year follow-up period. However, persons who did not have hearing difficulties at baseline had significantly higher life-space mobility score both at baseline and at the two-year follow up compared to those who reported hearing difficulties, even when controlling for the presence of chronic medical conditions and the influence of cognitive functioning, age and sex. It is likely that this trend existed before the cohort was followed up. Thus, although the changes observed in the life-space mobility score between the hearing categories were modest, the results indicate that hearing problems may contribute to restrictions in life-space mobility over time among older adults.

According to previous studies [18, 23], a score of 60 and higher on the life-space assessment represents unrestricted life-space, defined as a "person's ability to get out of one's neighborhood independently" and thus is a marker of independent mobility and resilient aging [20]. Our findings suggest that older adults with hearing difficulties reach this critical threshold for restricted life-space mobility sooner than older adults without hearing difficulties.

To our knowledge, the 18-month follow-up study of Allman and colleagues [24] is the only previous study to examine the association between hearing problems and life-space mobility. In their study, the correlation between hearing difficulties and decline in life-space mobility was attenuated when adjusted for other health conditions. It is possible that their study lacked the power needed to observe an association, as their sample contained significantly fewer people who were categorized as having hearing problems.

There may be several explanations for our findings. According to earlier studies, communication problems are the most prevalent participation restrictions mentioned by older adults with hearing difficulties [8]. For older adults, the desire to interact with other people is typically one of the main reasons for going outside the home [34]. However, challenges in communication may cause feelings of frustration, embarrassment and being left out of things, which in turn may lead to social withdrawal [10, 26, 35–37] and reduce participation in social activities [9, 13], thereby reducing life-space mobility. Older adults with a higher frequency of social participation and greater number of social networks are more likely to have larger life space than those with less social contacts [22, 38]. As life-space mobility reflects individuals' actual mobility and frequency of participation in activities outside the home, it may be that poorer life-space mobility is indicative of a decreased desire among older persons with hearing difficulties to be active and exploit community amenities and engage in social activities. Thus changes in life-space mobility can also reflect the adaptations [18] older adults make in response to impaired hearing. For example, a person may not withdraw completely from situations that pose a challenge to hearing, but engage in them less often [9].

Hearing difficulties not only impede communication with other people, but may also impair the ability to observe environmental hazards. Acoustic information supports observation of the environment while moving [39], and hence its reception is important, e.g., in preparing for elements of danger such as motor vehicles. Hearing difficulties compromise the ability to localize sounds reliably [6, 10], which may make it difficult to piece together what to monitor in the environment, leading eventually to reluctance to expose oneself to such challenging situations and thus reduced activity outside the home. Hearing difficulties have also been reported to be associated with higher rates of walking difficulties [35] and decreased walking speed and postural balance as well as mobility decline and falls [12–14]. Walking and balance difficulties together with inaccurate environmental acoustic information may further impair safe mobility and reduce the desire of older adults to go outdoors, resulting in reduced life-space mobility. Avoidance of challenging acoustic environments may lead to a detrimental cycle where restrictions on life-space mobility cause further decline in physical ability and social relationships.

This study included a large population-based sample of community-dwelling older adults and there were very few missing data in the sample. Although the participants were rather well-functioning, the sample also included people with health problems [25]. It is thus reasonable to assume that the associations found here most likely represent those prevalent among the general population of comparable age. We used multiple questions to assess hearing difficulties in situations that are typically challenging for persons with age-related hearing impairment and we also asked the participants to evaluate the perceived degree of their hearing difficulties. This approach may yield a more comprehensive picture of the extent of hearing difficulties than that gained by using a single question.

A potential limitation of our study is that hearing was self-reported. However, self-reports of hearing are commonly used in epidemiological studies, and previous studies support the validity of self-reported measures of hearing impairment [26, 28, 35, 40]. Furthermore, self-reports are relevant since they make use of information about the difficulties older adults perceive in their everyday situations [41]. A short follow-up is another potential limitation of our study. All of our participants were at least 75 years old at baseline. As hearing decline is usually a gradual process, it is likely that the influence of hearing difficulties on life-space mobility were already present before the cohort was initiated. However, the age range between 75 and 90, of our participants corresponds to that when people are increasingly vulnerable to decline in life-space mobility due underlying changes in health, and in sensory and physical functions [24, 42]. Our results did not show a more accelerated decline in life-space mobility among those with hearing difficulties; however, the logistic regression with restricted life-space mobility as the outcome suggests that hearing difficulties precedes restrictions in life-space mobility. Although we may not have definitely established causation, it is unlikely that limitations in life-space mobility lead to self-reported hearing difficulties. However, we cannot exclude the possibility of residual confounding to the results caused by unmeasured factors.

Further studies with longer follow-ups starting from middle-age are needed to confirm the associations reported in this study. Also, some persons were excluded from the study because they were not able to communicate due to hearing problems during the initial telephone screening or home interview. Therefore, it is likely that the number of persons with severe hearing impairment in this study was under-represented. The associations observed between hearing and life-space mobility might have been stronger had these persons participated.

Conclusions

To conclude, the present study provides new information on longitudinal changes in life-space mobility among older people with and without hearing difficulties. Given the increasing proportion of older adults in the population, it is particularly important to understand the role of hearing difficulties as a risk factor for restricted life-space mobility and consequent decreased participation in society. Our findings emphasize the need for early assessment and recognition of hearing difficulties in order to diminish the likelihood of subsequent losses in functional capacity. In future, additional attention should also be given to the balance between individual resources and environmental demands in older adults who have hearing difficulties. More specifically, it would be important to know more precisely how the acoustic characteristics of the environment and environmental noise affect older persons' possibilities to maintain social relationships and active participation in daily life in real world situations.

Abbreviations

LSA: the University of Alabama at Birmingham Life-Space Assessment (LSA) questionnaire; SE: Standard error; OR: Odds ratio; 95 % CI: 95 % confidence interval; LISPE: "Life-space mobility in old age" study; MMSE: Mini-mental state examination; IQR: Interquartile range; GEE: Generalized estimating equations.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

HP drafted the manuscript. Analyses of the data were carried out by HP, TM and TT. TM, MR, EP, TT, TR and AV made critical revision of the article. TR, MR, EP and AV were responsible for the conception of this study and study design. All authors participated in data collection and interpretation of the data. TR is PI for the LISPE project. All authors read and approved the final manuscript.

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II

PERCEIVED BENEFIT FROM HEARING AID USE AND LIFE-SPACE MOBILITY AMONG COMMUNITY-DWELLING OLDER ADULTS

by

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Perceived Benefit from Hearing Aid Use and Life-Space Mobility among Community-Dwelling Older Adults

ABSTRACT

Objectives: To examine the association between perceived benefit from hearing aid (HA) use and life-space mobility among older adults.

Methods: Cross-sectional analysis of 76-to-91-year-old community-dwelling adults (n=702). Data on perceived hearing with and without a HA were obtained via postal questionnaire and data on life-space mobility (Life-Space Assessment, range 0-120) via phone interview.

Results: Participants who perceived more benefit from HA use, had a better life-space mobility score (mean 65, SD 2.6) than participants who had less benefit from using a HA (55, SD 3.2). Participants who benefitted more from HA use did not differ from those who did not have a HA (63, SD 0.9) in their life-space mobility score.

Discussion: Perceived benefit from HA use is associated with higher life-space mobility among community-dwelling older adults. Future studies are needed to examine whether use of an appropriate HA promotes life-space mobility among those with difficulties in hearing.

Key words: Hearing, hearing aid, life-space, aging, older people

Perceived Benefit from Hearing Aid Use and Life-Space Mobility among Community-Dwelling Older Adults

Difficulty in hearing is a common health concern among older adults affecting about two-thirds of people aged 70 years and older (Lin, Thorpe, Gordon-Salant et al., 2011). Hearing difficulties can hamper interaction with other people and safe orientation in the environment (Arlinger, 2003; Helvik, Jacobsen & Hallberg, 2006), thus complicating engagement in daily life situations (Wallhagen, Strawbridge, Shema et al., 2001). Hearing aid (HA) use may improve hearing performance and ease the perceived negative consequences of hearing difficulties (Kochkin & Rogin, 2000), thereby supporting participation in society. However, while most HA users are likely to perceive benefit from HA use (Wong, Hickson & McPherson, 2003), fewer than half of older adults with impaired hearing report using them (Bainbridge & Ramachandran, 2014; Hartley, Rochtchina, Newall et al., 2010; Lin, Thorpe, Gordon-Salant et al., 2011). Among the main reasons for not using a HA are that it is perceived to provide poor benefit, device is found uncomfortable (Hartley, Rochtchina, Newall et al., 2010; McCormack & Fortnum, 2013) or stigmatizing (Gagné, Southall & Jennings, 2011) or, a hearing problem is not perceived severe enough for needing a HA (Gopinath, Schneider, Hartley et al., 2011; Knudsen, Oberg, Nielsen et al., 2010).

In the present study, older adults´ participation in everyday life situations in society is examined through life-space mobility. Life-space mobility refers to the size of the spatial area a person moves through in everyday life, taking into account the frequency of moving and the assistance needed for movement, thus describing total mobility (Baker, Bodner & Allman, 2003). An individual with larger life-space has more opportunities to engage in desired activities in society (Kono, Kai, Sakato et al., 2004), while restrictions in life-space mobility may indicate more limited possibilities for participation (Rosso, Taylor, Tabb et al., 2013). Maintenance of life-space mobility may help to sustain better quality of life (Rantakokko, Portegijs, Viljanen et al., 2016).

Previously, only two studies have investigated the association between hearing difficulties and life-space mobility among older adults, and the results of these studies are somewhat inconsistent (Allman, Baker, Maisiak et al., 2004; Polku, Mikkola, Rantakokko et al., 2015). In both studies, self-reported hearing difficulties were found to be associated with poorer life-space mobility in community-dwelling older adults, but in the study of Allman et al. (2004) the association was not found statistically significant when adjusted for other health conditions (Allman, Baker, Maisiak et al., 2004). Comparison between these results is difficult because the studies differ in their sample sizes and the methodologies used to measure hearing difficulties. Moreover, neither study investigated the effects of HA use on life-space mobility. Thus, the aim of the present study was to explore whether hearing aid use, and more specifically perceived benefit from HA use, is associated with life-space mobility among community-dwelling older adults. In this study, perceived benefit from HA use refers to the difference between unaided and aided self-rated hearing ability. We compared life-space mobility of older adults who benefit less from HA to those who benefit more from HA. In addition, we explored whether these groups differ from those who do not use HA.

METHODS

Study design and participants

This study is based on cross-sectional analyses of the data obtained from the second follow-up of the "Life-Space Mobility in Old Age" (LISPE) project, which is a two-year prospective cohort study of community-dwelling Finnish older adults. The study design and methods, including non-respondent analysis, have been reported in detail elsewhere (Rantanen, Portegijs, Viljanen et al., 2012). Briefly, at baseline, a random sample of 2550 older community-dwelling persons between 75 and 90 years of age was obtained from the national population register and used as the basis for recruitment. After an information letter, the persons were contacted over the telephone to enquire about their willingness to participate. Inclusion criteria were being community-dwelling in the study area, and able to communicate (i.e. able to understand the questions and provide answers to them). In total, 848 eligible persons participated in the baseline interviews during spring 2012. Of these, 761 participated in the two-year follow-up, which consisted of a telephone interview and a postal questionnaire. If the participant was unable to answer the questions over the phone due to hearing problems, the possibility to take part in a face-to-face interview in their homes (n=3) or, to answer the study questions via a postal questionnaire (n=10) was offered and implemented. The 2-year follow-up postal questionnaire, which included data on HA use, was returned by 712 participants (Rantakokko, Portegijs, Viljanen et al., 2016). The LISPE project was approved by the Ethical Committee of the University of Jyväskylä. Participants were informed about the project and signed a written informed consent prior to the study.

Life-Space mobility

Life-space mobility was assessed via telephone interview using the University of Alabama at Birmingham Life-Space Assessment (LSA) questionnaire (Baker, Bodner & Allman, 2003). The LSA is based on self-report and contains 15 items. It measures mobility through different life-space levels (bedroom, other rooms in the home, outside home, neighborhood, town, beyond town) either by walking or using other forms of transportation, such as driving a car or using public transportation, during the four weeks preceding the assessment. Participants were asked how many days a week they attained each life-space level and whether they needed help from another person or from assistive devices. The life-space mobility score ranging from 0 to 120 (higher scores indicate better life-space mobility) was used in the analyses (Baker, Bodner & Allman, 2003).

Perceived hearing ability and perceived benefit from hearing aid use

In the postal questionnaire the participants were asked ”How is your hearing?” Specifically, participants were asked to assess their hearing by choosing the number on a scale from 0 to 10 that best corresponded to their perceived hearing ability. Higher scores indicated poorer performance. Participants, who reported having a HA, gave two answers: one assessing their hearing with, and the other without, their HA (Figure 1).


How is your hearing?

A. Without hearing aid

very good … very poor

0 1 2 3 4 5 6 7 8 9 10

B. With hearing aid

very good … very poor

0 1 2 3 4 5 6 7 8 9 10

Perceived benefit from hearing aid use was quantified by subtracting the aided hearing score from the unaided hearing score, a greater difference indicating greater perceived benefit. The median value of perceived benefit from HA use in the present sample was three, and was used as a cut point to categorize HA users. For the analyses, participants were divided into three groups: 1) More HA benefit (difference of 3 or more points between non-aided and aided hearing ability), 2) Less HA benefit (difference less than 3 points), and 3) No HA-group (participants who reported not having a HA). HA users were also asked whether they used their HA daily (yes/no), whether they had a HA only in one ear or in both ears and, with an open-ended question, to estimate how many hours per day on average they used their HA.

Potential confounders

Factors previously found to be associated both life-space mobility decline and hearing difficulties were considered as potential confounders. *Age and gender* were derived from the population register. *Number of years of education* was used as a socioeconomic indicator. *Self-reported physician-diagnosed chronic conditions* were obtained from a list of 22 chronic conditions and with an open-ended question. Chronic conditions that could theoretically be linked to hearing difficulties and life-space mobility, namely diabetes, rheumatoid arthritis, cardiac, circulatory and neurological diseases, were chosen as potential covariates. *Cognitive functioning* was assessed using the Mini-Mental State Examination (MMSE) (Folstein, Folstein & McHugh, 1975). Depressive symptoms were assessed with the 20-item Centre for Epidemiological Studies Depression Scale (CES-D) (Radloff, 1977).

Statistical analyses

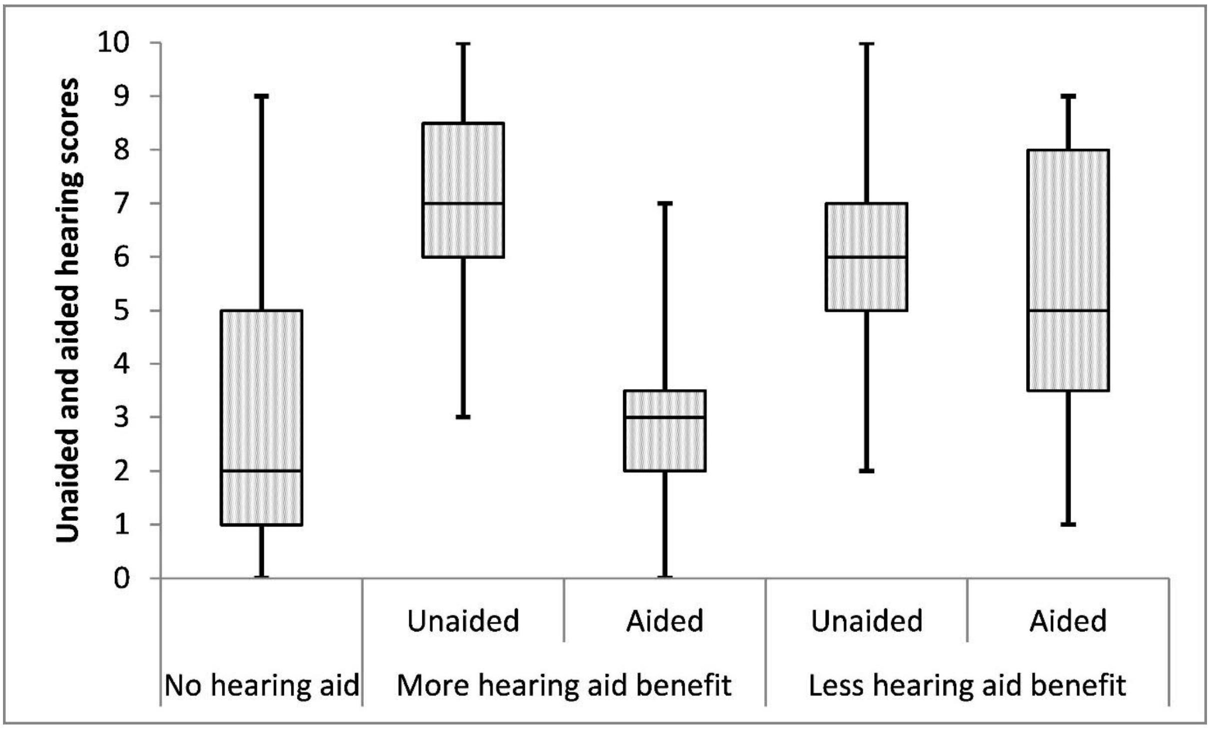
Of those participants who had returned the postal questionnaire (n=712), 584 reported that they did not have a HA and, 127 reported having a HA (data on HA use were missing for one participant). Of these participants who reported having a HA, information on the perceived benefit from HA use was available for 118 participants. These participants were included in the analyses and thus the final sample consisted of 702 participants. Life-space mobility data were available for 699 of these participants. As life-space mobility data were missing for less than 1% of the participants, missing values were not imputed.

Characteristics of the participants are described using means and standard deviations (SD) or percentages. One-way ANOVA was used for continuous variables and chi-square tests for categorical variables to compare characteristics between the groups categorized according to HA use and perceived benefit. Analysis of covariance (ANCOVA) was used to test the association between perceived benefit from HA use and life-space mobility. Levene's test of equality of error variances indicated that the error variance of the dependent variable (life-space mobility score) was equal across groups. Skewness and kurtosis of the life-space score distribution were acceptable in each group.

Of the potential covariates, only age and perceived hearing ability without a HA differed statistically significantly between the groups and were thus included in the analysis. A value of $p<.05$ was chosen as the level of statistical significance. IBM SPSS version 22.0 (SPSS Inc. Chicago, IL) was used for the analyses.

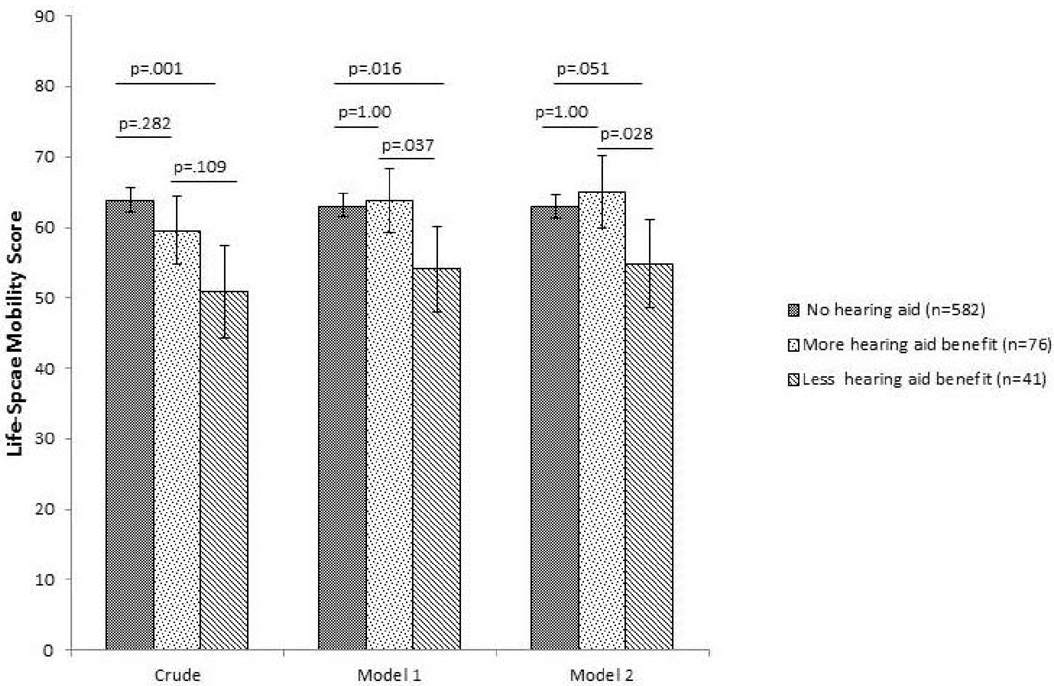
RESULTS

The mean age of the participants was 82 years (SD 4.2) and 63% were women. The mean life-space mobility score was 63 (SD 21.7), ranging from 6 to 120. Of the participants, 18% reported having a HA. The sample characteristics categorized according to perceived benefit from HA use are presented in Table 1. Among the participants who perceived more benefit from HA, 81 % reported using the HA daily and on average 9 hours/day. Among those who perceived less benefit from HA, 49% reported daily use and on average 6 hours/day. Of the 127 participants who reported having a HA, 5 participants (4%) reported having a HA in both ears (binaural fitting). Distribution of the unaided and aided hearing scores by categories of hearing aid use are shown in Figure 2.



The estimated marginal means for life-space mobility by categories of HA use are presented in Figure 3. In the crude model, the difference in the life-space mobility score was not statistically significant between participants who perceived more benefit from HA (mean 60, 95%CI 55-64) and those who perceived less benefit from HA (mean 51, 95%CI 44-

57; mean difference 8.7, 95%CI for difference -1.3 to 18.6). Participants who perceived more benefit from HA did not differ from no-HA group (64, 95%CI 62-66) in their life-space mobility score (mean difference -4.4, 95%CI for difference -10.6 to 1.9). However, no-HA group had significantly better life-space mobility score than those participants who perceived less benefit from HA (mean difference 13.0 , 95%CI for difference 4.8 to 21.3).



After further adjustment for age and perceived hearing ability without a HA (Figure 3, Model 2), the difference in life-space mobility score between those who perceived more benefit from HA and those who perceived less benefit from HA maintained at the same level but became statistically significant (65, 95%CI 60-70 vs. 55, 95%CI 49-61, respectively, mean difference 10.1, 95%CI for difference 0.8 to 19.4, p=.028). Participant who perceived more benefit from HA and no-HA group (63, 95%CI 61-65) did not differ in their life-space mobility score after this adjustment (mean difference 2.1, 95%CI for difference -4.8 to 8.9). The post-adjustment difference between no-HA group and participants who perceived less benefit from HA was borderline significant (mean difference 8.0, 95%CI for difference -0.03 to 16.1, p=.051).

DISCUSSION

Our study showed that persons who perceived more benefit from HA use had a significantly higher life space mobility score than those who perceived less benefit and that their life-space mobility score was comparable to that of those without a HA.

The present study contributes novel information on perceived hearing difficulties and life-space mobility. To our knowledge, only two earlier studies have investigated this association (Allman, Baker, Maisiak et al., 2004; Polku, Mikkola, Rantakokko et al., 2015). However, their findings were conflicting and neither of them focused on HA use. Allman et al. (2004) reported that after adjustment for other health conditions, hearing difficulty did not predict decline in life-space mobility over an 18-month follow-up. Another previous study (Polku, Mikkola, Rantakokko et al., 2015) showed that life-space mobility was lower among people with hearing difficulties but declined at a similar rate over the two-year follow-up period compared to the people who did not have hearing difficulties. The results of the present study provides further evidence for the association of poor hearing and low life-space mobility, as the perceived benefit from the HA use was associated with higher life-space mobility.

There may be several explanations for the current result. For older adults, the need to interact with others is one of the main reasons for going outside the home (Gardner, 2014). However, older people with hearing difficulties can experience communication breakdowns and avoid situations in which they might experience feelings of frustration or being left out (Arlinger, 2003; Gopinath, Hickson, Schneider et al., 2012). Self-stigma means that some older adults hold the same negative stereotypes about their hearing loss as those held by the society. Persons who exhibit self-stigma associated with hearing loss are more likely to reduce their activities outside the home in order to minimize the chances of revealing their hearing loss to others (Gagné, Southall & Jennings, 2011). Even though a person would not withdraw entirely from situations that are challenging for hearing, they may involve in them less frequently (Mikkola, Portegijs, Rantakokko et al. 2015; Polku, Mikkola, Rantakokko et al., 2015). Perceived benefit from the HA may facilitate participation in out-of-home situations, thereby supporting life-space mobility.

Hearing difficulties can also impair a person's ability to reliably detect and recognize acoustic environmental cues when moving around (Arlinger, 2003). These cues may be essential for safe orientation in space, e.g. in localizing sounds of the motor vehicles. Previous studies have shown that hearing impairment is associated with walking difficulties (Viljanen, Kaprio, Pyykkö et al., 2009), poorer postural balance (Viljanen, Kaprio, Pyykkö et al., 2009b) and fear of falling (Viljanen, Kulmala, Rantakokko et al., 2012). These difficulties together with impaired ability to detect environmental acoustic information may compromise safe mobility. Use of a HA may be hypothesized to reduce fear of falling and related activity restriction leading to increased out-of-home participation.

Perceived benefit from HA use is also related to the interaction between the person and his/her environment (Noble & Hetú, 1994). Listening situations differ in their auditory demands (Wong, Hickson & McPherson, 2003) and, for example, having a conversation in a group requires a lot more auditory processing than a conversation in a quiet room (Williger & Lang, 2014). A person who participates in activities that require a lot of communication is more likely to experience hearing difficulties as disturbing than a person who prefers solitary activities (Chang, Ho & Chou, 2009). Thus he or she may also be more likely to perceive benefit from HA use than the person who participates in fewer activities outside the home. It is probable that individuals with moderate or severe hearing impairment are more likely to use a HA and therefore, also more likely to experience more benefit from the use of a hearing aid (Knudsen, Oberg, Nielsen et al., 2010; Williger & Lang, 2014). For people with mild perceived hearing loss, the perceived gain from using a HA may be less. This was also supported by the current study as those who perceived benefit from HA use had lower self-rated hearing without a HA.

The strengths of this study include the use of large population-based sample, which increases the generalizability of the results. As our cohort included participants with and without hearing difficulties, the associations observed in this study likely represent those prevalent in a similar-aged general population. The study also has its limitations. Because of the cross-sectional design, the causality of the associations between the variables investigated cannot be determined. That is, we cannot say that perceiving benefit from the use of HA is a cause or a consequence of higher life-space mobility. Although we aimed to control for the effects of potential confounders, the possibility of residual confounding variables induced by unmeasured factors cannot be ruled out. Also, a few persons were excluded from the study because they were not able to communicate due to hearing problems. Therefore, it is likely that persons with severe hearing impairment were under-represented and selection bias cannot be completely ruled out. Had these persons participated, the associations observed between hearing aid benefit and life-space mobility might have been stronger. Further studies with larger number of hearing aid users are needed to confirm the associations reported in this study. We were not able to use audiological equipment to quantify hearing status or to validate the appropriateness of the hearing aids fitted. However, previous studies support the validity of self-reported measures of hearing impairment and HA benefit (Strawbridge, Wallhagen, Shema et al., 2000). One advantage of self-report questionnaire is that they capture information about the everyday activities and situations (Kiely, Gopinath, Mitchell et al., 2011). Moreover, subjective experiences, such as perceived benefit can be evaluated only via self-reports. In the present study no information was collected concerning the types of HAs used by the participants. Only 4% of the HA users reported having two HAs and therefore it was not possible to compare the participants who were fitted with one HA (monaural fitting) and those fitted with two HAs (binaural fitting). Future investigations of the effects of the HA use on life-space mobility should take into account the role of these variables.

In conclusion, our results indicate that perceived benefit from HA use is associated with better life-space mobility. The current result serves as a justification for future studies examining whether use of a proper HA will promote life-space mobility and participation among those with difficulties in hearing.

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Table 1: Characteristics of the Participants Categorized by Hearing Aid Use (n=702)

	No hearing aid (n=584) Mean (SD)	**Less hearing aid benefit (n=41) Mean (SD)**	**More hearing aid benefit (n=77) Mean (SD)**	**p[a]**
Age	81.3 (4.0)	83.3 (4.3)	83.9 (4.4)	<.001
Education in years	9.7 (4.2)	9.4 (4.2)	9.7 (4.4)	.872
MMSE score (range 0-30)	26.0 (2.7)	25.5 (3.2)	26.2 (2.3)	.820
CES-D score (range 0-60)	13.0 (7.7)	15.5(6.7)	13.8 (6.8)	.105
Perceived hearing ability without a hearing aid (range 0-10)[c]	2.9 (2.3)	5.8 (1.9)	7.3 (1.7)	<.001
Perceived hearing ability with a hearing aid (range 0-10)[c]	-	5.4(2.4)	2.7(1.4)	<.001
	% (n)	**% (n)**	**% (n)**	**p[b]**
Women	63 (366)	61 (25)	65 (50)	.899
Cardiac diseases	40(233)	54 (22)	44(34)	.191
Circulatory diseases	65 (378)	73(30)	56 (34)	.146
Diabetes	17 (101)	17 (7)	20 (15)	.891
Neurological diseases	6 (34)	7 (3)	9 (7)	.517
Rheumatoid arthritis	5(30)	2 (1)	4 (3)	.679

Notes: CES-D = Centre for Epidemiological Studies Depression Scale, MMSE= Mini-Mental State Examination

a= one-way ANOVA

b= Chi-Square test

c= Higher scores indicate poorer performance

Legends for figures

1. Assessment of Perceived Hearing Ability and Perceived Benefit from Hearing Aid Use.
2. Distribution of the unaided and aided hearing scores by categories of hearing aid use. Higher scores indicate poorer performance (0= very good, 10= very poor). Ends of the whiskers indicate the minimum and maximum values.
3. Estimated marginal means and 95% confidence intervals for life-space mobility (range 0-120) by categories of hearing aid use. Crude and adjusted scores. Model 1 is adjusted for age and Model 2 is adjusted for age and perceived hearing ability without a hearing aid.

III

HEARING AND QUALITY OF LIFE AMONG COMMUNITY-DWELLING OLDER ADULTS

by

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Hearing and quality of life among community-dwelling older adults

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ABSTRACT

Objectives: Hearing loss is a common health concern in older people, and the prevalence of hearing loss increases with aging. Poor hearing may cause difficulties in everyday life situations and reduce quality of life (QoL). The aim of this study was to assess the associations between different domains of QoL (physical, psychological, social, and environmental), perceived hearing difficulties in various everyday situations, and audiometrically measured hearing level among community-dwelling older adults.

Methods: Cross-sectional analysis of 76 to 91-year-old community-dwelling adults. Data on QoL (WHO Quality of Life Assessment short version) and perceived hearing difficulties were gathered via postal questionnaires (n=706) and screening pure-tone audiometry was performed at the participants' homes for a random subsample (n=161). Data were analyzed with linear regression models.

Results: Factor analysis on the perceived hearing difficulties questionnaire identified three dimensions: Speech hearing, Socioemotional effects and Spatial hearing. All the perceived hearing difficulty factors, but not the pure-tone audiometry results, were significantly associated with poorer values in all the QoL domains and the total QoL score.

Discussion: Perceived hearing difficulties in various everyday life situations are more strongly associated with older adults' quality of life than audiometrically assessed hearing impairment.

Key Words: Aging, Cohort, Hearing, Life-space, Quality of life.

INTRODUCTION

Age-related hearing loss (presbycusis) is one of the most common chronic health conditions among older adults and prevalence of it increases notably with age. Age-related degenerative changes in auditory system impair older adults' hearing ability (Gates & Mills, 2005). This influences notably an individual's capability to communicate and cope with everyday listening situations and to participate in everyday activities (Wallhagen, 2010), thus potentially having a negative effect on older adults' quality of life (QoL).

The conceptual basis of this study comes from the ecological model of ageing, also known as the press-competence model (PCM) (Lawton & Nahemow, 1973), which considers individuals' well-being to be strongly related to the person's capabilities and the environment where a person lives. According to PCM, the fit between an individual's capacities, such as health, sensory and motor skills and cognitive functioning, and the demands of the environment, is crucial for the individual's wellbeing. The environment includes both physical and the social context. Wellbeing deteriorates if a person cannot cope with environmental demands.

In this study, we explored QoL according the World Health Organization (WHO) definition, which states that QoL is "an individual's perception of their position in life in the context of the culture and value systems in which they live, and in relation to their goals, expectations, standards and concerns" (WHOQoL Group, 1998). According to the WHO, QoL comprises various important aspects of an individual's life: physical health, psychological health, environment and social relations (WHOQoL Group, 1998).

The present study defines hearing difficulties as hearing-related problems which an individual perceives to have in his/her everyday life. One of the most established hearing difficulties among older adults is difficulty in hearing speech (Arlinger, 2003), particularly in competing contexts such as sound-reverberating environments, or in the presence of background noise (Gatehouse & Noble, 2004). Hearing difficulties, by hampering an individual's social interaction, have negative socioemotional consequences (Hogan, O'Loughlin, Miller, & Kendig, 2009) and can cause feelings of embarrassment, frustration and being left out (Gopinath et al., 2012b). In addition, difficulties in spatial hearing impedes environmental orientation by weakening perception of acoustic information from the environment (Arlinger, 2003; Gates & Mills, 2005), which can also reduce the desire to participate in out-of-home activities (Mikkola et al., 2015b).

Several previous studies have reported an association between hearing difficulties and poorer QoL among older adults' (Chia et al., 2007; Dalton et al., 2003; Gopinath et al., 2012a; Hogan et al., 2009; Zhang et al., 2012). However, these studies either have not identified specific aspects of perceived hearing difficulty in everyday life (e.g. difficulties in speech comprehension, failure to detect and localize sounds, and, negative feelings and social constraints due to hearing problems), or have not differentiated between the different domains of QoL (Gatehouse & Noble, 2004; Hallberg, Hallberg, & Kramer, 2008).

The association between hearing ability and QoL may be confounded by sociodemographic factors and some health related factors, such as chronic diseases and cognitive functioning. Higher age and male gender are risk factors for hearing loss (Agrawal, Platz, & Niparko, 2008; Arlinger, 2003). According to previous studies, also QoL is negatively associated with age (Von Dem Knesebeck, Wahrendorf, Hyde, & Siegrist, 2007) and in older age groups men report having better QoL compared to women (Pinquart & Sorensen, 2001). Persons, and particularly men, with less education may have been more exposed to occupational noise than those with higher educational level, thus having a higher risk for hearing loss (Agrawal et al., 2008). In addition, it has been shown that higher educational level has a positive association with QoL (Von Dem Knesebeck et al., 2007). Further, some chronic diseases, such as diabetes (Agrawal et al., 2008), cardiac, circulatory (Agrawal et al., 2008) and neurological diseases (Crews & Campbell, 2004) are known to be associated with hearing loss among older adults, and furthermore, persons with chronic diseases frequently report lower QoL (Sprangers et al., 2000). According to previous studies, hearing loss is also associated with cognitive decline (Arlinger, 2003), which may have negative effect on older adults' QoL.

This study was conducted in a Finnish context. In general, according to OECD report, Finland does very well in most of the dimensions which are considered to be essential to a good life, such as education, subjective well-being, health status, personal security, environmental quality, earnings and social connections (OECD, 2014). In Finland, as in other Western counties, the proportion of older adults' increases and consequently also age-related hearing problems are becoming more prevalent (Mäki-Torkko, 2001). As Western cultures are typically information and communication societies, where ability to communicate effectively in everyday life is essential, the effects of hearing difficulties in everyday life can be substantial (Sorri, Jounio-Ervasti, Uimonen, & Huttunen, 2001). Public health services are available to all citizens in Finland. Some services are without charge and some services with small fees. Audiological services, such as hearing aid fitting, are provided for free after physician's referral from primary health care and are thus easily available (Mäki-Torkko, 2001). These services have the potential to improve older adults' QoL by decreasing the negative effects of hearing difficulties.

As search of the previous literature revealed, it remains unclear whether different aspects of perceived hearing difficulties are similarly associated with the different domains of QoL in older adults. In this study, based on the press-competence model, we explore the effect of different aspects of perceived hearing difficulty (i.e., hearing speech, hearing-related socioemotional problems and spatial hearing) in real-life environments, and audiometrically assessed hearing on different domains of QoL (i.e., physical, psychological, social and environmental) among community-dwelling older adults. We hypothesized that perceived difficulties in speech hearing and hearing-related socioemotional problems would have the strongest association with the psychological and social domains of QoL and, that spatial hearing would be associated mainly with the environmental domain of QoL. Further, we hypothesized that perceived hearing difficulties would be more strongly associated with QoL than audiometrically measured hearing.

METHODS

Study design and participants

In this study, the association between perceived hearing difficulties and QoL was analyzed by conducting cross-sectional analyses on the data obtained from a second follow-up of the "Life-Space Mobility in Old Age" (LISPE) project (Rantanen et al., 2012). The data from a new substudy were used to examine the cross-sectional association between audiometrically measured hearing and QoL.

The LISPE is a two-year prospective cohort study of Finnish community-dwelling older adults. The study design and methods, including non-respondent analysis, have been reported in detail earlier (Rantanen et al., 2012). A random sample of people aged 75-90-years (N=2550) was obtained from the Finnish national register at baseline, and a total of 2269 persons were contacted by a letter and over the phone to screen eligibility and willingness to participate. The inclusion criteria were: community-dwelling in the study area and able to communicate (i.e. able to understand the questions and provide answers to them). A total of 1 070 persons declined (unwilling to participate n = 551, poor health n = 398, no time n = 121), 304 were not eligible, and 41 persons withdrew their consent between the phone interview and the home interview. Four participants were excluded due to communication problems during the home interview and the data of two persons were lost due to a technical problem. Thus, in total, 848 eligible persons participated in the baseline home-interviews during spring 2012. During the two-year follow-up period, 41 participants deceased, 15 were admitted to institutional care, and 12 persons could not be re-interviewed due to declined ability to communicate. Other reasons for attrition were unwillingness to continue (n=6), moving outside the study area (n=6), poor health (n=5) and not reached (n=2). Hence 761 persons participated in the two-year follow-up, which consisted of a telephone interview and postal questionnaire. The follow-up participation rates have been reported in detail elsewhere (Rantakokko et al., 2015). If the participant was unable to answer the questions over the phone due to hearing problems, the possibility to take part in a face-to-face interview in their homes (n=3) or, to answer the study questions via a postal questionnaire (n=10) was offered. The two-year follow-up postal questionnaire, which included questions on both perceived hearing difficulties and QoL, was returned by 712 participants.

For a new substudy, titled as "Hearing, cognition and well-being", a random sample of 230 participants was drawn from the original LISPE baseline cohort in January 2014. The aim of the substudy was to determine the degree to which difficulties in hearing and/or vision influence older adults' social participation, life-space mobility and functional ability. In total, 216 people from this sample were eligible to take part in the substudy. During the 2-year follow-up telephone call, the interviewer informed these eligible participants about the substudy and asked if they would be willing to participate in it. Of this group, a total of 169 people agreed to participate in the substudy and the measurements were conducted in their homes during spring 2014. Audiometric measures were drawn from the data of this substudy (Figure 1).

The LISPE project and its substudy were approved by the Ethical Committee of the University of Jyväskylä. Participants were informed about the project and signed a written informed consent.

Hearing

Perceived hearing ability

Perceived hearing ability was assessed using a 16-item postal questionnaire titled Hearing in Real-Life Environments (HERE). Participants were asked to assess their hearing in daily situations by choosing the number on a scale from 0 to 10 that best corresponded to their perceived hearing ability (Table 1). Higher scores indicated poorer performance/more difficulties. Participants, who owned a hearing aid gave two answers to each question: one assessing their hearing with, and the other without, their hearing aid. The items used in the questionnaire were modified from items in the Abbreviated Profile of Hearing Aid Benefit-questionnaire (APHAB) (Cox & Alexander, 1995), the Speech, Spatial and Qualities of Hearing Scale (SSQ) (Gatehouse & Noble, 2004) and the Hearing Handicap Inventory for the Elderly (HHIE)(Ventry & Weinstein, 1982). The idea of two scales for those with a hearing aid was further developed from APHAB. The rationale for developing a new questionnaire was the need for a compact questionnaire which would provide comparable information on hearing difficulties with and without a hearing aid. We chose a numerical rating scale to ensure sufficient variation in data.

[Table 1 here]

We took for analysis the best hearing performance for each item with or without a hearing aid, whichever was better. This was considered to be the best indicator of perceived hearing performance in everyday life, as some people may only use hearing aids in situations where they perceive a benefit doing so.

Hearing sensitivity

Pure-tone screening audiometry (Oscilla USB-330) with Peltor noise-reducing headphones with a noise reduction rating of 21 dB was used to measure the pure-tone air-conduction hearing thresholds for both ears in the participants' homes. The automatic Hughson-Westlake protocol was used at frequencies 0.125, 0.25, 0.5, 1, 2, 4 and 8 kHz for each ear separately. The frequency was first set to 1 kHz and a tone was automatically given at an intensity of 30 dB. If the participant gave no response, the intensity was increased by 5 dB each time the tone was presented. For each response the sound intensity was decreased by 10 dB and, conversely, increased by 5 dB when there was no answer. The maximum intensity was 90dB. If the participant was unable to hear at an intensity of 90dB, 100dB was marked as the hearing threshold. The test uses the 2 out of 3 method of answering in determining when to proceed to the next frequency in order to find the lowest sound intensity the person was able to detect. The audiometry data were automatically stored on a personal computer. Hearing aids were not worn during the hearing examination. Background noise was measured prior to testing by using a Standard ST-805 sound level meter. The mean level of background noise was 17 dB, ranging between 10dB and 44 dB, and in 86% of cases was 21dB or less, which is the level that headphones can filter out.

The better ear hearing threshold level (BEHL), defined as the pure-tone average (PTA) over the speech frequencies of 0.5-4 kHz (World Health Organization, 2000) was used in the analyses as a continuous variable.

Quality of Life

Quality of Life (QoL) was assessed with the 26-item World Health Organization Quality of Life Assessment short version (WHOQOL-BREF)(WHOQoL Group, 1998) via a postal questionnaire. The scale consists of four domains: physical health (7 items: mobility, ability to carry out daily activities, energy, pain, need for medication or other treatment, sleep and, working capacity), psychological health (6 items: involves topics that reflect level of positive and negative feelings, self-esteem, body image, cognition and spirituality), social relationships (3 items: individual's satisfaction with personal relationships, sex life and social support), and environment (8 items: reflects individual's satisfaction with the physical environment and its safety, financial resources, opportunities to obtain health care services and information, opportunities to participate in leisure activities and, possibilities to use public transportation) (Skevington, Lotfy, & O'Connell, 2004; WHOQoL Group, 1998).

Higher scores in each domain indicate better QoL. Scores for each domain were transformed on scale from zero to 100. In addition, a total QoL score for all domains was calculated. The total score ranges from 0 to 130, higher scores indicating better QoL. The WHOQOL-BREF domain scores have good discriminant validity, content validity, internal consistency and test-retest reliability (Skevington et al., 2004; WHOQoL Group, 1998). The overall QoL score was calculated when less than 20% of items were missing. Information on QoL was available for 706 of the 712 participants. As data were missing for less than 1% of the participants, missing values were not imputed.

Covariates

Age and gender were derived from the population register. Other covariate information was based on face-to-face interviews at baseline. *Number of years of education* was used as a socioeconomic indicator. *Self-reported physician diagnosed chronic conditions* were obtained from a list of 22 chronic conditions and with an open-ended question. Chronic conditions that could theoretically be risk factors for both hearing difficulties and poorer QoL, namely diabetes, cardiac, circulatory and neurological diseases, were chosen as potential covariates. *Cognitive functioning* was assessed using the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975).

Statistical analyses

Factor analysis was used to test the structure of the 16-item scale on perceived hearing difficulties. Factor analysis was performed in Mplus using the oblique geomin-rotation of the factor solution (version 7, 2012; Muthén &Muthén, Los Angeles, CA). Estimation was based on the maximum likelihood method with the assumption that missing data were missing at random, thereby also permitting inclusion of partial response patterns. Subjects were excluded from the analysis only when scores were missing for all items. Table 1 shows the factor loadings on each item in the questionnaire for each factor. Communalities represent the share of item variance explained by the factor solution. Factor scores were computed using the exploratory structural equation modelling approach. Subscale Cronbach alpha coefficients were computed in SPSS (version 22.0).

A three-factor structure was found suggesting that coherent entities were measured. The three dimensions reflect different aspects of perceived hearing difficulties, i.e. *Socioemotional effects, Speech hearing and Spatial hearing.* One item from the questionnaire ("I find traffic noises uncomfortably loud") was excluded from the final analyses as it had a weak loading (.13-.35) on all three factors (Table 1). Exclusion did not change the factor structure or factor loadings significantly. Cronbach alphas for the final factors were 0.93 for Socioemotional effects, 0.96 for Speech perception and 0.89 for Spatial hearing. In total, four participants had missing data on all items and were not included in the analyses. Information on speech hearing was missing for 8% (n= 59), and information on spatial hearing and, socioemotional effects were missing for 6% of the participants (n= 44 and 45, respectively).

The characteristics of the participants are described using means and standard deviations (SD) or percentages. Pearson correlation coefficients were calculated between the dimensions of perceived hearing difficulties and $\text{BEHL}_{(\text{PTA } 0.5\text{-}4\text{kHz})}$. Of the 169 participants in the substudy, eight persons did not return the postal questionnaire, and thus information of QoL was available for 161 participants. Audiometric measures were available for 168 of the substudy participants. As audiometric data were missing only for one participant, missing values were not imputed.

Linear regression analyses were used to assess the strength of the association between QoL and the dimensions of perceived hearing difficulties in the whole sample and between QoL and the audiometric measures in the substudy sample. Factor scores for perceived hearing difficulties were used in these analyses. The interaction of gender and hearing difficulties on QoL was tested, and since no such interaction was found, men and women were included in the same linear regression models. In all models, the inclusion criterion for the covariates was an association ($p \leq .20$) with both the predictor (i.e. hearing) and the outcome variable (i.e. QoL). Of the potential covariates, only age was associated with measured hearing threshold (BEHL) and QoL, while age, gender and cardiac diseases were associated with both QoL and self-reported hearing difficulties. A value of $p<.05$ was chosen as the level of statistical significance. IBM SPSS version 22.0 (SPSS Inc. Chicago, IL) was used for the regression analyses.

RESULTS

The sample characteristics are presented in Table 2. The mean age of the participants was 82 years, 63% were women and 18% reported owning a hearing aid. The mean QoL total score was 95.0 (range 54-130). The characteristics of the substudy participants with audiometric data (N=168), did not materially deviate from the characteristics of the total sample. Among the participants in the substudy, the mean $\text{BEHL}_{(\text{PTA } 0.5\text{-}4\text{kHz})}$ was 39 dB (SD 14.4, range 10dB - 83dB) (Table 2). BEHL correlated moderately with all the dimensions of perceived hearing difficulties (Speech hearing $r=.471$, $p<.001$; Socioemotional effects $r=.423$, $p<.001$; and Spatial hearing $r=.299$, $p<.001$).

[Table 2 here]

The associations between the dimensions of perceived hearing difficulties and QoL domains are presented in Table 3. Higher scores in any dimension of perceived hearing difficulties were significantly associated with poorer QoL in each QoL domain. The regression coefficients varied between -.192 and -.296 for the association of the dimensions of speech hearing and socioemotional effects with the QoL total score, and with the physical, psychological and environmental domains of QoL, whereas for the association with the social domain of QoL, the regression coefficients ranged between -.134 and -.173. The dimension of spatial hearing showed a somewhat weaker association with all the domains of QoL with regression coefficients between -.102 and -181. Further adjustment for covariates did not materially change the results (Table 3).

[Table 3 here]

Table 4 shows the results of the regression analysis for the association between measured hearing level and QoL domains in the substudy. No significant associations were found between measured hearing level ($BEHL_{PTA\ 0.5\text{-}4kHz}$) and any of the QoL domains (Table 4). Models adjusted for hearing aid use were also constructed (data not shown in the table). This adjustment did not essentially change the results, but the association between measured hearing level and the psychological domain of QoL became borderline significant (β=.186, p=.068). In addition, we conducted a sensitivity analysis to test the influence of hearing aid use on results by conducting the analysis separately for hearing aid users and non-users. Results remained largely unchanged.

[Table 4 here]

DISCUSSION

Our study showed that perceived hearing difficulties in different real-life environments, but not the audiometrically assessed hearing, were negatively associated with the different domains of QoL among community-dwelling older adults.

QoL has been shown to decline notably after age 75 years in the general population and especially in older adults with hearing disability (Hogan et al., 2009). Our findings support the previously noted association between perceived hearing difficulties and poorer QoL (Chia et al., 2007; Dalton et al., 2003; Gopinath et al., 2012a; Hallberg et al., 2008; Hogan et al., 2009; Zhang et al., 2012), although there are differences between the studies in the samples used, the instruments used to measure QoL and the methods used to measure hearing difficulties. Moreover, our study gives more detailed information than has previously been reported on the associations between the different dimensions of perceived hearing difficulties in everyday life situations and domains of QoL.

In this study participants assessed how much their perceived hearing difficulties affected their ability to manage on in real-life environments, thus reflecting the fit between individual competencies and environmental demands according to the press-competence model by Lawton and Nahemov (1973). There are several plausible explanations for our findings. Perceived hearing difficulties can hamper various daily activities, leading people to feel handicapped and lowering their psychological wellbeing (Gatehouse & Noble, 2004; Hallberg et al., 2008; Hogan et al., 2009). Commonly reported hearing-related communication problems, such as difficulties in hearing speech, and associated feelings of exclusion can cause e.g. withdrawal from social activities and other situations that pose a challenge to hearing (Arlinger, 2003; Gopinath et al., 2012b; Mikkola et al., 2015b). The psychological domain of QoL includes items such as self-esteem, enjoyment and meaningfulness of life, while the social domain of QoL relates, e.g., to individuals satisfaction with their personal relationships. Thus it is understandable that perceived difficulties in hearing speech in various situations and the resultant difficulties in communication, or hearing-related socioemotional problems were associated with poorer QoL in these domains. It should be noted, that even though some items used to assess socioemotional effects of perceived hearing difficulties and items in social domain of the QoL scale may seem similar, they are not overlapping. WHOQOL-BREF identifies how people feel and how satisfied they are in general, while HERE assessment focuses specifically on the effects of perceived hearing difficulties.

Hearing difficulties not only complicate interaction with others, but difficulties in spatial hearing can also make observation of the acoustic environment uncertain (Arlinger, 2003; Gates & Mills, 2005). As Gatehouse and Noble (2004) point out, a persons' ability to reliably and accurately detect acoustic cues in the environment is crucial for safe orientation when moving around and thus "serves the observer's wellbeing and sense of proper connection with the world" (Gatehouse & Noble, 2004). While acknowledging that the associations between spatial hearing and domains of QoL were rather modest in our study, we conclude that difficulties in spatial hearing may increase feelings of insecurity while moving around and so impede this "sense of well-connectedness", thereby also impairing QoL in the environmental domain.

Further, hearing impairment has also been shown to correlate with poorer functional status measured by ADL and IADL functions (Dalton et al., 2003) and difficulties in lower limb performance and mobility (Mikkola et al., 2015a). This could explain the association between perceived hearing difficulties and the physical domain of QoL, which includes items such as mobility and the ability to manage daily activities.

Zhang et al. (2012) reported that hearing-related difficulties in daily tasks were significantly associated with poorer QoL scores in every domain, the effects being greatest in the physical and social domains of QoL, and lowest in the environmental domain (Zhang et al., 2012). The estimated effect sizes resemble those in our study, although in our sample the social domain showed a slightly weaker association with perceived hearing difficulties compared to the other domains of QoL. This unexpected difference is probably due to differences in the method used to evaluate perceived hearing difficulties. Zhang and colleagues used a single question and did not assess hearing difficulties in specific situations.

The present study found no significant association between audiometrically assessed hearing and QoL. Previous studies have reported conflicting findings. In some studies, the severity of the hearing loss was associated with poorer QoL (Chia et al., 2007; Dalton et al., 2003), while other studies found no such association (Gopinath et al., 2012b; Hogan, Phillips, Brumby, Williams, & Mercer-Grant, 2015; Teixeira et al., 2008). For example, Teixeira and colleagues did not observe a relationship between the presence or degree of hearing loss and any domain of QoL (Teixeira et al., 2008).

These findings support our view that physiologic hearing deficit (i.e. audiometric data) does not automatically reflect how people perceive their hearing difficulties and the consequences this has for them in everyday life (Gopinath et al., 2012a). Pure-tone audiometry assesses mainly one component of hearing performance, namely peripheral sensory functioning in optimal circumstances, whereas, e.g., speech understanding is a far more complicated process that also involves aspects of cognitive processing (Gatehouse & Noble, 2004). Furthermore, two individuals with same audiometric results may face different challenges in their everyday lives, depending on the environment they are living in and the demands it puts on the individual. For example, for individuals who engage in activities that require interpersonal contacts poor hearing may have different psychosocial consequences from those experienced by people who prefer more individual activities (Scherer & Frisina, 1998).

As PCM bring forward, individual's ability to cope with environmental demands is crucial for the individual's wellbeing (Lawton & Nahemow, 1973). Therefore, even a severe audiometrically assessed hearing loss may not affect QoL if the person is able to cope with it, for example by avoiding situations which are demanding on hearing (Wiley, Cruickshanks, Nondahl, & Tweed, 2000). However, QoL may decline if a person experiences hearing difficulties as hampering everyday life (Hogan et al., 2015). Thus, QoL may be more closely associated with perceived hearing ability in the community than with actual audiometrically measured hearing (Chia et al., 2007).

The strengths of our study are that our data were collected from a population-based cohort rather than from a cohort with specific hearing difficulties. Our cohort thus comprised participants with and without hearing difficulties and the associations observed in this study likely represent those prevalent in a similar-aged general population in Finland. We assessed several aspects of hearing, namely perceived hearing difficulties in various everyday situations and audiometrically measured hearing. This approach produces a more complete picture of hearing difficulties than a single question.

Some limitations should be taken into account. The audiometric measurements were conducted in the participants' homes instead of in standardized conditions. We used only pure tone audiometry, which measures the ability to hear tones, but not the ability to understand words or speech. In addition to the pure tone test, using more direct test for assessing difficulties in hearing speech (for example Hearing in Noise Test) in the further studies would provide more detailed information on the association between measured hearing and QoL.

Also, the data were cross-sectional and therefore it is not clear whether hearing loss preceded the decline in QoL. Longitudinal research is needed to examine the temporal order and potential causality. We cannot exclude the possibility of residual confounding caused by unmeasured factors. It should also be noted that both perceived hearing difficulties and QoL were self-reported in the present study. Thus it is possible that there are some endogenous associations, meaning that both self-evaluations are shaped by a confounder such as personality traits or general health pessimism (Podsakoff et al., 2003). This may partly explain why perceived hearing difficulties were more strongly associated with QoL than audiometrically assessed hearing. However, persons' own perception of his/her hearing performance in various everyday situations and of QoL cannot be captured without self-reports (Weinstein, 2015). Also, some persons were excluded from the study because they were not able to communicate due to hearing problems. Therefore, it is likely that persons with severe hearing impairment were under-represented and selection bias cannot be completely ruled out. Had these persons participated, the associations observed between hearing difficulties and QoL might have been stronger.

To conclude, our results indicate that perceived hearing difficulties in everyday life situations are more strongly associated with older adults' wellbeing than audiometrically assessed hearing impairment, as associations were observed with all the domains of QoL. Hearing difficulties are often seen as an inevitable consequence of aging, and therefore their impact is easily dismissed. However, our findings imply that, along with audiometric measurements, health care practitioners should also take into account the effects that hearing problems have on people's ability to manage in everyday life.

In future, it is also important to explore similarities and differences in the associations between hearing difficulties and QoL in different cultural contexts. Even though age-related impairment in hearing is universal, there may be cross-cultural differences in the ways the hearing difficulties affect older adults' everyday life (Zhao et al., 2015). As QoL is culturally constructed, those variables that most influence QoL in Western cultures may not be completely equivalent in different cultural settings.

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Table 1. Hearing in Real-Life Environments (HERE)-scale. Geomin-rotated exploratory factor analysis loadings, communality estimates and subscale Cronbach alphas for hearing scale items.

Item		Factor			Communality
		1 Socioemotional effects α=0.93	2 Speech hearing α=0.96	3 Spatial hearing α=0.89	
My hearing difficulties hamper my social life (for example meeting friends or acquaintances, participating in leisure-time activities or different gatherings).		**0.81**	0.08	0.04	0.66
I feel left out when I am with a group of people because of my hearing difficulties.		**0.90**	0.01	0.01	0.81
Hearing problems cause me to feel frustrated.		**0.94**	-0.01	-0.03	0.89
Hearing problems cause me to feel embarrassed.		**0.85**	-0.01	-0.08	0.73
I need help from other people because of my hearing difficulty.		**0.59**	0.23	0.00	0.40
How is your hearing.		-0.10	**0.91**	0.00	0.83
When I am having a conversation with another person at my home I find it difficult to hear his/her speech.		-0.01	**0.90**	-0.09	0.82
I have to ask the person I´m talking to repeat what he/she is saying when having a conversation in a quiet room.		0.06	**0.84**	-0.12	0.73
It is difficult for me to follow what another person in saying when other people are simultaneously talking around us.		-0.02	**0.85**	0.11	0.73
It is difficult for me to follow what performers are saying at the theatre, in a concert or some other similar situation		0.05	**0.81**	0.11	0.67
It is difficult for me to follow speech in places where you can hear an echo (e.g. priest's sermon in church).		-0.00	**0.82**	0.14	0.70
I have to strain to hear when listening to something or someone.		0.10	**0.84**	-0.01	0.71
I can estimate from a sound the direction from which the sound is coming (e.g. dog barking or sound of a car).		0.47	0.04	**0.51**	0.48
I can estimate from the sound how far away the sound source is (e.g. dog barking or sound of a car).		0.46	-0.00	**0.63**	0.60
I can estimate from the sound whether the sound source is coming towards me or going away from me (e.g. a barking dog or a car).		0.59	-0.01	**0.47**	0.54
I find traffic noises uncomfortably loud.		0.35	0.28	0.13	0.22
Factor correlations	1	1.0			
	2	0.74	1.0		
	3	0.37	0.51	1.0	

Table 2. Sample characteristics of the total sample and substudy sample.

	Total sample		Substudy sample	
	n	**Mean (SD)**	**n**	**Mean (SD)**
Age	712	81.7 (4.2)	161	82.2 (4.2)
Education in years	712	9.8 (4.2)	158	9.6 (4.3)
MMSE score (range 0-30)	712	26.4 (2.6)	161	26.1 (2.5)
Quality of life				
QoL total score (range 0-130)	706	95.0 (13.8)	160	94.1 (13.6)
Physical domain (range 0-100)	706	64.0 (18.6)	161	62.8 (17.9)
Psychological domain (range 0-100)	706	64.4 (14.3)	161	64.3 (14.1)
Social domain (range 0-100)	705	64.4 (18.7)	160	63.5 (17.2)
Environmental domain (range 0-100)	706	72.8 (15.3)	160	71.3 (16.0)
Self-reported hearing [a]				
Speech hearing (range 0-10)	653	2.8 (2.1)	157	2.7 (2.1)
Socioemotional effects (range 0-10)	667	1.4 (1.7)	160	1.3 (1.7)
Spatial hearing (range 0-10)	668	2.4 (2.1)	159	2.1 (1.9)
BEHL (PTA0.5-4kHz), dB				38.8 (14.4)
		%(n)		**%(n)**
Women	712	62.5 (445)	161	62.1 (100)
Hearing aid owners	711	17.8 (127)	161	18.6 (30)
Diabetes	712	17.4 (124)	161	15.5 (25)
Cardiac diseases	712	41.0 (292)	161	44.7 (72)
Circulatory diseases	712	64.2 (457)	161	62.7 (101)
Neurological diseases	712	6.3 (45)	161	6.2 (10)

Notes: IQR= Interquartile range , MMSE= Mini-Mental State Examination, BEHL= Better ear hearing threshold level, PTA= pure tone average 0.5-4kHz, dB= decibel

a= Mean scores of the items in each factor. Higher scores indicate poorer performance/more difficulties.

Table 3. Association between dimensions of perceived hearing difficulties and quality of life in the total sample (N=706). Linear regression analysis.

		Model 1[a]			Model 2[b]		
		β	SE	p	β	SE	p
QoL domain	**Dimension of hearing difficulty**						
Total score							
	Speech hearing	-.259	.51	<.001	-.226	.50	<.001
	Socioemotional	-.296	.52	<.001	-.269	.50	<.001
	Spatial hearing	-.181	.58	<.001	-.151	.56	<.001
Physical							
	Speech hearing	-.260	.70	<.001	-.222	.67	<.001
	Socioemotional	-.275	.70	<.001	-.243	.67	<.001
	Spatial hearing	-.178	.79	<.001	-.144	.75	<.001
Psychological							
	Speech hearing	-.218	.54	<.001	-.199	.54	<.001
	Socioemotional	-.269	.54	<.001	-.252	.54	<.001
	Spatial hearing	-.180	.60	<.001	-.162	.60	<.001
Social							
	Speech hearing	-.134	.72	<.001	-.115	.72	.001
	Socioemotional	-.173	.72	<.001	-.157	.72	<.001
	Spatial hearing	-.114	.70	.002	-.098	.80	.009
Environmental							
	Speech hearing	-.192	.58	<.001	-.171	.58	<.001
	Socioemotional	-.235	.58	<.001	-.219	.58	<.001
	Spatial hearing	-.102	.65	.007	-.082	.65	.028

Notes: β= Standardized coefficient beta, SE= the standard errors of the coefficients, QoL= quality of life.
a: Crude model
b: adjusted for sex, age and cardiac diseases

Table 4: Association between measured uncorrected hearing level (BEHL $_{PTA\ 0.5\text{-}4kHz}$) and quality of life in the substudy sample (N=161). Linear regression analysis.

	Model 1[a]			Model 2[b]		
	β	SE	p	β	SE	p
QoL domain						
Total score	-.004	.08	.958	.084	.08	.325
Physical	.022	.10	.784	.119	.11	.164
Psychological	.057	.08	.475	.141	.08	.099
Social	-.089	.10	.266	-.031	.10	.717
Environmental	.025	.09	.750	.089	.10	.306

Notes: β= Standardized coefficient beta, SE= the standard errors of the coefficients, BEHL= better ear hearing threshold level, PTA= pure tone average 0.5-4KHz.
a: Crude model
b: adjusted for age

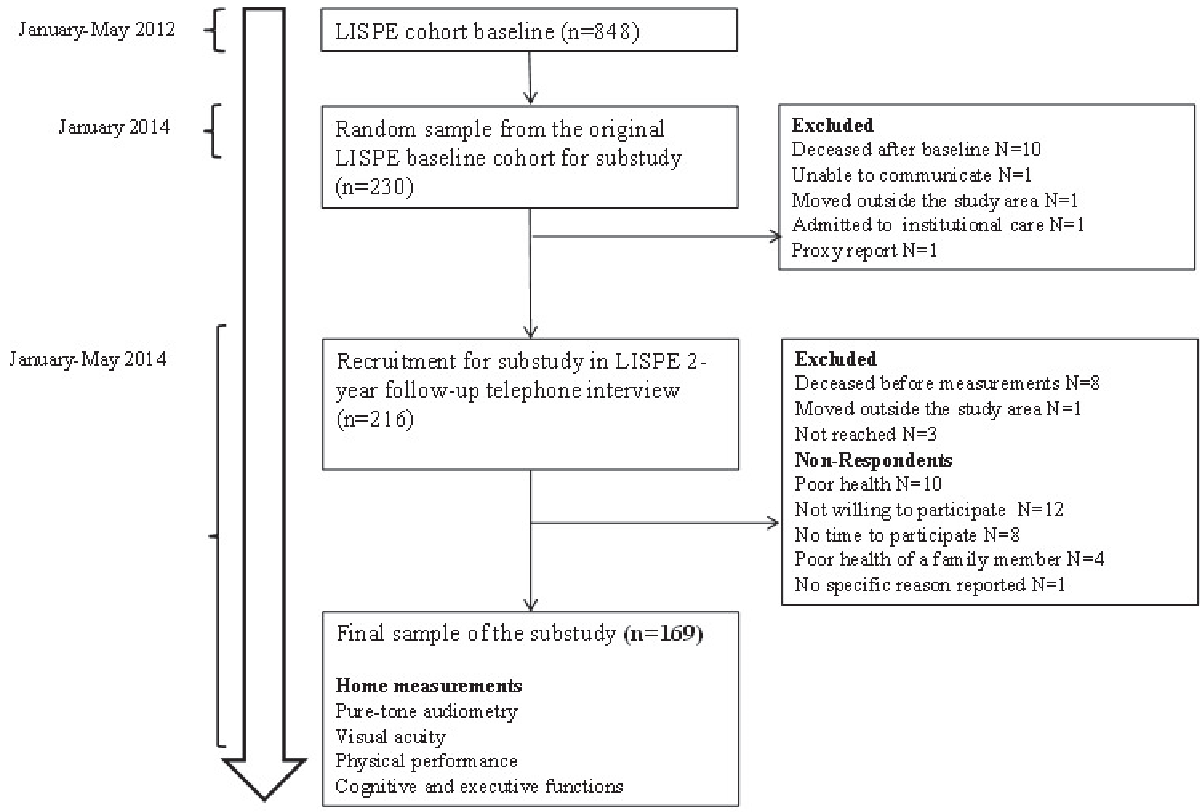

Figure 1. Flow chart of the " Hearing, cognition and well-being"-substudy.

IV

LIFE-SPACE MOBILITY AND DIMENSIONS OF DEPRESSIVE SYMPTOMS AMONG COMMUNITY-DWELLING OLDER ADULTS

by

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Life-space mobility and dimensions of depressive symptoms among community-dwelling older adults

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Aging & Mental Health

ABSTRACT

Objectives. To examine the association between life-space mobility and different dimensions of depressive symptoms among older community-dwelling people.

Methods. Cross-sectional analyses of baseline-data of the "Life-space mobility in old age" cohort study. The participants were community-dwelling women and men aged 75-90 years (N=848). Data were gathered via structured interviews in participants' home. Life-space mobility (the University of Alabama at Birmingham (UAB) Life-Space Assessment – questionnaire) and depressive symptoms (Centre for Epidemiological studies Depression Scale, CES-D) were assessed. Other factors examined included sociodemographic factors, difficulties walking 500m, number of chronic diseases and the sense of autonomy in participation outdoors (subscale of Impact on Participation and Autonomy questionnaire). ***Results.*** Poorer life-space mobility was associated with higher prevalence of different dimensions of depressive symptoms. The associations were partially mediated through walking difficulties, health and the sense of autonomy in participation outdoor activities.

Conclusion. Poorer life-space mobility interrelates with higher probability for depressive symptoms, thus compromising older adults' mental wellbeing. A focus on older adults' life-space mobility may assist early identification of persons, who have elevated risk for depressive symptoms. The association between life-space mobility and depressive symptoms should be studied further utilizing longitudinal study designs to examine temporality and potential causality.

Key Words: life-space, depression, aging, older people

INTRODUCTION

With aging, major life course events, such as loss of a spouse (Schaan, 2013), changes in health and physical ability (Enkvist, Ekström, & Elmståhl, 2012; Hirvensalo et al., 2007), cognitive decline (Djernes, 2006) and changes in social networks (Glass, De Leon, Carlos F Mendes, Bassuk, & Berkman, 2006), as well as potential effects of cumulative adversity over the life-course (Fiske, Wetherell, & Gatz, 2009) can increase the risk for depressive symptoms. It has been suggested, that regardless of whether the underlying risks for depression are due to psychological, biological or social factors, one of the main reasons for increased depressive symptoms in old age is reduced engagement with the environment (Fiske et al., 2009).

A useful way to view older adults´ functioning and participation in a real world situation is through life-space mobility. Life-space mobility refers to the size of the spatial area in which a person moves in everyday life, the frequency of going out and the need for assistance (Baker, Bodner, & Allman, 2003; Stalvey, Owsley, Sloane, & Ball, 1999). Life-space mobility does not measure only individuals' ability to walk, but includes also other forms of mobility, such as using public transportation or driving a car. A larger life-space provides an individual with more opportunities to engage with society (Kono, Kai, Sakato, & Rubenstein, 2004), while restricted life-space mobility may reflect limited access to societal amenities (Brown et al., 2009; Rosso, Taylor, Tabb, & Michael, 2013). Thus life-space mobility does not refer merely to older adults' functional ability and the spatial extent of movement.

Although major depression among older adults is rather infrequent, affecting only 1-5% of the older population (Hasin, Goodwin, Stinson, & Grant, 2005), the prevalence of sub-threshold levels of depression among community-dwelling older adults is substantially higher, at 8-16% (Blazer, 2003; Djernes, 2006). Besides clinically diagnosed depression, also sub-threshold levels of depression are associated with many disadvantages, such as increased functional limitations, morbidity and mortality (Chopra et al., 2005; Hybels, Blazer, & Pieper, 2001; Penninx et al., 1998).

Previous studies, which have used multi-item measurement scales to examine different dimensions of depression, have provided evidence that depression is a multidimensional entity (Hays et al., 1998; Johnson, Mcleod, Sharpe, & Johnston, 2008; Schroevers, Sanderman, Van Sonderen, & Ranchor, 2000; Watson & Clark, 1997). For example, the Centre for Epidemiological Studies Depression Scale (CES-D) (Radloff, 1977) which has been widely used in epidemiologic studies for assessing depressive symptoms includes four different dimensions of depression: depressed affect, somatic symptoms, positive affect and interpersonal problems. Because of the multidimensionality of these measurement scales, using only global summary score may hide relevant individual variability of depressive symptoms (Schroevers, Sanderman, van Sonderen, & Ranchor, 2000). Even though the overall level of depressive symptoms may not vary significantly, there may be differences in the patterns of particular symptoms (Cole, Kawachi, Maller, & Berkman, 2000).

It has been found that presentation of depressive symptoms is heterogeneous also among older adults (Chen, Eaton, Gallo, & Nestadt, 2000; Mora et al., 2012). This means that two persons with the same score on a depression scale will not necessarily have similar symptoms. Manifestation of depressive symptoms in older adults may also be different from their manifestation in younger people (Fiske et al., 2009; Sözeri-Varma, 2012). Typical depressive symptoms, such as sadness, may not be prominent (Ready et al., 2011), whereas somatic and vegetative symptoms (i.e. sleeplessness, loss of appetite, pain), lack of positive affect and sense of hopelessness about the future are more common (Chen et al., 2000; Fiske et al., 2009; Sözeri-Varma, 2012). On this account, we should pay attention to the diversity of the manifestations of depressive symptoms as looking only at the threshold of the total score of the depression scale may not be detailed enough to detect these differences.

Different dimensions of depression may have different correlates (Clark, Watson, Becker, & Kleinman, 1991; Fonda & Herzog, 2001; Hays et al., 1998; Zich, Attkisson, & Greenfield, 1990). Physical limitations and health have a strong association with somatic symptoms (Fonda & Herzog, 2001; Hays et al., 1998) and depressed affect (Hays et al., 1998). Hays et al. (1998) reported that functional disability was related to lower levels of positive affect, but not to interpersonal problems. Satisfaction with the amount of social interaction was protective for depressed affect and somatic symptoms. Interpersonal problems were found to correlate with an impaired social network. Respectively, Zich et al. (1990) pointed out that lower levels of positive affect may be associated with reductions in social networks or reduction of positive experiences.

Some studies have shown that the depressive symptoms presentation pattern may also vary to some extent according to gender (Angst et al., 2002; Glaesmer, Riedel-Heller, Braehler, Spangenberg, & Luppa, 2011; Johnson et al., 2008), although it has been suggested that these differences are not substantial (Fiske et al., 2009). In a study of Johnson et al. (2008) the focal constructs of CES-D scale were compared across gender groups in a population-based sample. They found that women had higher levels of depressed affect and somatic symptoms than men, but no gender differences in the subscales of interpersonal problems or in positive affect were observed. Angst et al. (2002) suggested that there may be gender differences in the total number of depressive symptoms reported so that depressed men report fewer symptoms compared to depressed women.

Previous studies have shown that among older adults depressive symptoms and restricted life-space mobility share similar correlates, such as female gender, higher age, lower educational level, poorer financial situation, poorer cognitive functioning (Barnes et al., 2007; Djernes, 2006; Fiske et al., 2009) and chronic diseases (Chang-Quan et al., 2010; Choi & McDougall, 2007; Fiske et al., 2009; Hybels et al., 2001). Mobility limitations are associated with reduced movement outside home (Wilkie, Peat, Thomas, & Croft, 2006) and have also a strong association with depressive symptoms (Hirvensalo et al., 2007; Lampinen & Heikkinen, 2003).

The concept of autonomy or mastery, referring to the degree of control which individuals feel to have over their lives and the environment (Jang, Haley, Small, & Mortimer, 2002), is essential for older adults' mental well-being and life satisfaction (Berg, Hassing, McClearn, & Johansson, 2006; Gignac, Cott, & Badley, 2000) and it is also associated with older adults life-space mobility (Portegijs, Rantakokko, Mikkola, Viljanen, & Rantanen, 2014). The sense of autonomy is optimal when an individual perceives to have opportunity to make decisions, and to live life the way one wants to (Cardol, de Haan, de Jong, van den Bos, Geertrudis AM, & de Groot, 2001). Among older adults', the most common restriction in participation is mobility limitation outside the home (Wilkie et al., 2006). Although the sense of autonomy in participation outdoors and physical performance correlate, they are not totally overlapping concepts. This is supported by a previous study where poor lower extremity performance and poor sense of autonomy in participation outdoors were independently associated with lower life-space mobility (Portegijs, Rantakokko, Mikkola, Viljanen, & Rantanen, 2013).

The association between life-space mobility and depressive symptoms has been reported in previous studies (Allman, Sawyer, & Roseman, 2006; Baker et al., 2003; Peel et al., 2005; Snih et al., 2012). However, to best of our knowledge, no studies exist on association between life-space mobility and the different dimensions of depression. Furthermore, knowledge on possible mediating factors between life-space mobility and depressive symptoms is limited. Consequently, the purpose of the present study was to examine the association between life-space mobility and different dimensions of depressive symptoms among 75-90-year-old community-dwelling older women and men. Our aim was to 1) examine whether the association between life-space mobility and different dimensions of depression differ, and to 2) assess whether differences in walking difficulties, health and the sense of autonomy in participation outdoor activities accounted in part for the association between life-space mobility and different dimensions of depressive symptoms.

METHODS

Design and Study Population

The data for this study were drawn from the baseline measurements of a 2-year prospective cohort study entitled “Life-Space Mobility in Old Age” (LISPE). The study design and methods have been reported in detail elsewhere (Rantanen et al., 2012). In brief, a random sample of 2550 people was taken from the population register and they were informed about the study and interviewed by phone. To be eligible for the study participants had to be able to communicate, reside in the recruitment area and be willing to participate. Baseline-data were gathered on 848 community-dwelling people aged 75 to 90 by in-person interviews in the participants’ homes using computer-assisted personal interview. The Ethical Committee of the University of Jyväskylä approved the project and all the study participants gave their written informed consent. Only persons who were able to answer to the interviews themselves were included in the baseline cohort.

Measurements

Life-Space Mobility

Life-space mobility was assessed by the University of Alabama at Birmingham (UAB) Life-Space Assessment (LSA) -questionnaire (Baker et al., 2003). The LSA is based on self-report, comprises 15 items, and assesses mobility according to the different life-space levels (distance), on which a person reports having moved either by walking or using other forms of transportation, such as driving a car or using public transportations, during the 4 weeks preceding the assessment. Participants were asked how many days a week they attained each life-space level (bedroom, other rooms, outside home, neighbourhood, town, beyond town) and whether they needed help from another person or from assistive devices. In this study, we used a composite score for life-space, which indicates distance, frequency and level of independence (range 0-120). Higher LSA scores indicate better life-space mobility (Baker et al., 2003).

Depressive symptoms

Depressive symptoms were assessed with the 20-item Centre for Epidemiological Studies Depression Scale (CES-D)(Radloff, 1977). The CES-D scale is a self-report depressive symptoms measure, which has been widely used in epidemiologic studies. Its validity and reliability have been demonstrated in heterogeneous samples (A. T. Beekman et al., 1997). The participant rated the frequency of each symptom during the previous week. Each item is scored from 0 to 3, with higher scores indicating more depressive symptoms (total score range 0-60). A total score was also calculated for participants with no more than one missing item (n=15). The cut-off score on the CES-D scale indicating a clinically significant level of depressive symptoms in community samples is 16 or more (Radloff, 1977). To examine different dimensions of depression, we computed scores for the four CES-D dimensions. Higher scores always represented a higher level of the dimension in question. The dimensions and their respective items were the following: depressed affect (having the blues, feeling depressed, life a failure, feeling fearful, feeling lonely, crying spells, feeling sad; range 0-21), somatic symptoms (being bothered, poor appetite, trouble concentrating, everything was an effort, restless sleep, talked less than usual, cannot get going; range 0-21), positive affect (feeling as good as others, hopeful about the future, feeling happy, enjoying life; range 0-12), and interpersonal problems (people were unfriendly, people dislike me; range 0-6).

Potential confounders and mediating factors

In this study the selection of potential confounders and mediating factors was based on the findings of previous studies on factors associated with life-space mobility and depressive symptoms (Baker et al., 2003; Barnes et al., 2007; Blazer, 2003; Chang-Quan et al., 2010; Choi & McDougall, 2007; Cohen-Mansfield, Shmotkin, & Hazan, 2010; Djernes, 2006; Hirvensalo et al., 2007; Hybels et al., 2001; Lampinen & Heikkinen, 2003; Peel et al., 2005; Penninx et al., 1998; Stalvey et al., 1999). *Basic demographic and socioeconomic indicators* of the study subjects included age, sex, education (total number of years of education) and self-reported financial situation (very poor or poor / moderate/ very good or good). Participants were also asked whether they lived alone or with another person. *The number of physician-diagnosed chronic conditions* was collected by self-report using a list of 22 chronic conditions and an open-ended question about any other physician-diagnosed chronic conditions. The relevance of diseases reported in the open question was checked by a physician. For the analyses, depression was excluded from the total number of chronic diseases. *Cognitive functioning* was assessed with the Mini-Mental State Examination (MMSE), which contains 30 items scored from 0-30. Higher scores indicate better cognitive functioning (Folstein, Folstein, & McHugh, 1975). *Walking difficulty* was studied as perceived difficulties in walking 500m (able without difficulty/ able with some degree of difficulty or unable to manage even with help)(34). *Sense of autonomy in participation outdoors* was measured using the domain “autonomy outdoors” from the Impact on Participation and Autonomy questionnaire (Cardol et al., 2001). Participants were asked to rate their perceived opportunities to 1) visit relatives and friends, 2) make trips and travel, 3) spend leisure time, 4) meet other people, and 5) live life the way they want. The response categories ranged from 0 (very good) to 4 (very poor). A sum score (range 0-20) was calculated, higher scores indicating more restrictions in perceived autonomy.

Statistical Analyses

The interaction of gender and life-space mobility on the CES-D total score was tested and a significant interaction was found ($p<.001$). The presence of an interaction implies that the effect of life-space mobility on depressive symptoms varies as a function of gender. Therefore men and women were analyzed separately. Characteristics of the participants are described by using means, medians and interquartile ranges (IQR) or percentages. Differences between men and women in the background characteristics were tested by using the Mann-Whitney U-test for continuous variables and χ^2- tests for categorical variables.

The association of each covariate with the CES-D total score and life-space mobility composite score was determined with χ^2-tests and Spearman correlation. Only variables with a significant association with both depressive symptoms and life-space mobility were chosen for further analyses because they could, therefore, influence the effect of life-space mobility on depressive symptoms. Life-space mobility data was available for all of the 848 participants and CES-D data for 843 participants (data for CES-D score was missing for 0,6% of the total sample, 2 women and 3 men).

Our interpretation of the analyses was based on the following guidelines: 1) fixed demographic characteristics are presumed to precede depressive symptoms; 2) variables which are considered as possible mediating factors (i.e. the sense of autonomy in participation outdoors, walking difficulties, and chronic diseases) are presumed to precede the *current* level of depressive symptoms. However, we acknowledge that some of these variables may have been affected by *prior* depressive symptoms (Hays et al., 1998).

Linear regression analyses were used to examine the association between the life-space mobility score and the CES- total score and the scores for four different dimension of the CES-D scale among men and women. We wanted to see whether the associations between life-space mobility and different dimensions of depression are explained by differences in health, walking limitation or sense of autonomy in participation outdoors (James & Brett, 1984). Linear regression models were used to obtain standardized regression coefficient and standard error estimates. Significance of the effects in gender-specific models were tested using the standard single parameter Wald-tests, and gender-differences in regression coefficients were tested using the likelihood ratio test for a single parameter. Confidence intervals are based on the inversion of the Wald-test for the given parameter. In the analyses, the first model was adjusted for confounders (age, financial situation and cohabitation, i.e. living alone or with another person). The second model was additionally adjusted for walking limitation and number of chronic diseases, and in the third model we also added the sense of autonomy in participation outdoors. Persons who had missing data on one or more variables were removed from regression analyses.

Statistical significance was set at $p<.05$ for all analyses. Linear regression analyses were accomplished using MPlus version 7 (Muthén & Muthén, 2012) and the other analyses conducted using the IBM SPSS 20.0 (IBM Corp., Armonk, NY, USA).

RESULTS

The median age of all the participants was 80.0 years (interquartile range 8.0) and 62% were female. Of the total sample, 53% were living alone. Number of chronic diseases was 4.0 (IQR 3.0) and years of education 8.0 (IQR 5.0). The median scores for the life-space mobility score and the total CES-D score in the total sample were 64.0 (IQR 30.0) and 9.0 (IQR 9.0), respectively. Altogether, 21% of the women and 12% of the men reported clinically significant depressive symptoms (CES-D total score $\geq$16).

Compared to men participants, women participants had significantly poorer life-space mobility score. Women participants were also older, they were more likely to live alone, and they had more chronic diseases and more difficulties in walking 500 meters. Women participants also had more limited sense of autonomy in participation outdoors. Men and women participants did not differ in MMSE total points (Table 1).

Mean scores on the total CES-D scale, as well as on four CES-D dimensions showed small but statistically significant differences between women and men. Women had a higher CES-D total score than men (10.4, SD 7.1 vs. 8.2, SD 6.0, p<.001). Women also had a slightly higher depressed affect score (2.6, SD 2.8 vs. 1.6, SD 2.0, p<.001), and somatic symptom score (3.8, SD 2.9 vs. 3.1, SD 2.5, p<.001) than men. For positive affect, women scored 0.5 points lower than men (8.3, SD 2.8 vs. 8.8, SD 2.5, p=.032). For the interpersonal problems dimension, no significant sex differences were found (p=.665). The bivariate correlation between the life-space mobility score and total CES-D score was -.297 (p<.001) for women and -.170 (p=.002) for men. Spearman correlation coefficients between life-space mobility score, CES-D total score and covariates are shown in table 2 for women and in table 3 for men.

To study whether the associations between the different dimensions of depression and life-space mobility differed, and to search for potential factors mediating the association, linear regression analyses were conducted (Table 4). For both sexes, life-space mobility was associated with the CES-D total score and all the dimensions of depression, with the exception of interpersonal problems among men (Table 4, model 1). After adjustment for walking difficulties and number of chronic diseases (model 2), the regression coefficient for the association between life-space mobility and depressed affect was substantially reduced for both sexes and, for men, also the association with somatic symptoms. This indicates that the association is at least partially mediated by perceived walking difficulties and number of co-morbidity. When the sense of autonomy in participation outdoors was added into the regression model (model 3), the association with positive affect was also attenuated for both women and men. Among women, the association between life-space mobility and interpersonal problems was partially explained by the sense of autonomy in participation outdoors.

The association that varied most significantly by gender was the association between life-space mobility and somatic symptoms. This association was stronger among women than among men (Table 4, model 1). For men the association was mainly related to the walking difficulties and number of chronic conditions (model 2). For women, the association was mostly mediated by the sense of autonomy outdoors (model 3). Although the confidence intervals for somatic symptoms in model 3 are overlapping (-0.143, 0.106 for men, -0.277,-0.028 for women), the effect is significant among women, indicating that the association between life-space mobility and somatic symptoms is not entirely mediated by walking difficulties, chronic diseases and sense of autonomy in participation outdoors.

DISCUSSION

The novel finding in this study was that the associations between life-space mobility and different dimensions of depression were partially mediated through different factors and that there were differences between men and women in these associations.

Older people with poorer life-space mobility had a higher prevalence of depressive symptoms. These results are in line with those of earlier studies (Allman et al., 2006; Baker et al., 2003; Cohen-Mansfield et al., 2010; Peel et al., 2005; Snih et al., 2012; Stalvey et al., 1999). However, studying each of the four dimensions of the CES-D scale separately showed that the associations between the different dimensions of depressive symptoms and life-space mobility were not direct, but rather were partially mediated by the person's walking difficulties, chronic conditions and more limited sense of autonomy in participation outdoors. We also noted some slight differences between the sexes in these associations. Although we did not have specific pre-assumptions about how life-space mobility would relate to different dimensions of depression, we questioned whether the associations would be different, and whether the associations would be mediated by different variables.

Previous studies have shown that health conditions and limitations in physical functioning have stronger associations with somatic symptoms than other dimensions of depression (Fonda & Herzog, 2001). Some items in the somatic symptoms dimension, such as feelings of effort, may though be related more to diseases than to depression (Covic, Pallant, Conaghan, & Tennant, 2007; Johnson et al., 2008). In our study the connection between life-space mobility and both depressed affect and somatic symptoms among men was mainly related to the walking difficulties and chronic conditions, while for women somatic symptoms were more closely related to their perception of autonomy outdoors.

Similar gender differences were observed in an earlier study, which reported that the association between physical health and depression was highly significant in men, but not in women (A. Beekman, Kriegsman, Deeg, & Van Tilburg, 1995). Our results suggest that for older women chronic diseases or walking limitations may not directly underlie depressive symptoms. Instead, the perceived difficulties and their consequences on independence and autonomy of daily living may be more crucial.

Positive affect and interpersonal problems, in turn, may be less influenced by poor health and functioning. For example, Hays et al. (1998) found that functional disability, including poorer ADL performance, upper and lower extremity function and mobility, had a stronger association with depressed affect and somatic symptoms than with positive affect or interpersonal problems, although, they did not conduct separate analyses for women and men. Our results coincide with this finding. Higher life-space mobility was associated with more positive affect for both men and women, and this association was mediated by the sense of autonomy in participation outdoors. Higher life-space mobility gives more opportunities to engage with the society and to take part in meaningful activities, thus reinforcing sense of autonomy and independence, which in turn is likely to be a source of positive affect (Pinquart & Sörensen, 2000). In this study the pattern of change in regression analyses was similar between CES-D total score and dimension score of positive affect. This may be explained by the fact that the participants had relatively higher scores on positive affect than on other dimensions of depressive symptoms. Hence, in our sample, positive affect may have had somewhat more effect on the CES-D total score than other dimensions.

In the present study, there was a trend indicating that the association between life-space mobility and interpersonal problems was significant, even though modest, only for women. It is possible that restricted life-space mobility predisposes to reductions in the social network, potentially leading to feelings of interpersonal problems (Hays et al., 1998).

Participation in social activities outside the home has been reported to have a more pronounced role on mental well-being among older women than men (Park, Jang, Lee, Haley, & Chiriboga, 2013). It may be that, for women, social contacts are more closely related to positive feelings than they are for men (Glaesmer et al., 2011; Pinquart & Sörensen, 2000). It should also be noted that the majority of those older adults who are living alone are women, and therefore that older women's social contacts may more strongly rest upon social contacts outside the home. Restrictions on life-space mobility result in fewer opportunities for community participation and involvement with social environment and in turn, fewer opportunities for positive interaction with other people. Larger life-space is associated with both higher frequency of participation in social activities as well with greater number of social networks (Barnes et al., 2007).

Several explanations for our findings can be suggested. Previous studies have shown that poor health and mobility increase depressive symptoms among older adults (Chang-Quan et al., 2010; Hirvensalo et al., 2007). For example, being homebound is a significant predictor of depressed affect among older adults (Cohen-Mansfield et al., 2010), whereas better mobility status predicts better mental well-being (Lampinen, Heikkinen, Kauppinen, & Heikkinen, 2006). Mobility difficulties limit older adults' possibilities to move outside home (Wilkie et al., 2006) and thus, restrict life-space mobility and also pose a great threat to person's sense of autonomy (Portegijs et al., 2014). With respect to sense of autonomy in participation outdoors, people who perceive greater control over their lives have shown lower rates of depressive symptoms, even where they might have physical impairments (Boyle, 2005; Jang et al., 2002). An alternative explanation for the present results is that older adults with depressive symptoms are less willing to move outside their home (Cohen-Mansfield et al., 2010; Penninx et al., 1998; Rosqvist et al., 2009), and consequently experience reduced life-space mobility. Unfortunately, our cross-sectional data do not allow us to draw any firm conclusions on the temporal order in this association. It is likely that the association between life-space mobility and depressive symptoms is bidirectional in that each increases the probability of the other, potentially leading to a vicious circle (Cohen-Mansfield et al., 2010).

Our results are consistent with the theoretical model of psychological well-being, presented by Ryff (1989). The theory posits that the capacity to control the surrounding world (i.e. "environmental mastery") and sense of self-determination (i.e. "autonomy") are two of the six main components of psychological well-being, along with self-acceptance, purpose in life, positive relations with others and personal growth (Ryff, 1989). Also in the empirical study by Ryff and Keys (1995) mastery of the surrounding environment had a strong correlation with lower levels of depression. Life-space mobility represents a person's actual involvement in the environment (Barnes et al., 2007) and consequently probably also reflects a person's "environmental mastery".

This study has several strengths. We assessed life-space mobility and depressive symptoms in a large population based sample of older adults. The study was originally designed to investigate outdoor mobility and consequently rich data were available on relevant topics. Further, the association between life-space mobility and different dimensions of depression has not been studied earlier; thus the present study contributes a novel viewpoint to the research on older adults' mental well-being. The participants were interviewed face-to-face in their homes by trained interviewers and there were very few missing data in the sample. The reliability and validity of the questionnaires used has been shown to be good (Baker et al., 2003; A. T. Beekman et al., 1997). Although the participants were rather well-functioning, the sample also included people with health problems (Rantanen et al., 2012). Consequently, the observed associations most likely represent those present in the similar-aged general population, thus supporting the generalizability of our findings. The current analyses of the data may be viewed as a basis for future prospective studies.

The study also has some limitations, which need to be recognized. The analyses were cross-sectional and therefore we were not able to examine the causal direction of the association. The association should be studied further utilizing longitudinal study designs. A second limitation of the study is that participants were rather well-functioning and it is likely that older adults with the most depressive symptoms declined to participate. It can be assumed that the associations would have been stronger if persons with severe depression had participated. The utilization of self-report scales assessing depressive symptoms should be also noted as a limitation, although the CES-D scale has been reported to correlate with clinical ratings of depression (Radloff, 1977). Men have also been reported to experience less depressive symptoms than women (Angst et al., 2002), which could lead to bias. To take this possibility into account, we conducted the analyses for both sexes separately.

In conclusion, these results indicate that poorer life-space mobility is interrelated with higher risk for different dimensions of depressive symptoms, thus compromising older adults' mental wellbeing. Older adults with depressive symptoms may be harder to identify since they have fewer interactions outside the home. Thus a focus on older adults' life-space mobility may assist early identification of persons, who have elevated risk for depressive symptoms, even before they fulfil the criteria for diagnosis of major depressive disorder. The current study showed also that the association between life-space mobility and different dimensions of depression may partly be mediated through separate underlying factors. This information may help to understand the individual differences in the way older adults express their depressive symptoms. It may also provide information on factors that are important to take into account when developing tools for prevention and treatment of depressive symptoms among older adults. As restricted life-space mobility and depressive symptoms are presumably in a reciprocal relationship, more research is needed to examine the temporal order and potential causality.

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GRAPHICS

Table 1. Baseline characteristics of the participants (n=848) categorized according to sex.

	Women (n=526)			Men (n=322)			
	Mean	**Median**	**IQR**	**Mean**	**Median**	**IQR**	**p[a]**
Age	80.3	80.0	8.0	79.5	79.0	7.0	.005
Education in years	9.2	8.0	5.0	10.3	9.0	5.0	.005
MMSE score (range 0-30)	26.2	27.0	3.0	26.2	27.0	3.0	.630
IPA total score (range 0-20)	6.4	6.0	5.0	5.7	5.0	3.0	.005
Number of chronic conditions	4.5	4.0	3.0	3.9	4.0	3.0	<.001
LSA-C (range 0-120)	59.9	60.0	28.4	71.3	72.0	26.0	<.001
CES-D total score (range 0-60)	10.4	9.0	9.5	8.2	8.0	9.0	<.001
Depressed affect (range 0-21)	2.6	2.0	4.0	1.6	1.0	3.0	<.001
Somatic symptoms (range 0-21)	3.8	3.0	3.0	3.1	3.0	4.0	<.001
Positive affect (range 0-12)	8.3	9.0	5.0	8.8	9.0	4.0	.032
Interpersonal problems (range 0-6)	0.3	.00	0.0	0.3	.00	0.0	.665

	%	(n)	%	(n)	p^b
Living alone	69.9	367	26.4	85	<.001
Walking difficulty, 500m	30.2	158	18.4	59	<.001
Perceived financial situation					.005
Good or very good	47.1	248	55.9	179	
Moderate	49.6	261	43.4	139	
Poor or very poor	3.2	17	0.6	2	

Notes:

a= Mann-Whitney U-test, comparison between women and men

b= Chi-Square test, comparison between women and men

IQR= Interquartile range; CES-D = Centre for Epidemiological Studies Depression Scale; MMSE= Mini-Mental State Examination; IPA = Autonomy outdoors from the Impact on Participation and Autonomy questionnaire

Table 2. Spearman correlation coefficients between life-space mobility score, depressive symptoms total score and covariates among women (n= 526)

	LSA-C	CES-D score	Age	Education in years	MMSE score	IPA total score	Number of chronic diseases
LSA-C	1.0						
CES-D total score	-.297**	1.0					
Age	-.362**	.127**	1.0				
Education in years	.131**	-.011	-.232**	1.0			
MMSE score	.142**	-.029	-.167**	.365**	1.0		
IPA total score	-.499**	.452**	.258**	-.129**	-.152**	1.0	
Number of chronic diseases	-.355**	.236**	.153**	-.086*	.003	.319**	1.0
Perceived financial situation	.171**	-.282**	-.046	.137**	.083	-.275**	-.176

Notes: **p<. 01, * p<.05

LSA-C= Life-space mobility composite score , CES-D = Centre for Epidemiological Studies Depression Scale; MMSE= Mini-Mental State Examination; IPA = Autonomy outdoors from the Impact on Participation and Autonomy questionnaire

Table 3. Spearman correlation coefficients between life-space mobility score, depressive symptoms total score and covariates among men (n= 322)

	LSA-C	CES-D score	Age	Education in years	MMSE score	IPA total score	Number of chronic diseases
LSA-C	1.0						
CES-D total score	-.170**	1.0					
Age	-.382**	.145**	1.0				
Education in years	.252**	.032	-.252**	1.0			
MMSE score	.189**	-.084	-.231**	.384**	1.0		
IPA total score	-.332**	.344**	.256**	-.103	-.164**	1.0	
Number of chronic diseases	-.238**	.129*	.208**	-.080	-.055	.283**	1.0
Perceived financial situation	.134*	-.029	-.040	.202**	.115*	-.219**	-.101

Notes: **p<. 01, * p<.05

LSA-C= Life-space mobility composite score, CES-D = Centre for Epidemiological Studies Depression Scale; MMSE= Mini-Mental State Examination; IPA = Autonomy outdoors from the Impact on Participation and Autonomy questionnaire

Table 4. Association between life-space mobility score and the different dimensions of depression among men (n=313) and women (n=509) aged 75 to 90 years and comparison of regression coefficients between men and women.

	Model 1[a]			Model 2[b]			Model 3[c]		
	β	SE	p	β	SE	p	β	SE	p
CES-D total score			.16			.34			.91
Women	-.236***	.043		-.168**	.048		-.048	.049	
Men	-.183**	.060		-.127*	.063		-.051	.062	
Depressed affect			.79			.70			.25
Women	-.110*	.046		-.047	.052		.047	.053	
Men	-.140*	.061		-.110	.064		-.046	.064	
Somatic symptoms			**.01**			**.05**			.13
Women	-.289***	.043		-.202***	.049		-.128*	.051	
Men	-.125*	.060		-.068	.063		-.019	.064	
Positive Affect			.98			.80			.63
Women	.179***	.045		.150**	.050		.026	.050	
Men	.201**	.060		.149*	.063		.070	.062	
Interpersonal Problems			.08			.09			.29
Women	-.095*	.047		-.113*	.052		-.062	.055	
Men	.032	.062		.023	.066		.027	.067	

Notes: β= Standardized coefficient beta, SE= the standard errors of the coefficients, p= comparison of regression coefficients between men and women. Bold type face indicates a statistically significant difference in regression coefficients between men and women at the 0.05 level of significance based on the likelihood ratio test.CES-D = Centre for Epidemiological Studies Depression Scale

a: adjusted for age, living alone and perceived financial situation

b: adjusted for model 1, walking difficulty (500m walk) and number of chronic diseases

c: adjusted for model 2 and autonomy in participation outdoors.

*p< .05. **p< .01. ***p< .001.

Conflict of Interest

Elements of Financial/ Personal Conflicts	Author 1 HP		Author 2 TM		Author 3 EP		Author 4 MR		Author 5 KK		Author 6 MK		Author 7 TR		Author 8 AV	
	Yes	**No**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**
Employment or Affiliation		x		x		x		x		x		x		x		x
Grants/Funds		x		x		x		x		x		x		x		x
Honoraria		x		x		x		x		x		x		x		x
Speaker Forum		x		x		x		x		x		x		x		x
Consultant		x		x		x		x		x		x		x		x
Stocks		x		x		x		x		x		x		x		x
Royalties		x		x		x		x		x		x		x		x
Expert Testimony		x		x		x		x		x		x		x		x
Board Member		x		x		x		x		x		x		x		x
Patents		x		x		x		x		x		x		x		x
Personal Relationship		x		x		x		x		x		x		x		x

The authors declare no conflicts of interest.

Author contributions

All authors meet the criteria for authorship stated in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals.

HP: analysis and interpretation of the data, writing the article.

TM: analysis and interpretation of the data, critical revision of the article.

EP: conception, design, data collection, critical revision of the article.

MR: conception, design, data collection, critical revision of the article

KK: analysis and interpretation of the data, critical revision of the article

MK: conception, design, data collection, analysis of the data, critical revision of the article;

TR: conception, design, data collection, critical revision of the article, PI for the LISPE project

AV: conception, design, data collection, critical revision of the article.

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The sponsors did not have any role in the design, methods, subject recruitment, data collection, analysis, or preparation of this manuscript.