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Influences on hearing aid use in people with dementia

A thesis submitted to the University of Manchester for the degree of Doctor of Philosophy in the
Faculty of Biology, Medicine and Health

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Abbreviations

AD	Alzheimer's Disease
ADLs	Activities of Daily Living
APEASE	Acceptability, Practicability, Effectiveness, Affordability, Side-Effects, and Equity
BADLS	Bristol Activities of Daily Living Scale
BEA	Better Ear Average
BCT	Behavioural Change Techniques
BCW	Behaviour Change Wheel
BTE	Behind the Ear
CINAHL	Cumulative Index to Nursing and Allied Health Literature
COM-B	Capabilities-Opportunities-Motivations model of Behaviour
COREQ	Consolidated Criteria for Reporting Qualitative Research
CP	Care Partner
dBHL	Decibels Hearing Level
DF	Degrees of Freedom
EFHOH	European Federation of Hard of Hearing People
EHIMA	European Hearing Instrument Manufacturers Association
GAD-7	Generalised Anxiety Scale-7
GCP	Good Clinical Practice
GRADE-CERQual	Grading of Recommendations Assessment, Development and Evaluation - Confidence in the Evidence from Reviews of Qualitative Research
HA	Hearing Aid
HASK	Hearing Aid Skills and Knowledge Test
HHIE	Hearing Handicap Inventory for the Elderly
HHIE-P	Hearing Handicap Inventory for the Elderly – Proxy
HHIE-S	Hearing Handicap Inventory for the Elderly – Screening
ICTRP	International Clinical Trials Registry Platform
ITE	In the Ear
JAMDA	Journal of the American Directors Association
JHNEBP	Johns Hopkins Nursing Evidence-Based Practice framework
MCI	Mild Cognitive Impairment

MeSH	Medical Subject Headings
MMAT	Mixed Methods Appraisal Tool
MoCA	Montreal Cognitive Assessment
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
NPI	Neuropsychiatric Inventory
OR	Odds Ratio
PHQ-9	Patient Health Questionnaire-9
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO	International Prospective Register of Systematic Reviews
PwD	Person with Dementia
RCT	Randomised Controlled Trial
SD	Standard Deviation
SF-12	12-item Short Form Survey
sMMSE	Standardised Mini Mental State Examination
SST	Sensory Support Therapist
TDF	Theoretical Domains Framework
VaD	Vascular dementia

Abstract

Hearing loss is highly prevalent in people with dementia. Treating hearing loss with hearing aids represents an important opportunity to address hearing disabilities and improve quality of life. However, little is known about influences on hearing aid use in people with dementia. This is problematic because, until these influencing factors are sufficiently understood, they cannot be addressed in interventions aimed at supporting hearing aid use. Through identifying enablers, barriers, and correlates of hearing aid use in community-residing people with dementia, this thesis aimed to develop this understanding.

The work presented within this thesis was informed by behaviour change theory and includes three studies. First, a systematic review evaluated evidence within the extant literature of factors that are associated with hearing aid use in people with dementia. Data synthesis was underpinned by the Theoretical Domains Framework and key findings for which the evidence was strongest were formulated. Second, a qualitative exploration of enablers and barriers to hearing aid use was undertaken with eleven people living with dementia and their care partners through semi-structured interviews. The interview schedule was informed by the Theoretical Domains Framework. Third, correlates of hearing aid use in 239 people with dementia and hearing loss were evaluated. In this study, the Capabilities-Opportunities-Motivations model of Behaviour (COM-B) was used to organise potential predictor variables. The correlations of these variables with hearing aid use were evaluated through bivariate and multivariate logistic regression models.

Taken together, the findings of these studies suggest that influences on hearing aid use in people with dementia are multifaceted, incorporating a range of factors related to intrinsic capabilities and motivations of the person and extrinsic social and environmental opportunities. Capability factors include hearing aid handling skills, the extent of cognitive impairment, and the establishment of hearing aid routines. Motivation factors include recognition of hearing difficulty, perceived need for hearing aids, and consequences of using hearing aids. Social opportunity factors include social and professional support, and cultural influences on hearing aid use. Environmental opportunity factors include features of hearing aids and their resources, and establishment of set places to store and maintain hearing aids.

This thesis has developed theory-informed understanding of key influences on hearing aid use in people with dementia. The findings suggest that tailoring interventions to the capabilities and motivations of the individual, whilst accounting for their environment and support systems, may optimise hearing aid use. From this evidence, interventions to support hearing aid use and improve quality of life for people living with dementia and comorbid hearing loss can be developed.

Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning. The papers included as chapters in this thesis are under the terms of the publishers' copyright agreements. There are no conflicts of interest.

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Preface

The PhD candidate is an occupational therapist with an MSc in Advanced Occupational Therapy who worked clinically with older adults living with dementia for nearly two decades. Within this context she undertook clinical research delivery for several years, including as a research practitioner on a Randomised Controlled Trial of Assistive Technology and Telecare in Dementia (Gathercole et al., 2021) (Trial ID ISRCTN86537017), and was involved in developing and delivering a Sensory Intervention for people living with comorbid dementia and sensory loss in the SENSE-Cog trial (Regan et al., 2017; Regan et al., 2019) (Trial ID ISRCTN17056211). Her experiences of supporting people with comorbid dementia and hearing loss are rooted within the SENSE-Cog trial. As such, she has experience as a clinician-researcher in the subject at hand for this thesis. These experiences shaped the lens through which the research for this thesis was conducted.

At commencement of the PhD, the candidate was employed on the SENSE-Cog trial as the Senior Sensory Support Therapist, delivering the Sensory Intervention in the Greater Manchester area and supervising intervention delivery across the other European study sites (Athens, Dublin, Lancashire, Nice, Nicosia, Warrington). The idea for the PhD emerged whilst the candidate was collaborating on writing the process evaluation protocol for the SENSE-Cog RCT (Leroi et al., 2020a). At that stage it became evident that there was no intention to evaluate adherence to the hearing aids that were provided as part of the Sensory Intervention. The candidate considered this to be an issue of potential importance and formulated a research proposal that would evaluate adherence and seek to build understanding about factors that influence adherence to hearing aids in people who are living with dementia.

There are several underlying assumptions that guided the PhD candidate. These are: i) that hearing aids are helpful for people with dementia and acquired hearing loss; ii) people with dementia have the potential to adapt to using hearing aids and to learn how to use them; iii) intervention approaches that foster hearing aid adherence are beneficial and necessary in this population due to the impact of dementia upon functional ability. The candidate acknowledges that these are personal assumptions that may not be universally accepted.

Chapter one:

Introduction

This chapter includes a narrative evaluation of background literature concerning the prevalence and impact of hearing loss in dementia, the use of hearing aids in treating hearing loss, factors affecting the use of hearing aids, and interventions to support hearing aid use. Following this, the aims and objectives of the thesis are presented, along with information about the theoretical frameworks and research context that underpin the studies within the thesis. The chapter concludes with an overview of the format of the thesis.

Background

This PhD focuses on developing understanding of influences on hearing aid use in persons living with dementia and age-acquired hearing loss in community settings. It is estimated that there are around 885,000 people in the United Kingdom living with dementia (Wittenberg et al., 2019) with 61.3 % living in the community (Alzheimer's Society, 2014). Those living in the community are therefore amongst the majority.

Prevalence of hearing loss in dementia

Hearing impairment and dementia are both conditions that increase in prevalence with age (Quaranta et al., 2015; Alzheimer's Association, 2020). It is perhaps unsurprising, therefore, that the prevalence of hearing loss in older adults who are living with dementia is high. Evidence suggests that hearing loss is more prevalent in people with dementia or cognitive impairment than in the general population of older adults (Lau et al., 2022). Estimates of the prevalence of hearing loss among people with dementia living in the community vary between 46% and 94% (Gold, Lightfoot and Hnath-Chisolm, 1996; Buford-Blair et al., 2015; Nirmalasari et al., 2017; Nieman et al., 2018). In these studies, the highest estimated prevalence of hearing loss was reported when a combination of audiometric evaluation and self-report of hearing impairment was completed in a memory clinic setting (Gold, Lightfoot and Hnath-Chisolm, 1996), with the lowest estimate occurring when proxy-reported within an epidemiological study (Nieman et al., 2018). The differences in estimated prevalence are therefore likely to be due to variations in the method of assessment and differing threshold criteria employed to define hearing loss. Self- or proxy-reporting is a less reliable method of establishing the presence of hearing loss than completion of an audiometric evaluation (Gold, Lightfoot and Hnath-Chisolm, 1996), suggesting that audiometric evaluation may provide a truer indication of prevalence. When an audiometric assessment is completed, the prevalence of at least a mild hearing loss (>25 dB HL) reported in these studies is 60% in community-dwelling people with dementia or cognitive impairment (Nirmalasari et al., 2017), suggesting that most people with dementia will also experience hearing difficulties.

Impact of living with dementia and comorbid hearing loss

Hearing loss and dementia are both conditions that increase burden in relation to quality of life and healthcare utilisation. They have both been identified as being amongst the primary causes of disability in later life (Vos et al., 2020). Overlapping characteristics of hearing loss and dementia exist. These characteristics include social isolation, impaired conversation, decreased understanding of speech, repeated questioning, and dependency upon significant others (Hopper and Hinton, 2012; Kilimann et al., 2015). Additionally, both conditions may increase strain in relationships with family members (Pichora-Fuller et al., 2013).

Research has shown that people with comorbid dementia and hearing loss experience increased negative outcomes in relation to function in activities of daily living, social engagement, and communication than those with dementia alone (Guthrie et al., 2018), and that hearing loss may worsen neuropsychiatric symptoms of dementia such as depression (Kim et al., 2021). This suggests that the challenges of living with dementia are exacerbated when experienced comorbidly with age-acquired hearing loss. Effective management of hearing loss in dementia is therefore important.

Treating hearing loss

Audiological rehabilitation has been defined by Kiessling et al. (2003 p.2596) as ‘a problem-solving process aimed at optimising the individual’s auditory activities and avoiding or minimising any restrictions to participation’. Intervention options include the provision of audiological devices such as hearing aids or cochlear implants, auditory training, and communication education (Pichora-Fuller, Mick and Reed, 2015). The primary intervention in audiological rehabilitation is treatment with air-conduction hearing aids (National Institute for Health and Care Excellence, 2018), and their effectiveness in reducing hearing-related disability has been demonstrated (Ferguson et al., 2017). Hearing aids may be provided monaurally or binaurally and may be behind-the-ear (BTE) or in-the-ear (ITE) in design.

Hearing aids aim to help people with acquired hearing loss to compensate for the auditory deficits that they experience by amplifying sound (Hoppe and Hesse, 2017), thereby addressing the auditory restrictions that impact on communication and function in daily life (Ferguson et al., 2017). There is an anecdotal suggestion within the literature that health care professionals may question the viability of hearing aid use in dementia (Lemke, 2011; Pichora-Fuller et al., 2013), but evidence suggests that it is viable to successfully fit hearing aids in this population (Palmer et al., 1999; Allen et al., 2003; Hooper et al., 2019; Dawes et al., 2022). However, the National Institute for Health and Care Excellence (NICE) (2018) have identified that people with dementia are at particular risk of under-presenting to audiology services due to reduced awareness or under-reporting of their needs, suggesting that additional support from family and general health practitioners may be required ‘upstream’ of the audiological assessment itself to facilitate timely referrals into audiology services for assessment. Furthermore, although many audiologists are aware of the overlaps between hearing impairment and dementia (Leroi et al., 2019), they may feel that they lack the skills and opportunity to address the needs of people with dementia due to their additional complexities (Wright et al., 2014), suggesting that guidelines for treating hearing loss in dementia are warranted (Dawes et al., 2022; Littlejohn et al., 2022).

Use of hearing aids in people with dementia

Previous research suggests that treating hearing impairment with hearing aids represents an important opportunity to improve quality of life for people with dementia (Mamo et al., 2018; Dawes et al., 2019). However, people with dementia or cognitive impairment are less likely to use hearing aids than the general population of older people (Lupsakko, Kautiainen and Sulkava, 2005; Fisher et al., 2015; Naylor et al., 2022; Powell et al., 2023), and their use has been shown to reduce over time (Allen et al., 2003; Powell et al., 2023). In view of this, it is important to understand whether the amount of hearing aid use influences outcomes such as quality of life for people with dementia. Unfortunately, there is no agreed standard for what constitutes optimal, successful, or even regular hearing aid use for people with dementia; for example, whether the amount of use is the most important factor within this, or whether situational use is just as beneficial, as suggested by hearing aid users in the general population (Laplante-Lévesque et al., 2013). Empirical evidence regarding this is sparse; however, a randomised controlled semi-crossover trial of hearing aid use in dementia (Adrait et al., 2017; Nguyen et al., 2017) provides some points for consideration. Within this trial, caregiver-reported information about the duration, frequency, and type of activity wear of hearing aids was obtained. The researchers categorised compliance as bad, moderate, good, or very good via a composite score. Analysis demonstrated that there was a significant improvement in quality of life associated with good compliance to hearing aids. Furthermore, in a study conducted by Allen et al. (2003), significant improvements in hearing-related disability were associated with daily wear, compared with participants that had lower hearing aid use. These outcomes provide a signal that for people with dementia and age-acquired hearing loss, good compliance – i.e. regular and consistent wear – may help to support quality of life, suggesting that this should represent the target behaviour of hearing aid use.

Factors affecting the use of hearing aids

Becoming used to hearing aids is recognised to be a process of adjustment (Dawes, Maslin and Munro, 2014), with successful use being fostered through the acquisition of a range of knowledge and skills in their use and maintenance (Bennett et al., 2018b). However, many hearing aid owners experience difficulty with these skills (Bennett et al., 2018a). Difficulty in adjusting to use is reported to be one of the main reasons for non-use of hearing aids in the general population, alongside lack of perceived benefit, and problems with the fit or comfort of the devices (McCormack and Fortnum, 2013; Ng and Loke, 2015). Conversely, age and severity of hearing loss have been found to be positively associated with use of hearing aids, with people who are older and with worse hearing being more likely to wear them (Jerram and Purdy, 2001; Gopinath et al., 2011; Tahden et al., 2018; Knoetze et al., 2023). Motivation was identified by Salonen et al. (2013) as an important factor in

becoming a regular user of hearing aids; those who were more motivated were more likely to persist even if they experienced difficulties. Furthermore, reviews have consistently identified that people who self-report that they experience hearing loss are most likely to use hearing aids (Knudsen et al., 2010; Knoetze et al., 2023), indicating that a person's awareness of their hearing loss is highly influential. Finally, the support of family or friends has also been identified as an influencing factor (Meyer et al., 2014; McKee et al., 2019). This suggests that adjustment to using hearing aids and adherence to hearing aids can be problematic in the general population (McCormack and Fortnum, 2013; Dawes, Maslin and Munro, 2014).

One might expect that adjustment and adherence to hearing aids could be more challenging for people with dementia due to deterioration in their cognitive and functional abilities. For example, people with dementia may have increased difficulties in using hearing aids due to dementia-related factors such as reduced cognitive and visuospatial abilities, and neuropsychiatric symptoms such as apathy (Cipriani et al., 2020; Dawes et al., 2022). These may have a compounded impact upon the use of hearing aids in people with dementia, including handling and maintaining them effectively, and persisting through difficulties, which are known barriers to hearing aid use in the general population (McCormack and Fortnum, 2013). Furthermore, given that self-awareness of hearing loss is a highly important factor in influencing the use of hearing aids, this may be problematic for people living with dementia due to the loss of self-awareness that is commonly associated with the condition (Mograbi, Huntley and Critchley, 2021). Whilst these factors may be of relevance in dementia, there is a paucity of research that has explored barriers and facilitators to hearing aid use in this population to date. As such, whilst it may be hypothesised that people with dementia could experience determinants to using hearing aids that differ from those in the general population, thereby requiring a different approach to supporting their use, this has not been adequately explored to date and represents an evidence gap.

Interventions to support hearing aid use

A Cochrane review evaluated the effectiveness of interventions to support hearing aid use in adults with hearing loss (Barker et al., 2016). Most of the 37 studies that were included in this review used a supported self-management approach, such as providing information and opportunities to practise skills. The authors concluded that whilst there was some evidence that these interventions improved outcomes such as communication, there was no evidence that they increased daily hearing aid use in the adult population. Researchers have suggested that the lack of interventions informed by behaviour change theory could potentially explain the equivocal findings of this Cochrane review (Armitage et al., 2017) as theory-informed interventions may optimise effectiveness (Davis et al., 2015). A subsequent intervention aimed at improving hearing aid use in adults, the i-Plan, was

developed (Barker, Atkins and de Lusignan, 2016; Barker, Lusignan and Deborah, 2018) using the Behaviour Change Wheel (BCW). This provides a theory-informed, systematic way to understand and address influences on behaviours (Michie, Atkins and West, 2014). Although initial implementation findings from this trial suggested that hearing aid use outcomes were no different between control and intervention groups (Ismail et al., 2021), the outcomes of a subsequent refined intervention suggested that action planning increases hearing aid use in adults when compared to no action planning (Ismail et al., 2022). This suggests that implementing a behaviour change theory-informed approach may help to support hearing aid use. However, none of these trials included people with dementia. As outlined above, hearing aid use is lower among people with dementia than their peers, and it is reasonable to suggest that people with dementia may experience additional challenges to hearing aid use.

Intervention approaches to support hearing aid use in people with dementia include tailoring the intervention to the cognitive and sensory needs of the individual to improve hearing aid handling skills (Leroi et al., 2020b; Sheikh et al., 2021) and to foster persistence (Palmer et al., 1999; Leroi et al., 2020b). Involvement of care partners in supporting hearing aid use is also suggested to be beneficial (Palmer et al., 1999; Hutchison, Covan and Bogus, 2012b; Dupuis et al., 2016; Nguyen et al., 2017; Leroi et al., 2020b; Sheikh et al., 2021). However, this research is predominantly small scale or low quality, with the effectiveness of these strategies to support hearing aid use being poorly evaluated and reported. Furthermore, the rationale that informed the development of these interventions is infrequently reported, except for within the SENSE-Cog study (Regan et al., 2019). The prototype sensory support intervention implemented in this study was informed by a multi-method investigation into the support needs of people with dementia and sensory loss and underpinned by behaviour change theory (Leroi et al., 2017). However, the evidence that informed this intervention focused on the outcomes of hearing and vision interventions, such as cognition and quality of life (Dawes et al., 2019), rather than on factors that influence hearing aid use. To the best of the PhD candidate's knowledge, no interventions to support hearing aid use in dementia have been developed from an evidence-informed understanding of influences on hearing aid use. This represents an important gap: if there is a lack of awareness of factors that influence the target behaviour of hearing aid use in dementia, interventions may not effectively support hearing aid use. There is therefore a need to develop this evidence base.

Thesis aims and objectives

The overall aim of this PhD was to develop understanding of influences on hearing aid use in people with dementia and comorbid hearing loss.

The objectives of this PhD were:

1. To evaluate the extant literature to identify factors that are associated with hearing aid use in people with dementia
2. To explore enablers and barriers to hearing aid use from the perspective of people with dementia
3. To evaluate correlates of hearing aid use in people with dementia

It was anticipated that the insights that were drawn from the studies included in this thesis could inform the development of interventions to support hearing aid use and improve quality of life for people living with dementia and comorbid hearing loss.

Theoretical frameworks

Research into hearing aid use has previously been described as 'under-theorised' (Barker et al., 2016, p. 8). The research within this PhD was underpinned by two interlinked theoretical models of behaviour change – the Capabilities-Opportunities-Motivations theory of Behaviour (COM-B) (Michie, van Stralen and West, 2011; Michie, Atkins and West, 2014) and the Theoretical Domains Framework (TDF) (Michie et al., 2005; Cane, Connor and Michie, 2012). These theoretical models support understanding of influences on behaviour and form the foundation of behaviour intervention design (Michie, Atkins and West, 2014). As little is known about the drivers, enablers, and barriers to enacting the behaviour of hearing aid use in people with dementia, these theoretical frameworks provide an appropriate framework to explore and evaluate these.

The Capabilities-Opportunities-Motivations model of behaviour

The Capabilities-Opportunities-Motivations model of behaviour (COM-B) depicts sources of behaviour. Michie et al. (2014) purport that for a behaviour to occur, a person needs to have the physical and psychological skills to enact it (Capability), an enabling social and physical environment (Opportunity), and the automatic and reflective processes that drive them to engage in the behaviour (Motivation). According to the COM-B model, barriers in any of these component areas affects enactment of the behaviour (Michie, Atkins and West, 2014).

It is evident that a range of capability, opportunity and motivation demands underpin the behaviour of hearing aid use in dementia. For example, the physical skills required to manipulate and insert hearing aids successfully may include manual dexterity, grip, muscle strength and range of movement. These skills lie within the *physical capability* component of the COM-B model. In relation to the *social opportunity* component of the COM-B model, social influences such as the level and type of support that is provided by family members or formal caregivers may be relevant.

Furthermore, aspects of *reflective motivation* such how optimistic a person is about the usefulness

of hearing aids may influence their use. These examples provide a snapshot of the potential components that influence the behaviour of hearing aid use. Further consideration of this is presented in Table A1.1 within Appendix 1.

The Theoretical Domains Framework

Based on behaviour change theories, the TDF consists of fourteen domains of theoretical constructs that categorise influences on behaviour (Cane, Connor and Michie, 2012). These domains are Knowledge; Skills; Social/Professional Role and Identity; Beliefs about Capabilities; Optimism; Beliefs about Consequences; Reinforcement; Intentions; Goals; Memory, Attention and Decision Processes; Environmental Context and Resources; Social Influences; Emotions; and Behavioural Regulation (Cane, Connor and Michie, 2012). The TDF domains link directly into each of the capability, opportunity, and motivation components of the COM-B model, expanding these to facilitate more detailed understanding. The TDF has been implemented in a range of empirical studies across a variety of professional groups and has been shown to demonstrate utility in the generation of in-depth understanding of factors that influence behaviour (Dyson et al., 2011; Francis, O'Connor and Curran, 2012; Atkins et al., 2017). An overview of the links between the COM-B model and TDF domains are illustrated in Table A1.2 within Appendix 1. TDF domain definitions are also included in this Table.

Using the Behaviour Change Wheel in intervention design

The COM-B model and TDF framework inform understanding of the demands of a behaviour and form the central hub of Michie et al.'s (2014) three-layered Behaviour Change Wheel (BCW). Michie et al. (2014) suggest that the COM-B / TDF behaviour systems of the BCW can inform behaviour change intervention design. They assert that through generating understanding of (a) the capability, opportunity and motivation demands of a behaviour, and (b) which of these components need to be addressed to achieve the intended behaviour, a 'behavioural diagnosis' of what needs to change can be formulated. From this starting point, intervention functions (BCW middle layer) and policy categories (BCW outer layer) that support the change can be identified and implemented within an intervention designed to support the target behaviour. This systematic approach to intervention design aligns with guidance for developing complex interventions (Skivington et al., 2021).

Defining the target behaviour

Michie et al. (2014) contend that the first step in developing understanding of a particular behaviour is to define the target behaviour. Defining the target behaviour is not straightforward in this case because we do not know what constitutes optimal hearing aid use, as discussed above. Therefore, to answer the 'what', 'where' and 'who' of the behaviour (Michie, Atkins and West, 2014), the

following pragmatic definition of the target behaviour is used in this thesis: *'Daily use of hearing aids by people with dementia and age-acquired hearing loss in their home and community environments'*.

The studies within this thesis aimed to develop informed understanding of the factors that influence the behaviour of hearing aid use in people with dementia through the COM-B and TDF behavioural systems at the centre of the Behaviour Change Wheel. Until these influencing factors are sufficiently understood, they cannot be addressed in interventions aimed at supporting hearing aid use. Thus, the research within this thesis represents a crucial first stage in designing interventions to support hearing aid use in dementia and represents the first stage of Michie et al.'s (2014) BCW process of intervention design. From this evidence-informed understanding, intervention options to support hearing aid use can be identified (BCW stage two) and used to inform implementation options such as which behavioural change techniques are most relevant to evoke change (BCW stage three) (Michie, Atkins and West, 2014).

Research Context

The empirical studies in this thesis were nested within the European SENSE-Cog Randomised Controlled Trial (RCT) (Trial ID: ISRCTN17056211). This was a 36-week randomised controlled trial comparing an individualised Sensory Intervention to standard care. The aim of the RCT was to evaluate whether the Sensory Intervention improved quality of life in community-dwelling people with comorbid dementia and hearing and / or vision impairment. The primary outcome of the RCT was the quality of life of the person with dementia at 36 weeks (Regan et al., 2019).

To be eligible for inclusion in the SENSE-Cog trial, participants with dementia were aged 60 years or older and living in the community. They had a clinical diagnosis of Alzheimer's, vascular or mixed dementia in the mild to moderate stage, evidenced by a Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005) score of at least 10, and age-acquired hearing and/or vision impairment. Hearing impairment was defined by hearing worse than 35 dBHL at 1000 Hz and above in the better ear using a portable Siemens HearCheck™ screening device. Each participant had a care partner, who had to be an informal caregiver (such as a family member or friend) in regular contact with the person with dementia and aged 18 years or older to be eligible for inclusion (Regan et al., 2019). Participants with dementia and their care partners were enrolled into the study as dyads, with each member of the dyad having active involvement in the study procedures, according to their randomised trial arm. The SENSE-Cog trial enrolled 252 participant dyads across eight sites in five European countries (Cyprus, England, France, Greece and Ireland) between May 2018 and May 2021 (Leroi et al., 2024).

For people with hearing loss, the Sensory Intervention within the SENSE-Cog RCT comprised clinical assessment of hearing, provision of Starkey Muse i2400 Mini BTE hearing aids if clinically indicated, and home-based sensory support of up to ten visits over eighteen weeks from a ‘Sensory Support Therapist’ (SST). The SST visits primarily aimed to support adherence to hearing aids through training, goal setting and monitoring, alongside promoting effective communication. Secondary components of the sensory support included adjusting the environment to support sensory function, fostering social inclusion, and facilitating access to support services (Regan et al., 2019).

Ethical considerations

The primary empirical studies within this PhD were conducted in accordance with the principles of the Declaration of Helsinki (World Medical Association, 2013) and Good Clinical Practice guidelines (GCP) (European Medicines Agency, 2017). Ethical approval for the overall SENSE-Cog study was gained in each of the participating European sites, according to local requirements. In the UK sites, ethical approval was granted by the Haydock Health Research Authority National Research Ethics Service on 12/02/2018 (REC reference 17/NW/0702; IRAS project ID 213875). All researchers working on the trial received training in GCP guidelines, including the PhD candidate. Amendments to the SENSE-Cog trial protocol in relation to this PhD were submitted and approved (Version 6.0 dated 17.02.2020). Approval from the Research and Development departments of all research sites was obtained prior to the commencement of recruitment, and letters of access were gained from the relevant NHS Trusts prior to commencement of primary qualitative data collection for this thesis by the PhD candidate.

Consent process

The person with dementia and their study partner were enrolled to the main SENSE-Cog trial after providing informed written consent in line with guidelines set by the relevant legal frameworks in Cyprus, France, Greece, Ireland, and the UK. The researcher who obtained consent completed an assessment of the person with dementia’s capacity to provide informed consent. Those who had the capacity to provide consent for participation in the study signed their own consent forms. For those persons with dementia in whom capacity was lacking, a nominated consultee was asked to assent on their behalf, as per guidance within the Mental Capacity Act (Department of Health, 2005) (Leroi et al., 2024). Participants that were recruited for the qualitative study within this thesis (chapter three) had already provided written informed consent for inclusion as part of the consent process outlined above. A process consent approach (Dewing, 2007) was adopted in addition to this, with potential participants confirming to the Sensory Support Therapist whether they consented to be approached for inclusion in these interviews following completion of the Sensory Intervention.

Thesis format

This thesis is presented in the journal format. It comprises three standalone studies, meeting the threshold of required studies for a thesis in this format. The studies have each been published in peer-reviewed journals, confirming that the work presented within this thesis is of publishable quality. Chapters that have been published are presented in accordance with the formatting guidelines of each journal, as detailed at the beginning of each respective chapter. For the published studies presented in chapters two, three and four, references are provided at the end of each chapter. References for the remainder of the thesis are presented following the discussion chapter.

Chapter Two:

In chapter two, a systematic literature review to identify and evaluate the existing evidence base relating to factors that influence hearing aid use in people with dementia is presented. The research question that guided this study was '*What factors are associated with hearing aid use in people with dementia?*' An evidence synthesis of this nature had not been published previously. The protocol for this study was pre-registered on the PROSPERO international prospective register of systematic reviews (CRD42020173094). The review included an interpretive data synthesis according to the domains of the Theoretical Domains Framework (Cane, Connor and Michie, 2012), critical evaluation of the literature, presentation of key findings for which the evidence was strongest, and suggestions for intervention approaches and future research.

This chapter has been published in the Journal of the American Directors Association:

Hooper, E., Brown, L.J.E., Cross, H., Dawes, P., Leroi, I., Armitage, C.J. (2022) Systematic Review of Factors Associated With Hearing Aid Use in People Living in the Community With Dementia and Age-Related Hearing Loss. *J Am Med Dir Assoc.* 23(10):1669-1675.e16. doi: 10.1016/j.jamda.2022.07.011.

Chapter Three:

Chapter three consists of a semi-structured interview study with eleven participant dyads from the Sensory Intervention arm of the SENSE-Cog trial (Regan et al., 2019). Within this study, dyads constitute a person with dementia and hearing loss who received hearing aids as part of the trial and their care partner. The study was guided by the research question '*What are the perceptions of enablers and barriers to hearing aid use of people with dementia and their care partners?*' Research of this nature with people who are living with dementia is sparse and had not previously drawn upon theories of behaviour change. The interview schedule for this study was informed by the Theoretical Domains Framework (Cane, Connor and Michie, 2012). Using guidance for conducting TDF-based research (Atkins et al., 2017), this study explored enablers and barriers to hearing aid use from the perspectives of people living with dementia and their care partners, adopting a two-stage analysis of

deductive TDF content analysis followed by inductive analysis of the mapped data. Key intervention functions that align with the Behaviour Change Wheel (Michie, Atkins and West, 2014) were proposed.

This chapter has been published in the *Journal of Applied Gerontology*:

Hooper, E., Brown, L.J.E., Cross, H., Dawes, P., Leroi, I., Armitage, C.J. (2024) Enablers and barriers to hearing aid use in dementia. *Journal of Applied Gerontology*, advance online publication available from January 18, 2024. doi: 10.1177/07334648231225346

Chapter Four:

In chapter four, an evaluation of predictors of hearing aid use is presented. This study was a secondary analysis of cross-sectional pre-randomisation baseline data from the SENSE-Cog trial (Regan et al., 2019), to establish (a) the incidence of hearing aid use and (b) predictors of hearing aid use. The sample for this study was 239 participants that screened positively for hearing loss at enrolment into the SENSE-Cog trial. In this study, the COM-B model was used to organise potential predictor variables, and the correlations of these variables with hearing aid use were evaluated through bivariate and multivariate logistic regression models. No previous research had evaluated the relative importance of a range of factors associated with hearing aid use in dementia, inhibiting the implementation of targeted interventions to promote hearing aid use for people with dementia. Implications for practice arising from the variables that were significantly associated with hearing aid use were presented according to their relevant COM-B domain.

This chapter has been published in the *Journal of Aging and Health*:

Hooper, E., Brown, L.J.E., Dawes, P., Leroi, I., Armitage, C.J. (2024) What are the correlates of hearing aid use for people living with dementia? *Journal of Aging and Health*, advance online publication available from March 18, 2024. doi: 10.1177/08982643241238253

Chapter Five:

In this discussion chapter, influences on hearing aid use arising from the findings of this thesis are presented, and intervention options and implementation options considered. The findings are discussed within Michie et al.'s (2014) Behaviour Change Wheel intervention design process to form insights that may be useful for the development of interventions to support hearing aid use in people with dementia. A broader discussion of the overall findings is also presented, along with consideration of the strengths and limitations of this thesis, areas for future research and overall conclusions.

The first author of each empirical study is the author of this thesis and took the lead in the development, implementation, analysis / evaluation, and preparation of the manuscripts for publication of the research presented within this thesis. For chapters two, three and four, co-authors Professor Christopher Armitage, Dr Laura Brown, Professor Piers Dawes, and Professor Iracema Leroi advised on study design, data analysis and data interpretation, and assisted in manuscript revisions. Dr Hannah Cross also provided input as a second independent reviewer in the systematic review presented in chapter two and as an independent coder of a selection of the interview transcripts in the qualitative study presented in chapter three.

Chapter two:

Systematic review of factors associated with hearing aid use in people living in the community with dementia and age-related hearing loss

This chapter includes a systematic review of factors associated with hearing aid use in people living in the community with dementia and age-related hearing loss. Considering the growing interest in establishing whether the effective management of hearing loss in persons with dementia influences cognitive and functional outcomes, a systematic evaluation of the evidence base was timely. There had been no previous attempts to collate and systematically evaluate evidence from the extant literature about factors that influence hearing aid use among people with comorbid dementia and age-acquired hearing loss. This study was therefore novel. The assimilation and evaluation of best available evidence was the first stage in developing understanding of enablers and barriers to hearing aid use in this population and formed the baseline from which the studies presented in chapters three and four were developed.

This study has been published in the Journal of the American Directors Association (JAMDA):

Hooper, E., Brown, L.J.E., Cross, H., Dawes, P., Leroi, I., Armitage, C.J. (2022) Systematic Review of Factors Associated With Hearing Aid Use in People Living in the Community With Dementia and Age-Related Hearing Loss. *J Am Med Dir Assoc.* 23(10):1669-1675.e16. doi: 10.1016/j.jamda.2022.07.011.

The JAMDA format is used for this chapter, including the use of superscript numerical reference formatting. Supplementary materials from the journal article are included as follows: The PRISMA flowchart is presented within the body of the text, and supplementary methods information, Table of characteristics of included studies, quality and evidence level appraisal Table, and Table of GRADE-CERQual outcomes are presented in Appendix two.

Systematic review of factors associated with hearing aid use in people living in the community with dementia and age-related hearing loss

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Brief summary: This systematic review investigates factors that influence hearing aid use in people with dementia living in the community. The findings suggest that hearing aid use in this population is influenced by: (i) degree of hearing aid handling proficiency; (ii) positive experiential consequents; (iii) degree of hearing aid comfort or fit; (iv) person-environment interactions; and (v) social reinforcement.

Abstract

Objectives: To investigate factors that influence hearing aid use according to the Theoretical Domains Framework (TDF). The TDF is a behavioural science framework that aids understanding of factors that influence behaviour.

Design: Systematic review.

Setting and participants: People living in the community with dementia and age-related hearing loss who have air conduction hearing aids.

Methods: Systematic literature review following PRISMA guidelines. We searched for studies in nine databases, including Ovid MEDLINE, Scopus, and OpenGrey. We undertook an interpretive data synthesis by mapping findings onto the TDF. We assessed confidence in the findings according to the GRADE-CERQual approach.

Results: Twelve studies (6 quantitative, 3 qualitative, and 3 mixed methods) were included in the review. The majority of these were rated low-moderate quality. We identified 27 component constructs (facilitators, barriers, or non-correlates of hearing aid use) nested within the 14 domains of the TDF framework. Our GRADE-CERQual confidence rating was high for five findings. These suggest that hearing aid use for people living in the community with dementia and hearing loss is influenced by: (i) degree of hearing aid handling proficiency; (ii) positive experiential consequents; (iii) degree of hearing aid comfort or fit; (iv) person-environment interactions; and (v) social reinforcement.

Conclusions and Implications: Hearing aid interventions should adopt a multi-faceted approach that: optimises the capabilities of people with dementias to handle and use hearing aids; addresses or capitalises on their motivation; and ensures their primary support network is supportive and encouraging of hearing aid use. The findings also emphasise the need for further high-quality research that investigates optimal hearing aid use, influencing factors, and interventions that support hearing aid use.

Introduction

Hearing impairment affects up to 90% of older adults who are living with dementia,¹⁻³ and is more prevalent in people with dementia than among their peers with intact cognition.^{4,5} The negative consequences of combined hearing and cognitive impairment include reduced quality of life, and increased social isolation and dependency on others.⁶⁻⁸ Previous research suggests that treating hearing impairment with hearing aids represents an important opportunity to improve quality of life for people with dementia.^{9,10}

Research within the general population has identified a range of factors associated with hearing aid use. Lack of perceived need for, or benefit from, hearing aids; difficulty adjusting to use; and problems with the fit or comfort of the devices are all barriers to use.¹¹⁻¹⁵ Conversely, increased age and severity of hearing loss are both positively associated with use of hearing aids.¹⁶⁻¹⁸ In addition, motivation to use hearing aids may make people more likely to tolerate initial difficulties with hearing aids to become regular users of them.¹⁹ People who report that they experience disabling effects of hearing loss are most likely to use hearing aids,^{11,20-22} and the support of family or friends has also been identified as a facilitating factor for hearing aid use.^{22,23}

One might expect that using hearing aids could be more challenging for people with dementia than in the general population due to the deterioration in cognitive and functional abilities associated with dementia. For example, awareness of hearing loss is an important correlate of hearing aid use,^{11,20,21} yet loss of self-awareness commonly occurs in dementia.²⁴ Furthermore, people living with dementia may have increased difficulties in using hearing aids due to dementia-related factors such as reduced cognitive, visuospatial and executive function abilities,²⁵ and increased apathy.²⁶ These factors may negatively influence a person's ability to manipulate and maintain hearing aids, as well as their ability to persevere through difficulties such as initial discomfort.²⁷ People with dementia may also require support in order to use hearing aids successfully.^{28,29} For those living in the community, family support may be of greatest relevance.²⁸

Previous reviews of factors that influence hearing aid use have not considered the distinct needs of people living with dementia. Identifying barriers and facilitators to hearing aid behaviour is therefore a crucial first step in developing interventions that support hearing aid use in this population.^{30,31} The Theoretical Domains Framework (TDF) is a proven behavioural science framework that provides a comprehensive framework for understanding determinants of behaviour,^{32,33} and identifying factors that need to be addressed to effect behaviour change.³⁴ It was chosen as a framework for data synthesis in this review because there may be a range of factors that influence hearing aid use.³⁵ The objective of this literature review was therefore to identify, evaluate and synthesise literature on

factors that are associated with the use of hearing aids in people with dementia, according to the TDF.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Statement³⁶ guided the methodology of this review. The protocol for this study was pre-registered on the PROSPERO international prospective register of systematic reviews (CRD42020173094).

Eligibility criteria

Studies were eligible for inclusion, regardless of design, if the study:

- (a) Included people diagnosed with dementia and age-related hearing loss who had received air conduction hearing aids and were living in the community
- (b) Reported data related to hearing aid use and / or factors that influence use
- (c) Was primary research

We did not impose any restrictions in relation to language or publication date.

Search strategy

We searched the following electronic databases in May 2021: Ovid MEDLINE, Scopus, PsychINFO, and Cumulative Index to Nursing and Allied Health Literature (CINAHL). Additionally, we undertook searches of the Cochrane Databases of Systematic Reviews, reference lists of relevant papers, trial registers ClinicalTrials.gov and the World Health Organisation international clinical trials registry platform (ICTRP), and unpublished 'grey' literature via OpenGrey and Evidence Search.

We identified search terms based on free text words, Medical Subject Headings (MeSH), and reviews of relevant literature. Search terms were adapted, where necessary, to meet the requirements of the databases.

Study selection

Two reviewers independently screened a sample of the titles and abstracts. Following consensus discussion, clarification of the inclusion criteria and further independent screening, we achieved perfect inter-rater agreement (Cohen's $k = 1.00$). The first author then screened the remaining titles and abstracts. Once screening was complete, two reviewers independently appraised the full text of all potentially relevant studies against the full inclusion and exclusion criteria.

Data extraction

We performed the data extraction using a bespoke form. We contacted the authors of the two included conference abstracts to request missing data, one of whom responded to our request.

Quality assessment

We critically appraised the quality of the selected studies using the Mixed Methods Appraisal Tool (MMAT).^{37,38} Within the MMAT, reviewers appraise each included study against core validity criteria for differing study designs (qualitative, quantitative RCT, quantitative non-randomised, quantitative descriptive, or mixed methods). The Johns Hopkins Nursing Evidence-Based Practice (JHNEBP) framework³⁹ was used to appraise and categorise the studies according to the level of research evidence (Level I – experimental, II – quasi-experimental, III – non-experimental or qualitative, IV – practice guidelines or position statements, or V – case reports).

Data synthesis

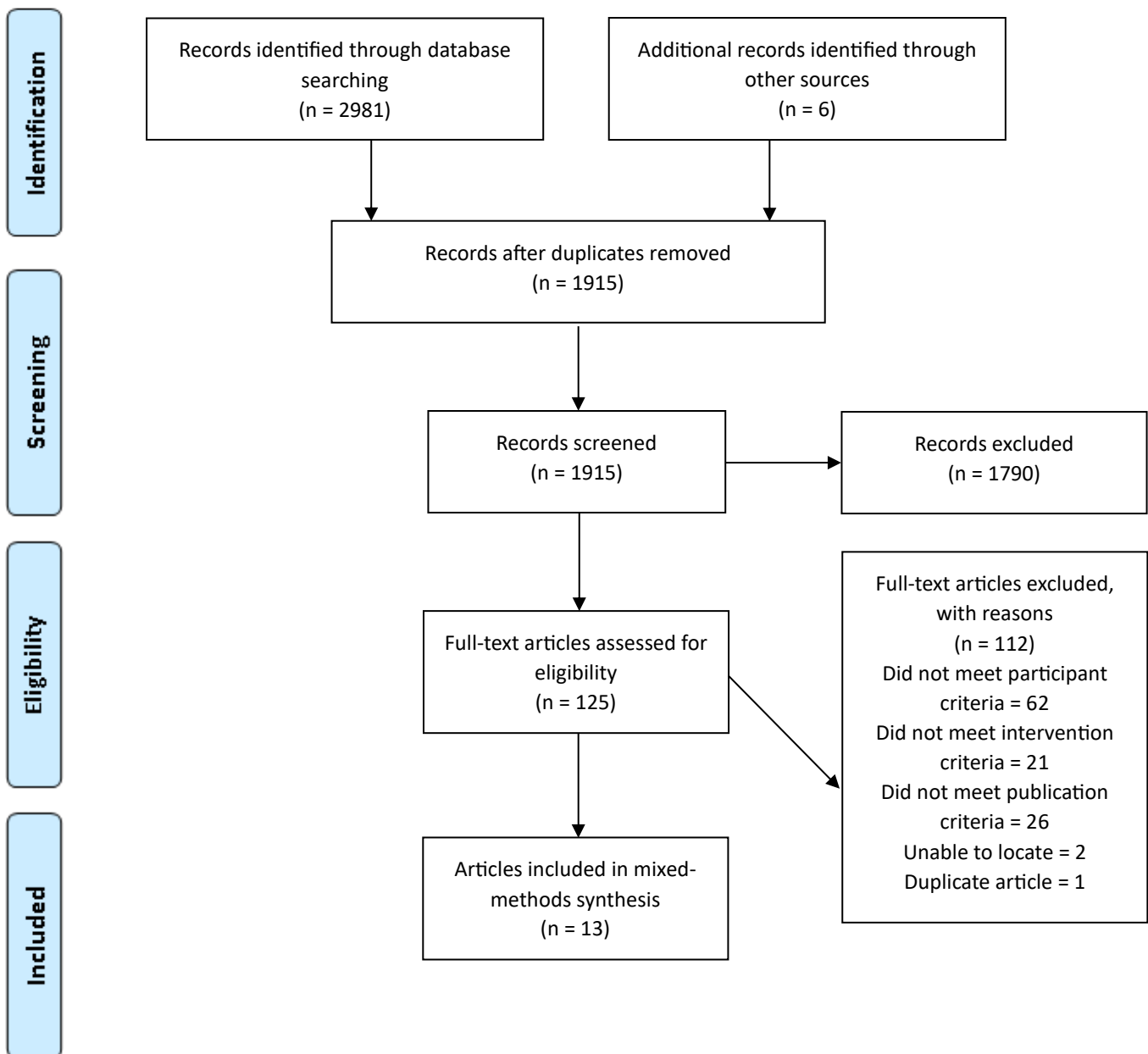
Because this is a mixed methods review, quantitative and qualitative data were treated with equal status and analysed concurrently, according to the A-QUAL + QUAN framework.⁴⁰ An interpretive data synthesis was undertaken by mapping extracted findings to the 14 domains of the Theoretical Domains Framework.^{41,42} Any determinants of hearing aid use that did not fit into the domains of the TDF were categorised as ‘other’ to ensure completeness of the synthesis.

Confidence in the findings was assessed according to the Grading of Recommendations Assessment, Development and Evaluation Confidence in the Evidence from Reviews of Qualitative Research (GRADE-CERQual) approach.⁴³ For this, we assessed each finding in relation to methodological limitations, coherence, adequacy, and relevance. The outcomes of these appraisals informed an overall assessment of confidence in the findings, according to the GRADE-CERQual criteria of high, moderate, low, or very low. Further details of the methods are outlined in Supplementary File S1.

Results

The combined database and hand searches resulted in 2987 returned records. Following de-duplication, 1915 unique records remained. After screening the titles and abstracts, we retained 125 records for full text review against the eligibility criteria. Of these, 112 were excluded, resulting in final inclusion of 13 records (Supplementary Figure S1). Two journal articles presented relevant results from the same study. The final 13 records therefore represented 12 studies with data of relevance to the present review.

Supplementary Figure S1. *PRISMA* Flow Diagram



Study characteristics

Supplementary Table S1 presents characteristics of the included studies. Six quantitative or mixed methods intervention studies, three quantitative descriptive observational studies, two qualitative case reports and one qualitative phenomenological study were included. Sample sizes ranged from 1 to 647 participants. Ages of the participants ranged from 49 to 96 years old. Care partners, such as spouses or adult children, were included in all the intervention studies, one of the quantitative descriptive studies, and two of the qualitative studies.

Participants had varying degrees of cognitive impairment, from mild to advanced dementia. Hearing status was reported according to a variety of parameters in 9 of the 12 studies. Degree of hearing impairment varied from mild to severe hearing loss. Whether or not hearing aids were being used was reported in a variety of ways including caregiver report (six studies), researcher descriptions (three studies), identification in clinical records (two studies), and participant report (one study). Frequency and / or duration of hearing aid use was measured in four studies using caregiver logs. No studies used data logging, despite this being a feature of most hearing aids.⁴⁵

Quality appraisal

Evidence levels and quality varied across the included studies. The majority (eight) of the included studies were of Level III evidence. Of these, Gregory et al.'s⁴⁶ qualitative study, and Leroi et al.'s⁴⁷ and Sheikh et al.'s⁴⁸ mixed methods studies were rated as high quality. However, the participant sample who received the extended intervention, which yielded data of most relevance to the present review in Leroi et al.'s⁴⁷ study, was small (n=4 dyads). Palmer et al.'s⁴⁹ qualitative case study, and Nirmalasari et al.'s⁵⁰ and Kim et al.'s⁵¹ quantitative descriptive studies were rated as moderate quality. The remaining Level III studies were rated as low quality, with limitations in the reporting (Nieman et al. 2018)⁵² or trial design and conduct that resulted in high researcher subjectivity and risk of bias (Hutchison et al. 2012 a, b).^{53,54}

There were two Level II studies (Dupuis et al. 2016; Palmer et al., 1999).^{55,56} These quantitative non-randomised studies were both rated as low quality, with small sample sizes and incomplete outcome data. There was one Level I study, a randomised controlled trial (Nguyen et al., 2017)⁴⁴ which was rated as moderate quality due to lacking complete outcome data and adherence to the intervention. Additionally, lack of a power calculation or justification of sample size rendered the adequacy of the included sample unclear. The final case report (Hawkins, 2011)⁵⁷ was Level V evidence and rated as low quality. The full MMAT quality³⁷ and JHNEBP³⁹ quality and evidence levels appraisals are presented in Supplementary Table S2.

Influences on hearing aid use according to the Theoretical Domains Framework (TDF)

Extracted data were mapped to all domains of the TDF. Three additional findings did not fit within the TDF domains and were categorised as 'other'. Summary findings, along with GRADE-CERQual⁴³ ratings of confidence in the findings are presented in Table 1.

In total, 27 component constructs (facilitators, barriers, or non-correlates of hearing aid use) nested within the 14 domains of the TDF framework. Of these, our confidence rating was high for five constructs, moderate for seven, and low for fifteen. Further detail of the GRADE-CERQual⁴³ assessment outcomes are presented in Supplementary Table S3.

Table 1. Findings summary table

Finding	GRADE-CERQual confidence rating	Studies Contributing to the Review Finding	TDF domain (definition provided for first occurrence) ³¹
Degree of hearing aid handling proficiency influences hearing aid use: difficulty in handling inhibits use whereas being able to handle aids proficiently enables	High confidence	28, 44-46, 52, 53, 55	Skills (An ability or proficiency acquired through practice)
Experiencing positive consequents of hearing aids is associated with their use	High confidence	28, 44-47, 51, 53, 54	Reinforcement (Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus)
Degree of fit /comfort influences hearing aid use: problems with fit are a barrier whereas finding them comfortable is an enabler	High confidence	44, 45	Reinforcement
Factors related to person-environment interactions influence hearing aid use: excessive noise or perceived lack of need in differing listening situations lead to reduced use	High confidence	44	Environmental context and resources (Any circumstances of a person’s situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour)
Receiving social reinforcement enables hearing aid use	High confidence	44, 45, 53	Social influences (Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours)
Standard manufacturer guidance does not enable hearing aid use	Moderate confidence	45, 55	Knowledge (An awareness of the existence of something)
Misplacing hearing aids is a barrier to their use; having a set place for storage is an enabler	Moderate confidence	44, 53	Memory, attention and decision processes (The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives)

Mind-set towards the visibility of hearing aids influences their use: concern about their visibility is a barrier whereas welcoming their visibility is an enabler	Moderate confidence	44, 46	Role and identity (A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting)
Absence of - or negative - expectancy about the outcomes of hearing aids are barriers to their use	Moderate confidence	44, 46	Beliefs about consequences (Acceptance of the truth, reality or validity about outcomes of a behaviour in a given situation)
Degree of intent influences hearing aid use: lack of intent is a barrier whereas positive intent is an enabler	Moderate confidence	44, 53	Intentions (A conscious decision to perform a behaviour or a resolve to act in a certain way)
Negative emotional responses to hearing aids are a barrier to their use, whereas positive impact on affective state resulting from hearing aid use is an enabler	Moderate confidence	44-46, 49, 51, 55	Emotion (A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event)
Lack of care partner hearing aid knowledge is a barrier; presence of care partner knowledge, skills and optimism are enablers	Moderate confidence	45-47	Social influences
Degree of procedural knowledge influences hearing aid use: lack of knowledge impedes use whereas improvement in knowledge enables use	Low confidence	28, 44, 45, 55	Knowledge
Awareness of the presence of disabling hearing loss is associated with hearing aid use	Low confidence	45-47, 51, 52	Knowledge
Degree of self-confidence in ability to handle hearing aids influences their use: low confidence is a barrier whereas increasing confidence is an enabler	Low confidence	45, 55	Beliefs about capabilities (Acceptance of the truth, reality or validity about an ability, talent, or facility that a person can put to constructive use)
Proactive care partner support with handling and maintaining hearing aids enables their use	Low confidence	44, 47, 52	Social influences
Severity of cognitive impairment does not appear to be associated with hearing aid use	Low confidence	50, 53, 54	Memory, attention and decision processes
Forgetting to use hearing aids is a barrier to their use; implementing compensatory strategies is an enabler	Low confidence	44	Memory, attention and decision processes

Developing habitual routines enables hearing aid use	Low confidence	44	Behavioural regulation (Anything aimed at managing or changing objectively observed or measured actions)
Degree of adaptation to hearing aids influences their use; perseverance is an enabler	Low confidence	44, 53	Behavioural regulation
Resistance to change is a barrier to hearing aid use	Low confidence	55	Behavioural regulation
Optimism about efficacy of hearing aids enables their use	Low confidence	44	Optimism (The confidence that things will happen for the best or that desired goals will be attained)
Identification of goals relating to hearing aids enables their use	Low confidence	28, 45, 47	Goals (Mental representations of outcomes or end states that an individual wants to achieve)
Lack of financial resources are a barrier to hearing aid use	Low confidence	50, 52	Environmental context and resources
Age may not influence hearing aid use	Low confidence	50, 53, 54	Other
Degree of hearing loss may not influence hearing aid use	Low confidence	48, 52-54	Other
Ethnicity influences hearing aid use; non-White ethnic groups are less likely to use hearing aids	Low confidence	50	Other

The key findings of this review are those for which there is the strongest current evidence and in which we have the highest confidence. These are:

(i) A person's degree of hearing aid handling proficiency influences hearing aid use; difficulty in handling inhibits use whereas being able to handle aids proficiently enables use. Hearing aid skills difficulties that we identified related to insertion, removal, adjustment, and maintenance. This finding maps into the TDF domain skills.

There was high confidence in this finding because although there were methodological limitations in some of the studies, a body of evidence across seven studies formed the finding.^{46-48,54-57}

Some studies in our review sought to aid the development of hearing aid handling skills.^{47,48} Due to a lack of controlled studies, we were unable to determine whether providing additional support to develop hearing aid handling skills increased hearing aid use compared with standard care pathways. None of the included studies adopted cognitive rehabilitation strategies within their skills development approaches.

(ii) Experiencing positive consequents of hearing aids is associated with their use. A range of positive consequents of hearing aid use was reported in the included studies. However, no study reported whether these consequents directly influenced hearing aid use. This finding maps into the TDF domain reinforcement.

The greatest amount of evidence mapped to this finding, across eight of the included studies.^{44,46-49,53,55,56} Although there were moderate concerns about the methodological quality and relevance of the studies that contributed to this finding, there were only minor concerns about coherence and no concerns about adequacy, rendering overall confidence as high.

(iii) The degree of fit /comfort of hearing aids influences their use; problems with fit are a barrier whereas finding them comfortable is an enabler. This finding also maps into the TDF domain reinforcement.

Although only represented in two of the included studies,^{46,47} leading to moderate concerns about adequacy, the data were rich enough to support the interpretation, and came from high quality, relevant studies.

(iv) Factors related to person-environment interactions influence hearing aid use; excessive noise or perceived lack of need in differing listening situations lead to reduced use. This finding maps into the TDF domain environmental context and resources.

Although evidence for this finding came from just one study,⁴⁶ it was a high quality, relevant study and there were no concerns about coherence.

(v) Social influences: Receiving social reinforcement in the form of prompts and encouragement enables hearing aid use. This finding maps into the TDF domain social influences.

Evidence that contributed to this finding were drawn from three relevant studies of good-high quality,^{46,47,56} with only minor concerns about threats to coherence and adequacy.

Discussion

This systematic review has identified factors that are associated with hearing aid use in people living in the community with dementia and age-related hearing loss. Mapping of data from 12 relevant studies to the TDF revealed 27 different constructs for hearing aid use. The strongest evidence mapped to the skills, reinforcement, environmental context and resources, and social influences domains of the TDF.

Our findings suggest that people with dementia experience similar determinants of hearing aid use as the general population. In particular, similar barriers relating to hearing aid handling skills difficulties,^{12,20} fit and comfort of the devices,¹² and difficulty in tolerating amplified background noise^{19,58,59} were evident. Equally, similar facilitators relating to self-perceived benefit¹¹ and social support²² were evident. Our findings therefore indicate that these factors are at least as important for people with dementia as the general population, suggesting that intervention approaches should account for this. However, there was insufficient evidence in the current literature to evaluate the impact of cognitive, functional, and spatial challenges upon hearing aid use. These may represent critical differences between people with dementia and the general population, and so warrant further investigation.

In relation to intervention approaches, there was some evidence in our findings that people with dementia may benefit from learning strategies to optimise their hearing aid handling skills, such as those offered by cognitive rehabilitation.⁶⁰ In these respects, our findings suggest that hearing aid care pathways require flexibility and a skilled workforce. However, standard pathways lack the flexibility to support the specific needs of people with dementia,⁶¹ and audiologists report that they lack formal training in dementia.⁶²

Additionally, our findings suggest that social support plays a critical role in supporting hearing aid use in dementia. This is congruent with advice in clinical papers, which recommend that family members of people with dementia participate in audiology appointments so that they can support the effective use of hearing aids.^{29,63,64} However, a recent study revealed that 18% of people with

dementia that live in the community received little or no support for their daily living needs.⁶⁵ There may therefore be around a fifth of people with dementia living in the community who do not have adequate social support for their hearing aid use. In these cases, our findings suggest that it may be useful for hearing professionals to explore other options to provide social support around hearing aid use, such as within home care plans. Given that recognising and managing changes to a person with dementia's social support over time (such as following the death of a spouse) has been highlighted as an important way to support continued hearing aid use,⁶² our findings suggest that regular reviews of the presence and effectiveness of support systems is also crucial.

Strengths and limitations

Strengths

In this systematic review, we used the TDF framework to collate barriers and enablers to hearing aid use in dementia. An advantage of using the TDF is that it provides theoretically informed direction about ways in which interventions can be targeted.^{31,34,66} Additionally, use of an existing framework to organise the findings engenders confidence in the validity of the framework and enables integration into the wider literature base.

We also conducted a broad search of the literature to be as inclusive as possible. We did not exclude studies because of quality and did not impose any restrictions on language or publication date. Use of the MMAT,³⁷ JHNEBP³⁹ and GRADE-CERQual⁴³ frameworks provided structure to our assessments of quality and confidence in the findings.

Limitations

There was limited published literature that directly addressed our research question. The level of evidence was predominantly low, and the quality of evidence was largely of a low-moderate grade. The studies that met the inclusion criteria generally had small sample sizes and represented a perspective in predominantly high income, English-speaking countries (with the exception of Sheikh et al.'s⁴⁸ feasibility study in South Asia). There was a lack of controlled studies or overt exploration of influences on hearing aid use, which limited our ability to understand causal factors affecting hearing aid use. These factors limit the generalisability of our findings.

Future research

Michie et al.³¹ propose three incremental stages in the design of behaviour change interventions: firstly, understanding the behaviour; secondly, identifying intervention options; and thirdly, identifying intervention content and implementation options. Whilst this review represents a starting point in understanding factors that influence the behaviour of hearing aid use in people with

dementia, there was insufficient evidence to evaluate the impact of cognitive, functional, and spatial challenges upon hearing aid use. There was also insufficient evidence to evaluate whether the onset of dementia affected hearing aid use in established hearing aid users. Furthermore, the target behaviour for optimal hearing aid use remains unknown in this population and lacks consensus in the general population.⁶⁷ Therefore, there is a critical need for a programme of high-quality research that investigates (a) optimal hearing aid use and (b) influencing factors of hearing aid use in dementia. Once a robust understanding of the target behaviour and influencing factors exists, identification of intervention options, development of intervention content, and identification of implementation options can follow.

Conclusions and Implications

Our findings suggest that the determinants of hearing aid use in dementia are multifaceted. Intrinsic determinants include a person's skills in handling hearing aids and motivating factors related to the consequences and comfort of hearing aids. Extrinsic determinants include the listening context and presence of external prompts and encouragement. Within these constructs, both facilitators and barriers to hearing aid use are evident.

Our findings suggest that enhanced support pathways that tailor to the abilities and motivators of the individual with dementia whilst also accounting for their social support systems over time represent the best opportunity to optimise hearing aid use. Further robust research to establish parameters of the target behaviour of optimal hearing aid use, and to generate further understanding of influencing factors is indicated.

Conflicts of interest: None

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Chapter three:

Enablers and barriers to hearing aid use in people living with dementia

The systematic review that was presented in chapter two demonstrated that although component constructs for barriers, facilitators, or non-correlates of hearing aid use in dementia mapped into each of the fourteen domains of the TDF, the strength of evidence varied markedly. As such, confidence was high for only five of the twenty-seven constructs that were identified, with low confidence ratings applied to over half. The systematic review revealed that that no studies had directly investigated correlates of hearing aid use, limiting understanding of factors affecting hearing aid use. A need therefore existed to develop understanding of influencing factors, to inform interventions that support hearing aid use. This chapter includes a qualitative study that investigated enablers and barriers to hearing aid use in dementia with eleven UK-based dyads from the European SENSE-Cog trial.

This study has been published in the *Journal of Applied Gerontology*:

Hooper, E., Brown, L.J.E., Cross, H., Dawes, P., Leroi, I., Armitage, C.J. (2024) Enablers and barriers to hearing aid use in people living with dementia. *Journal of Applied Gerontology*, advance online publication available from January 18, 2024. doi: 10.1177/07334648231225346

The *Journal of Applied Gerontology* format is used for this chapter, including APA referencing. Supplementary materials are included in Appendix three and include the COnsolidated criteria for REporting Qualitative research (COREQ) checklist and the interview schedule.

Enablers and barriers to hearing aid use in people living with dementia

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Conflict of Interest: The authors declare that there are no conflicts of interest.

Ethical Approval: We gained ethical approval for the study from the Haydock NHS Research Ethics Committee (IRAS ID213875; SENSE-Cog protocol version 6.0).

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Abstract

Hearing loss is highly prevalent in dementia; however, people with dementia are less likely to use hearing aids consistently than people with intact cognition are. This qualitative study is the first of its kind to explore factors that influence hearing aid use from the perspective of community-living people with mild to moderate dementia and their care partners. Eleven UK-based dyads from the European SENSE-Cog Randomized Controlled Trial of a sensory intervention for people with dementia completed semi-structured interviews based on the Theoretical Domains Framework (TDF). Our findings suggest that the TDF domains *environmental context and resources*, *behavioural regulation*, *reinforcement*, and *social influences* are of greatest relevance to hearing aid use in dementia. Within these domains, we identified a range of factors that may influence the target behaviour of hearing aid use. The findings suggest that adoption of multifaceted, flexible intervention approaches may support hearing aid use in dementia.

What this paper adds:

This study extends understanding about enablers and barriers to hearing aid use that people with dementia experience.

Enablers include establishing routines for wear and care, quality hearing aids, experiential benefits, and responsive support.

Barriers include difficulty with hearing aids and their maintenance, especially if support to troubleshoot is not timely.

Applications of study findings:

Our findings suggest that interventions for supporting hearing aid use in dementia should include training, environmental restructuring, enablement, incentivization and education.

Our findings suggest that a need for enhanced service provision for people with dementia and concurrent sensory loss exists.

Introduction

Hearing loss is highly prevalent among people with dementia, with rates of 60%-94% being reported (Gold, Lightfoot and Hnath-Chisolm, 1996; Nirmalasari et al., 2017). Untreated hearing loss can lead to adverse consequences including increased social isolation, loneliness and dependence upon others (Guthrie et al., 2018). Hearing aids are the recommended intervention for hearing loss (National Institute for Health and Care Excellence, 2019), including for people living with dementia (Ray, Denning and Crosbie, 2019). Many people living with dementia are able to use hearing aids (Dawes et al., 2022) with benefits including increased quality of life (Atef et al., 2023), and improved cognitive function (Bisogno et al., 2021). However, people with dementia are less likely to use hearing aids consistently than people with intact cognition are (Naylor et al., 2022).

A recent systematic review of enablers and barriers to hearing aid use in dementia identified a range of factors that influence use (Hooper et al., 2022). These included the person's hearing aid handling skills, experiential consequences, aspects related to fit and comfort, social influences, and the demands of the listening environment. While this review goes some way to identifying influencing factors, none of the included studies addressed factors affecting hearing aid use as their primary research question. This may have restricted the range of influencing factors that were identified in the review and is a limitation of the existing evidence-base. Other factors that may influence hearing aid use could include challenges related to the impact of dementia, such as cognitive and functional difficulties (Lupsakko, Kautiainen and Sulkava, 2005) and socio-economic barriers to accessing hearing care services and hearing aids (Willink, Reed and Lin, 2019).

The objective of the present study was to use a theory-informed approach, based on the Theoretical Domains Framework (TDF) (Cane, Connor and Michie, 2012), to gain insight into factors that influence hearing aid use from the perspective of people with mild to moderate dementia and their care partners. This is the first primary research study to adopt a theory-informed approach to investigate this with this population. The TDF is a comprehensive framework that integrates multiple theories of behaviour change (Cane, Connor and Michie, 2012). Comprised of 14 domains of behavioural influence, the TDF links directly into the Behaviour Change Wheel (Michie, Atkins and West, 2014) and facilitates a 'behavioural diagnosis' of factors that influence the target behaviour. Michie and colleagues (2014) propose that this forms a key first step in the process of developing targeted, testable behaviour change interventions. This is relevant to the present study because the current evidence base is insufficient to understand factors that influence the behaviour of hearing aid use in dementia (Hooper et al., 2022). There is therefore a need for research to develop this understanding, prior to designing interventions that aim to address these influences to optimize hearing aid use in this population.

Methods

Sample

We enrolled a convenience sample of participants from the intervention arm of the European SENSE-Cog Randomized Controlled Trial, which evaluated the impact of an individualized sensory intervention for people with dementia on quality-of-life outcomes (Regan et al., 2019). To be eligible for inclusion in the parent study, participants had to be aged 60 or over, residing in the community, have a previously established clinical diagnosis of Alzheimer's, Vascular or mixed dementia, and have age-acquired hearing and / or vision loss. Dementia needed to be at the mild-moderate stage, quantified by a Montreal Cognitive Assessment (MoCA) score of at least 10 (Nasreddine et al., 2005). Hearing loss was defined by hearing worse than 35 dB HL at 1000Hz and above in the better ear, using the portable Siemens HearCheck™ device. Existing ownership of hearing aids did not preclude participation. Further detail is described elsewhere (Regan et al., 2019).

In the United Kingdom, recruitment to the parent study took place through the National Health Service and the Join Dementia Research registry (www.joindementiaresearch.nihr.ac.uk) from April 2018 to April 2021. Participants were recruited in dyads, comprising the person with dementia (PwD) and a care partner (CP). Participants were randomized to receive either a sensory intervention or care as usual. For participants with hearing loss, the sensory intervention comprised correction of their hearing through Starkey Muse i2400 behind-the-ear hearing aids and a multi-component program of home-based support delivered by a Sensory Support Therapist (SST). Although the intervention included hearing aid adherence support and training, no minimum requirement of hearing aid use was specified.

For the present study, we offered an invitation to participate in interviews to sequential UK-based participants with hearing loss and dementia in the intervention arm of the SENSE-Cog trial between the 18-week (intervention-end) and 36-week (trial-end) visits. All participants had provided written informed consent for inclusion at trial enrolment. Taking a process consent approach (Dewing, 2007), verbal consent for inclusion in the interviews was re-confirmed by the SST at the conclusion of their sensory intervention.

Interview procedure

We developed a semi-structured interview schedule based on TDF domain labels, definitions, and constructs (see Table 1). Members of the SENSE-Cog Research User Group, who were people with dementia and their care partners, (Miah et al., 2018) reviewed the proposed interview schedule, which we subsequently refined based on their feedback. We completed a pilot interview, and were

satisfied that the language within the schedule was understandable and relevant to our target population (Atkins et al., 2017). The interview schedule is included in the supplementary appendix.

Table 1. Qualitative interview schema – TDF domains and definitions (Cane et al., 2012) with example questions and responses

Domain	Definition	Example question	Exemplar response
Knowledge	An awareness of the existence of something	What advice or guidance have you been given about your hearing aids?	<p><i>CP: What we didn't know, was what we have found out through [SST] really, was that they need frequent cleaning and batteries need changing very frequently. I think you managed the batteries alright, but I don't think you ever cleaned those old ones.</i></p> <p><i>PwD: No. I don't think that I did</i></p> <p><i>CP: Nobody told you [that] you were supposed to.</i></p> <p><i>PwD: No (Dyad 2)</i></p>
Skills	An ability or proficiency acquired through practice	When it comes to using your hearing aids, what do you find easy (or hard)?	<i>PwD: Erm, there's nothing that I find difficult. Sometimes it's a bit fiddly changing the batteries – they're so tiny, aren't they? (PwD 5)</i>
Memory, Attention and Decision Processes	The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives	How do you remember to use your hearing aids?	<i>PwD: I won't forget to put them in because I'll miss something. And I don't like missing things (PwD 3)</i>
Behavioural Regulation	Anything aimed at managing or changing objectively observed or measured actions	What is your routine for hearing aid use?	<i>PwD: And the first thing I do when I get up is put them in ... so, that's just part of life of putting them in, except if I'm washing my hair or something else like that where I feel that water could hit the hearing aids (PwD 9)</i>
Social/Professional Role and Identity	A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting	How does wearing hearing aids make you feel about yourself?	<i>PwD: It's no good shouting and crying and, you know, playing heck. It's nobody's fault, because you start to think, 'why me'? And somebody said, 'why not'? You know, well somebody's got to be like that ... It's not a sin, nothing to be ashamed about. In fact, I'm well pleased with mine (PwD 1)</i>
Beliefs about Capabilities	Acceptance of the truth, reality, or validity about an ability, talent, or faculty that a person can put to constructive use	How confident are you about looking after and using your hearing aids yourself?	<p><i>PwD: Quite confident, quite confident.</i></p> <p><i>I: Okay. Is there any aspect of it that you still feel unsure about?</i></p> <p><i>PwD: No, no, no (PwD 6)</i></p>
Optimism	The confidence that things will happen for the best or that desired goals will be attained	When you found out that you needed hearing aids, what were your expectations of these?	<p><i>CP: Yes, of course, she was hoping the fact that she was going to get hearing aids would help her to be able to hear speak again and join in socially.</i></p> <p><i>I: Is that right, [PwD]?</i></p> <p><i>PwD: Oh, yes. Definitely (Dyad 7)</i></p>
Beliefs about Consequences	Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation	Are there any positive (or negative) effects of wearing hearing aids that makes you more (or less) likely to keep using them?	<i>PwD: I don't know really, this one is a better one I can hear better ... I can hear better. And I can hear people talking clearly (PwD 4)</i>
Intentions	A conscious decision to perform a behaviour or a resolve to act in a certain way	How much do you intend to use your hearing aids? What affects these intentions?	<i>PwD: It's necessary so I can hear all the time ... I mean there's no point taking them out because you never know when you're going to pick ... need to hear a conversation (PwD 6)</i>
Goals	Mental representations of outcomes or end states that an individual wants to achieve	What do you want to achieve by wearing hearing aids?	<i>PwD: Well so that, when people talk to me, I can hear them talking at an acceptable level, so in theory, I know how to reply ... on the one hand, I want to be able to hear what's going on, all the usual noises and things you can normally</i>

			<i>hear with normal hearing. I want to be able to hear that. And then when somebody speaks to me, I want to be able to hear what they're saying to me, and how to answer them (PwD 8)</i>
Reinforcement	Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus	In what ways is your hearing different with hearing aids?	<i>PwD: Ooh, hundred per cent better it is, I can hear the [grand]children talking to me, that's ... these two mean everything (PwD 10)</i>
Emotion	A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event	What positive or negative emotions does using hearing aids bring about in you?	<i>PwD: It feels better for me. 'Cause I know what's going on then and I can get on with it (PwD 11)</i>
Environmental Context and Resources	Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour	Is there anything about the environment around you that makes it easier (or harder) for you to use your hearing aids?	<i>PwD: I've got a little purse that I keep the hearing aids in ... it's in the kitchen ... it's got the batteries and the cleaning ... it's all in the same place on the kitchen windowsill (PwD 5)</i>
Social influences	Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours	Does someone else help you to manage your hearing aids? What is it like for you to have this support?	<i>PwD: Yes. If I said 'oh, I'm not', he'd [husband] say 'yes you are, won't take you a minute' I: And do you sometimes feel like a bit like 'oh I don't want to wear them'? PwD: Exactly you know. And it doesn't spoil your clothes, or how you are, because you know I've got short hair, so there nothing ... I don't not wear them because of that reason, it's just that I forget (PwD 1)</i>

In qualitative research, the credibility of the report rests on the voices of the participants being revealed (Denzin and Lincoln, 2018). When interviewing people who are living with dementia, this can present challenges because responses may be short or difficult to interpret due to verbal communication difficulties. We therefore adopted guidance for interviewing people living with dementia (Murphy et al., 2015) alongside additional consideration about managing the sensory needs of this particular participant group.

We conducted the interviews with the participating dyad together so that the person with dementia was supported to recall their personal experiences, facilitating triangulation of data within the interview and enhancing credibility of the data (Knudsen et al., 2012). Adopting a dyadic approach to interviews in dementia research is not uncommon (Samsi and Manthorpe, 2020). As the purpose of the present study was to evaluate enablers and barriers to hearing aid use in dementia, rather than to explore relational aspects of dyadic hearing aid management, the role of the care partner within the interview was predominantly as a supporting and confirmatory respondent. We therefore directed

questions to the person with dementia first before inviting their care partner to share their experiences. We endeavoured to ensure that the participant with dementia had heard and understood the questions through repeating, rephrasing, and inviting the care partner to reframe questions where necessary.

The first author undertook the interviews. She is an occupational therapist and postgraduate researcher with experience of dementia and in-depth knowledge of the parent trial. The remaining authors are from psychology, psychiatry, and audiology backgrounds, with a range of expertise including behaviour change theory.

The authors had not met with any of the participants prior to the interviews. Each participant was interviewed once between March 2020 and September 2021. Interviews were conducted face-to-face (n=6) or remotely, via telephone (n=2) or video conferencing (n=3), according to national COVID guidelines at the time of the interviews. Mean interview duration was 61 minutes (range 26-89 minutes).

Analysis

Interviews were audio-recorded, transcribed verbatim and anonymized. Field notes were made following each interview. The account from each dyad was considered a distinct unit and the data were analysed accordingly. Informed by guidance for conducting qualitative TDF-based research (Atkins et al., 2017), we approached the data analysis in two phases. Firstly, we used the TDF as a framework for deductive content analysis. For this, the first author and another researcher independently coded the transcripts of three interviews into TDF domains. The percentage agreement between the two coders was 84%, which was above the 60% threshold of acceptability outlined by Atkins et al. (2017). The first author then coded the remaining interviews independently. In the second phase, we completed an inductive analysis of the mapped data to generate themes for responses with similar underlying ideas that related to the target behaviour of hearing aid use. Throughout this process an expert in the TDF provided input when necessary. We did not return transcripts to participants for comment or feedback. However, we sent a summary of the findings to the participants following completion of the analysis.

Results

Eleven of the 18 eligible participant dyads agreed to participate. Reasons for non-participation were recorded and included personal decision of the person with dementia or care partner, gatekeeper decision of the SST, and ill-health. We present characteristics of the participants with dementia and their care partners in Table 2. The median age of the participants with dementia was 80 (range 72-89) years. For the care partners this was 73 (range 42-89) years. Of the participants with dementia, the

majority (n=9) were diagnosed with Alzheimer’s disease, with vascular and mixed dementia also represented. Eight of the participants were established hearing aid users, with three receiving hearing aids for the first time through the parent study. The majority (n=10) reported that they used their hearing aids for over 8 hours a day; the remaining participant (PwD 4) wore theirs 4-8 hours a day. The majority (n=9) lived with either their spouse or another family member, with two living alone.

Table 2. Participant characteristics (Person with Dementia and Care Partner)

Dyad	Participant with dementia (PwD)				Care partner		
	Gender	Cognitive score ^a (Impairment category ^b)	Hearing loss ^c (Category ^d)	Perceived impact of hearing loss ^e	Prior hearing aid user (duration)	Gender	Relationship to PwD
1	F	12 (Moderate)	30 (Mild)	None	N (N/A)	M	Spouse
2	M	17 (Moderate)	45 (Moderate)	Significant	Y (5 years)	F	Spouse
3	F	17 (Moderate)	48.75 (Moderate)	None	N (N/A)	M	Son
4	F	15 (Moderate)	42.5 (Moderate)	Mild-moderate	Y (10 years)	F	Daughter
5	M	23 (Mild)	32.5 (Mild)	None	N (N/A)	F	Spouse
6	M	26 (Mild)	37.5 (Moderate)	Significant	Y (9 years)	F	Spouse
7	F	11 (Moderate)	46.25 (Moderate)	None	Y (2 years)	M	Spouse
8	M	17 (Moderate)	86.25 (Profound)	Significant	Y (15 years)	F	Spouse
9	F	23 (Mild)	50 (Moderately severe)	Mild-moderate	Y (17 years)	M	Friend
10	F	20 (Mild)	63.75 (Moderately severe)	Significant	Y (14 years)	F	Granddaughter
11	M	16 (Moderate)	62.5 (Moderately severe)	None	Y (30 years)	F	Spouse

^a Ascertained via the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005) at parent study enrolment

^b Score of ≥ 18 classified as mild impairment; score of ≥ 10 classified as moderate impairment

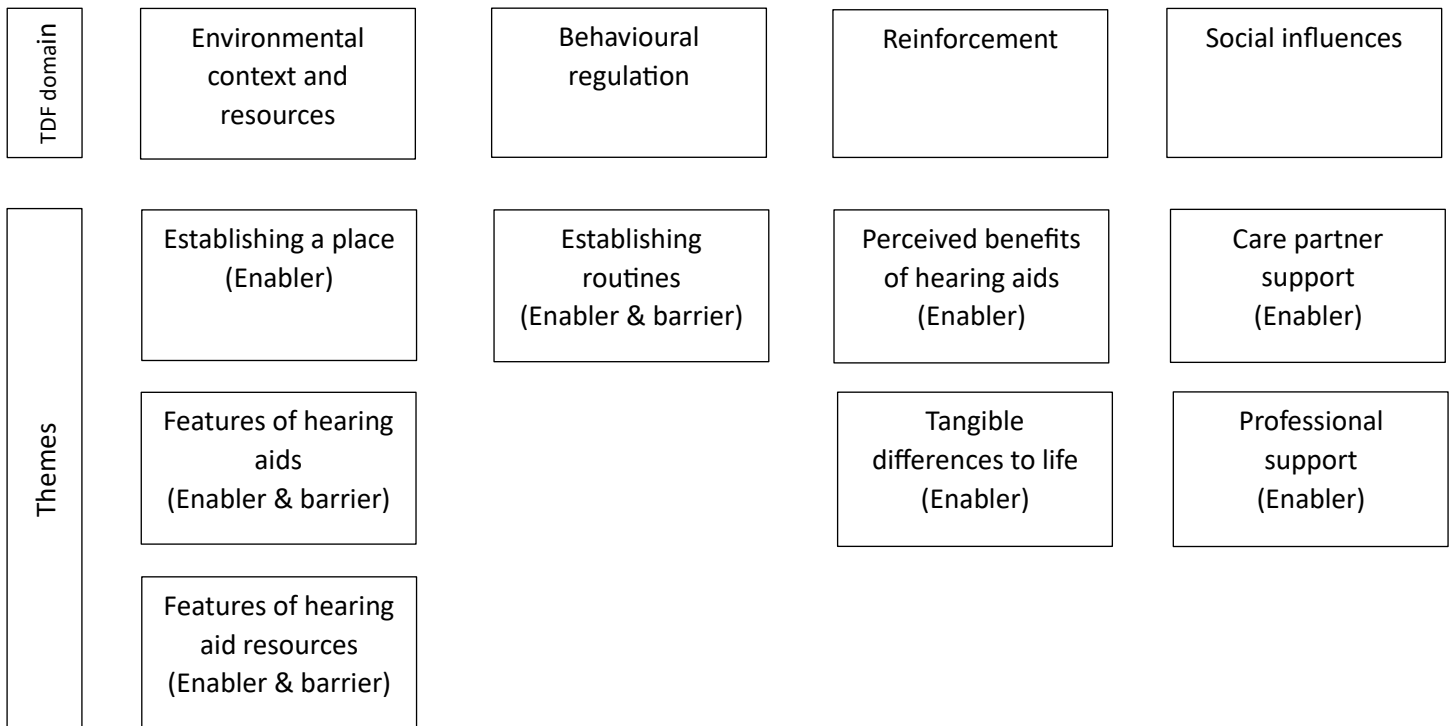
^c Better Ear Average dBHL over 0.5, 1, 2, 4KHz

^d World Health Organization hearing-impairment grading system (Humes, 2019)

^e Categorized from Hearing Handicap Inventory for the Elderly (Ventry and Weinstein, 1982) total scores as follows: 0-16 = no perceived impact; 18-42 = mild to moderate perceived impact; > 42 = significant perceived impact

Data mapped into all the TDF domains. The domains that featured most prominently in the data were ‘environmental context and resources’, ‘behavioural regulation’, ‘reinforcement’, and ‘social influences’. The themes that we identified within these domains are presented in Figure 1.

Figure 1. Enablers and barriers to hearing aid use in people living with dementia



Domain 1: Environmental context and resources

Three themes were generated in the domain *environmental context and resources*, representing both enablers and barriers to hearing aid use.

Establishing a place (enabler)

Participants described the benefit of establishing a set place to keep their hearing aids and to care for them. This helped them to keep track of their hearing aids and the resources that they needed to keep them in working order.

I have them in a little box ... the hearing aid case, batteries, cleaning (PwD 9)

Although participants predominantly described the establishment of a place for storing hearing aids as a successful strategy, some identified occasional difficulties with misplacement.

The majority of the time she puts them in the box, although sometimes we'll have to go searching the next day for them (CP 4)

Typically, participants reported that routinely using a solid surface, such as a specific table, during maintenance tasks such as cleaning the aids was beneficial. They also described the benefit of optimizing the environmental conditions during these tasks, including ensuring that lighting was adequate or using coloured card to enhance contrast.

When [the SST] was here, she gave us a couple of cards ... You put the card on the table, and you put your hearing aid on top of the card so you can distinguish where the hearing aid is from everything else (CP 7)

Features of hearing aids (enabler and barrier)

This theme relates to visual, auditory, or physical features of the hearing aids. These represented both enablers and barriers to their use.

Participants used cues from the hearing aids themselves to help keep them in working order and use them effectively. Visual cues related to coloured markings on the aids helped the participants to distinguish between their hearing aids. Auditory cues related to recognizing when the batteries needed to be changed or checking that the hearing aids were working.

You check they're working when you just tap them a bit ... just tap it like that and a bit of a song comes on. So, I thought, oh entertainment here! (PwD 1)

Participants who were established hearing aid users spoke of differences between hearing aids. The quality of the sound, auditory comfort related to less whistling, and simplicity of use seemed to be of importance, and in some cases influenced hearing aid use. Of these features, the quality of sound was identified as being the most important aspect by some participants.

The other hearing aids were simple because you didn't have to clean them as much as these ... I prefer these now 'cause they're better, well, they're not only a better quality, you're getting a better sound ... You can put up with [fiddly bits] because you're getting a better-quality sound (PwD 11)

Some participants found certain features of their hearing aids to be suboptimal, however. This related to aspects of size, fit, or volume (reported by some participants with more severe hearing loss). This led to frustration in a few, affected use in others, and sometimes led to increased dependence upon support. The content of this theme was predominantly generated from established hearing aid users.

On the one hand, the bigger ones were easier for her to handle ... and she used to clean the others, pull them apart and clean them herself whereas these she can't (CP 4)

Features of hearing aid resources (enabler and barrier)

Participants described ways in which having access to maintenance resources, including batteries and cleaning tools, helped them to keep their hearing aids in working order. However, some participants reported that aspects of handling these resources were difficult for them. For example, removing the labels from batteries and managing the size of batteries was problematic for some, leading to increased dependence on support or provoking feelings of frustration.

You know, I get the batteries and they have a little stick-on label on them. I find it difficult enough first of all trying to pick it up. They are so small. And then getting the label off, the label doesn't come off easily, you know, so that can be a bit of a problem (PwD 2)

As these relate to the nature of the resources themselves, such as size or packaging, we mapped these here rather than to the skills domain of the TDF.

Domain 2: Behavioural regulation

One theme was generated within this domain, representing an enabling factor for hearing aid use.

Establishing routines (enabler)

Participants described how the routines that they had established for the care and wear of hearing aids supported their use. In relation to hearing aid care, they described their routines for changing batteries and cleaning their aids. Most participants changed both batteries at the same time, in response either to an auditory cue or on a set day of the week. In the latter case, the auditory cue was unnecessary due to the routine that had been established. If participants had a set day for changing their batteries, they generally combined this with other hearing aid maintenance tasks.

I clean them on a Sunday, once a week ... usually my batteries run out on a Sunday, so while I'm changing my batteries, I usually get all the cleaning stuff and clean them at the same time, so it saves me a lot of hassle. (PwD 11)

For some of the participants, including a few established hearing aid users, the development of these routines arose from the sensory intervention that they had received. For others it was well established and automatic. Most of the established hearing aid users did not feel that the onset of dementia had affected their hearing aid care routines. Some, however, reflected that they were more intentional about certain aspects of their routines now.

When I take them off at night, I put them in very ... carefully, so it doesn't turn round, and I bring it out very carefully. So, they're formed right for the correct ear, you see? (PwD 6)

In relation to hearing aid wear, participants had predominantly established routines of wearing their hearing aids from morning until evening. They described this as being part of their daily routines, and typically linked with other self-care routines.

It's part and parcel of getting dressed ... Give them a polish, get them in, give them a – well, when they come out, they get a wipe, but they still get another one when they're going back in (PwD 3)

Domain 3: Reinforcement

Two themes were generated in the domain *reinforcement*. These both described enablers for hearing aid use.

Perceived benefits of hearing aids (enabler)

Participants reported finding hearing aids to be beneficial. The language that they used in relation to this ranged from expressing that the positives outweighed the negatives, to using emotive language that indicated they find them to be essential.

If I took them out, I'd be dead without it ... They're the best thing that ever happened to me, you know (PwD 10)

The sentiment that life was better with hearing aids was the case even for participants who had expressed dissatisfaction with aspects of their aids. It was evident that this was a motivating factor for these participants to persevere with hearing aid use.

I mean, they're a long way better than nothing really (PwD 8)

Tangible differences to life (enabler)

Participants relayed the way hearing aids made a tangible difference within many aspects of their life, including their ability to engage in leisure activities such as watching the television, or feeling more connected to the external environment such as increased traffic awareness or hearing the birds singing.

I can hear the birds singing outside, so that's the main thing ... and hear the cat when he cries at the door (PwD 4)

The most frequently reported difference related to connection with other people. Participants with dementia and their care partners spoke of the way in which they not only found communication to be easier with hearing aids, but also of increased participation and confidence as an outcome of hearing aid use.

Since I've got these, they've been marvellous and I can have a proper conversation, you know? [Before] I was saying 'yes' when I should have said 'no' and different things ... [Now] I don't hold myself back ... when I used to think 'I'll say this and say that', well I thought, 'well it's not important, I'll not bother saying'. But now I say everything to 'em (PwD 10)

Some of the participants with dementia indicated that when hearing is clearer, and communication is less effortful, that it supported their cognition. They portrayed this as a motivating factor for using hearing aids.

Hearing is important, then you can hear - formulate it. But if you're not getting a good hearing then it will affect your memory even more because you can't put the sentence together. When I can hear clearly, like now, I can understand what people are saying better (PwD 6)

Domain 4: Social influences

Two themes were generated in the domain *social influences*, comprising enablers and barriers to hearing aid use.

Care partner support (enabler)

Most of the care partners within the study reported ways in which they supported hearing aid use. This ranged from offering light-touch verbal prompting to providing full assistance with donning the aids and attending to maintenance tasks such as changing batteries and cleaning the hearing aid tubing.

Sometimes, maybe he's not pushed the tube far enough in his ear, so in that case it's not really working, is it? So, I will say 'you've not pushed that far enough down', so he will then sort of fiddle and push it down (CP 5)

There were three participants that were fully reliant upon assistance with donning their hearing aids, and receiving care partner support made it possible for them to use them. These participants had moderate dementia and two were new hearing aid users, although for one new and one established hearing aid user their dependence was, in part, due to difficulties with manual dexterity from arthritis.

She'd [PwD] never wear hearing aids if I didn't get them out and put them in for her. She struggles to put them in. She has arthritis (CP1)

The participants with dementia generally expressed that they were accepting and appreciative of this support, although some were motivated to retain as much independence as possible in the tasks surrounding hearing aid use to reduce burden on their partners.

My dear wife works hard enough. You know, she's always doing something and, if I can do it myself, it's, you know, takes something off her (PwD 2)

Professional support (barrier and enabler)

All participants had received a sensory support intervention through the parent study. Participants described how the nature of this support was an important factor in enabling successful hearing aid

use, including established hearing aid users. Key aspects related to aiding the development of skills, building routines around hearing aid use, and timely troubleshooting of any problems.

But [SST] ... used to talk about it like you're talking about it and any problems, you know, iron them out. And she used to send me sheets through the post, and that, to fill in, you know, these worksheets, and things. So, yeah, it's been very helpful ... they've got me ... into a routine, you see? (PWD 6)

The perceived accessibility and responsiveness of professional support was also important. This became a barrier when participants' expectations were not met, leading to disappointment, frustration, or lack of trust in services. This aspect was only raised by established hearing aid users.

That's the thing that upsets her [PWD] more than anything because ... her left ear is a problem because it keeps falling out ... so the hearing people suggested that we had these moulds made they said that that would be a lot better for us. So we've had the moulds made and the moulds have come but when the lady came to fit them, she hadn't got the right pieces to piece them together with the hearing aid that fits at the back of the ear ... it was a big disappointment and the fact that it was over two weeks ago is a bigger disappointment because we're still struggling with the ones that we've got now (CP 7)

Discussion

This qualitative research used a theory-informed approach to explore influences on hearing aid use in a sample of people with dementia and their care partners that had received hearing aids and a sensory intervention aimed at supporting their use. To the best of our knowledge, this is the first study of its kind to adopt a theory-informed approach to explore this, and we suggest that the findings represent a best-case scenario due to the enhanced support that the participants received. In relation to a 'behavioural diagnosis' (Michie, Atkins and West, 2014), our findings suggest that the TDF domains *environmental context and resources*, *behavioural regulation*, *reinforcement*, and *social influences* are of greatest relevance to hearing aid use in dementia. Within these domains, we identified a range of factors that may influence the target behaviour of hearing aid use. There were some differences according to whether the participants were new or experienced hearing aid users, and minor differences in relation to severity of hearing loss and cognitive impairment. However, no clear influences were noted regarding self-perceived impact of hearing loss.

Several of our findings align with previous research with this population. The establishment of routines to minimize the risk of misplacing hearing aids, the motivating impact of experiencing positive outcomes, and the importance of care partner support have previously been identified as enablers (Gregory et al., 2020; Hooper et al., 2022). Likewise, difficulties with handling of aids or resources and difficulties with fit have been reported as barriers in previous research (Hooper et al., 2022). This strengthens the credibility of the existing evidence-base.

Several novel findings within our study extend understanding. Our finding that optimizing environmental conditions such as lighting and contrast during hearing aid maintenance tasks acts as an enabler is novel. This may be of particular relevance to this population due to the impact of dementia on visuospatial function (Rizzo et al., 2000), and aligns with environmental modification approaches to enhance functioning in dementia (Woodbridge et al., 2018). Furthermore, the motivation to retain active roles in the care and use of hearing aids within the framework of care partner support, and the minimal impact that the onset of dementia had on previously established hearing aid care and use routines, have not been reported in previous research. These findings highlight the importance of support being person-centred with this population, aligning with practice recommendations (Dawes et al., 2022; Littlejohn et al., 2022).

Our findings suggest that several key *intervention functions* (Michie, Atkins and West, 2014) may be relevant for hearing care professionals and others supporting people with dementia and hearing loss. First, interventions should develop the person with dementia's routines for hearing aid care and wear, optimizing environmental conditions such as lighting and contrast during maintenance tasks. This is a *training* intervention approach that includes *environmental restructuring* (Michie, Atkins and West, 2014).

Second, the type of hearing aid should optimize hearing ability and include dementia-friendly features that support use, such as a clear battery-warning alert and visual prompts to aid differentiation between left and right aids. The hearing aids and associated resources should also be suitable for the person to handle. In this regard, offering trials of differing hearing aids may be advantageous (Dawes et al., 2022). This is an *enablement* intervention approach (Michie, Atkins and West, 2014).

Third, an *incentivization* intervention approach (Michie, Atkins and West, 2014) could enable people with dementia to recognize positive consequences of hearing aid use, fostering motivation for their use. In this regard, receiving ongoing reminders about tangible ways in which hearing aids enable communication and connection with other people may be beneficial. This may be particularly relevant for this population as hearing aid use in dementia has been shown to reduce over time (Powell et al., 2023).

Fourth, hearing care professionals should also work in partnership with care partners to build their skills and understanding in supporting the person with dementia's hearing aid use. This is an *education* intervention approach that would aim to foster *enablement* within the care partner – care recipient relationship (Michie, Atkins and West, 2014), and may be particularly important for first-time hearing aid users with dementia.

Lastly, follow-up should be available and responsive to needs as they arise to troubleshoot difficulties and maintain motivation for continued use. This *service provision* (Michie, Atkins and West, 2014) aspect presents a challenge because research suggests that a lack of time and resources impacts negatively on hearing care professionals' potential to support people with dementia who have more complex needs (Wright et al., 2014). In light of this, developing pathways for dementia-specific hearing clinics, such as the clinic outlined in NHS England's guide for hearing loss and healthy ageing, (NHS England, 2017) may be beneficial.

Strengths

This study has built upon the emerging understanding that exists regarding enablers and barriers to hearing aid use in dementia, drawing this together within the theoretical framework of the TDF. We consider that the implementation of this framework is a strength of this study. Furthermore, use of the TDF has enabled a 'behavioural diagnosis' (Michie, Atkins and West, 2014) of factors that influence hearing aid use in dementia, and structured consideration of intervention functions to address these influences.

Limitations

The participants within this study were a convenience sample drawn from a parent research trial. Participants in dementia research are generally younger, more highly educated, healthier and from a majority ethnic background than the wider population with dementia (Cooper, Ketley and Livingston, 2014), influencing the applicability of results. Furthermore, in our study all the participants had received new hearing aids and an intervention that was designed to foster hearing aid use, they were all actively using their hearing aids, and all had a care partner that was actively involved in the research intervention. These factors may have positively influenced the target behaviour of hearing aid use in our sample. Therefore, whilst this study has generated understanding of influencing factors for hearing aid use in dementia, it has not investigated how enablers and barriers to hearing aid use might differ for people with dementia who reject hearing aids, access standard audiology pathways, do not have care partner support, or have a greater severity of cognitive impairment. We suggest that our findings should be considered reflective of the best possible scenario.

Additionally, although the researchers adjusted their approach to optimize participation, it was more challenging to maintain effective communication with the participants with dementia in the five interviews that were conducted remotely due to national COVID restrictions. These interviews were shorter overall (mean duration 51 minutes, compared with a mean of 69 minutes for the face-to-face interviews) and the proportion of responses made by care partners was greater, suggesting that

the method of data collection influenced the quality of interaction. This is a known limitation of remote interviewing (Davies et al., 2020).

Future research

Michie et al. (2014) highlight that, through collecting and triangulating data about a target behaviour from multiple sources, a stronger understanding of influencing factors emerges. Whilst the present study has started to build on an existing, fragmented, evidence base, confidence would increase by researching influencing factors on hearing aid use in dementia from an increased variety of methods, including through quantitative investigation of a larger population group. Additionally, we have suggested intervention functions that may support hearing aid use in this population. Further research to develop and evaluate interventions that adopt these functions is warranted.

Conclusions and Implications

Our study has developed understanding of factors that influence the behaviour of hearing aid use in people living with mild-moderate dementia and age-acquired hearing loss. To the best of our knowledge, this is the first primary research study that has used a theory-informed approach to investigate this. Our findings suggest that hearing aid use in dementia is enabled through (i) establishment of routines that support hearing aid wear and care; (ii) provision of hearing aids that optimize hearing ability with features and resources that facilitate their use; (iii) experiencing benefits in daily life; and (iv) provision of formal and informal support that is responsive to the person with dementia's abilities. Our findings suggest that hearing aid use in dementia is hindered if the person has difficulty with aspects of either their hearing aids or maintenance resources, especially if support to troubleshoot these difficulties is not timely or responsive. We have suggested a variety of intervention functions that may support hearing aid use in dementia from our findings, which would benefit from further research to establish their efficacy.

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Chapter four:

What are the correlates of hearing aid use for people living with dementia?

The research presented within this chapter addresses some limitations of the research that is presented in chapters two and three. Whilst the qualitative exploration of enablers and barriers to hearing aid use that was presented in chapter three extends understanding and addresses some of the limitations within the evidence-base that were identified in the systematic review, the participants were all using their hearing aids and were in the unique position to have received hearing aids and an intervention aimed at supporting their use through the SENSE-Cog trial. Although the aim of qualitative research is to generate understanding rather than generalisable findings (Fossey et al., 2002), the uniqueness of the sample in chapter three was not necessarily representative of the SENSE-Cog participant pool, let alone the wider population with dementia.

This chapter includes a quantitative evaluation of correlates of hearing aid use in dementia. The data for this study were taken from the baseline sample of 239 participants enrolled onto the SENSE-Cog trial that screened positively for hearing loss. It has been published in the *Journal of Aging and Health*:

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What are the correlates of hearing aid use for people living with dementia?

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Running headline: Correlates of hearing aid use in dementia

Abstract

Objectives: To identify correlates of hearing aid use in people with dementia and age-related hearing loss.

Methods: Bivariate and multivariate logistic regression analyses of predictor variables from 239 participants with dementia and hearing loss in the European SENSE-Cog Randomised Controlled Trial (Cyprus, England, France, Greece, and Ireland).

Results: In multivariate analysis, four variables were significantly associated with hearing aid use: greater self-perceived hearing difficulties (OR 2.61 [CI 1.04-6.55]), lower hearing acuity (OR .39 [CI .2-.56]), higher cognitive ability (OR 1.19 [CI 1.08-1.31]), and country of residence. Participants in England had significantly increased odds of use compared to Cyprus (OR .36 [CI .14-.96]), France (OR .12 [CI .04-.34]) or Ireland (OR .05 [CI .01-.56]) but not Greece (OR 1.13 [CI .42–3.00]).

Conclusions: Adapting interventions to account for cognitive ability, country of residence, self-perceived hearing difficulties and hearing acuity may support hearing aid use in people with dementia.

Key words: Hearing aid, Dementia, Correlates

Introduction and background context

Hearing loss and dementia both increase in prevalence with age (Quaranta et al., 2015; Alzheimer's Association, 2020). Both hearing loss and dementia are within the top ten causes of disability-related burden globally for people aged 75 and over (Vos et al., 2020). There is also high comorbidity between the two conditions: the prevalence of hearing loss is at least 60% in people with dementia or cognitive impairment that live in the community (Nirmalasari et al., 2017), and it has been suggested that hearing loss may be a risk factor for developing dementia (Loughrey et al., 2018; Brewster et al., 2022).

Hearing aids are the primary means of managing hearing loss among people with or without dementia (Ray, Denning and Crosbie, 2019; Dawes et al., 2022). Among people living with dementia and hearing loss, hearing aid use may increase their quality of life, mental health, and communication (Mamo et al., 2018; Atef et al., 2023). However, people with dementia or cognitive impairment are less likely to use hearing aids than people without dementia (Lupsakko, Kautiainen and Sulkava, 2005; Fisher et al., 2015; Naylor et al., 2022; Powell et al., 2023). Lower levels of hearing aid use in people with dementia are likely due to both lower levels of uptake (Nirmalasari et al., 2017) and lower levels of sustained hearing aid use among those who obtain them (Allen et al., 2003; Naylor et al., 2022; Powell et al., 2023), highlighting a need to better understand, and then address, the factors that influence uptake and use in this population. One of the reasons that hearing aid uptake may be lower in people with dementia is because hearing loss may not always be recognized, or may be mistaken for symptoms of dementia (Hopper and Hinton, 2012; Pichora-Fuller et al., 2013) leading to lower referral rates. People with dementia may also be less likely to recognize and act on hearing problems (Batchy et al., 2011).

A recent systematic review reported that many of the correlates of hearing aid use in the general population also pertain to hearing aid use among people with dementia (Hooper et al., 2022). For instance, as with the general population (McCormack and Fortnum, 2013; Hickson et al., 2014; Ng and Loke, 2015; Knoetze et al., 2023), proficiency in handling hearing aids; experiencing positive consequences; the degree of hearing aid comfort or fit; the perceived demands of the listening situations; and receiving prompts or encouragement from others are all associated with hearing aid use among people with dementia (Hooper et al., 2022). Other research suggests that economic factors such as income-to-poverty ratio and level of health insurance may have an additive influence on hearing aid use in people with dementia compared to those without dementia (Powell et al., 2023), and that severity of hearing loss is associated with hearing aid use in people with dementia (Nirmalasari et al., 2017; Kim et al., 2021), as in the general population (Knoetze et al., 2023).

Research in the general population suggests that age and gender are associated with hearing aid use, with a trend towards people of older age and male gender being more likely to adopt hearing aids (Knoetze et al., 2023). However, the effects of these demographic factors on hearing aid use in people with dementia are not known.

The main limitation with previous research identified by Hooper et al. (2022) was that there has been little research that has investigated correlates of hearing aid use in people with dementia, which limits understanding of factors that influence use. Furthermore, no studies to date have attempted to determine the relative importance of a range of factors associated with hearing aid use in people with dementia. Understanding this could inform the development of interventions to promote hearing aid use and improve hearing-related quality of life. For the present study, we therefore investigated correlates of hearing aid use in a cross-sectional sample of community-residing people with dementia and hearing loss.

Methods

Participants

This study utilised screening and baseline data from the European SENSE-Cog Randomised Controlled Trial of a sensory intervention for people with dementia and hearing and/or vision loss on quality-of-life outcomes (Regan et al., 2019). Participants of the SENSE-Cog trial were enrolled between April 2018 and April 2021 across five European sites (Cyprus, England, France, Greece, and Ireland). All met the following inclusion criteria: Aged ≥ 60 years old; clinically diagnosed with dementia (Alzheimer's disease, Vascular dementia or mixed dementia), in the mild-moderate stage, as indicated by a MoCA score of ≥ 10 (Nasreddine et al., 2005); had adult-acquired hearing and / or vision impairment (hearing impairment was defined as bilateral hearing acuity worse than 35dBHL at 1000Hz and above in the better ear); residing in the community; and had a study partner. Study partners were family members or close friends of the person with dementia, aged over 18 years, in regular contact with the participant, and willing to participate in the study. Site-specific ethical approval was in place for the trial, in accordance with the individual requirements of each country. Further details are available in Regan et al. (2019).

The sample for the present study was a pre-randomisation subset of 239 participants with a diagnosis of dementia who met the eligibility criteria for inclusion in the main trial and screened positively for hearing loss at trial enrolment. This sample size was sufficient to test the fit of our regression model for an expected medium effect size (Field, 2018).

Study design

We performed secondary analysis of cross-sectional data to evaluate potential correlates of hearing aid use in people with dementia. The data were collected during pre-randomisation home visits by research assistants who were trained in the administration of the measures.

Theoretical framework

We organized our data according to the Capabilities, Opportunities and Motivations model of Behaviour change (COM-B) (Michie, van Stralen and West, 2011; Michie, Atkins and West, 2014). The COM-B model suggests that behaviour (B) - in this case hearing aid use - is generated from interactions between the components capability (C), opportunity (O), and motivation (M). In accordance with Michie et al. (2011), capability denotes the person's physical or psychological capacity to enact the behaviour. Opportunity represents external factors that enable or prompt the behaviour within the physical (environmental) or social (cultural) setting. Motivation refers to reflective and automatic processes that direct a person's behaviour. Analysis of influences on hearing aid use according to the framework of the COM-B model facilitates a 'behavioural diagnosis' of what needs to change for the target behaviour to occur (Michie, Atkins and West, 2014). We considered that use of this model would help to generate understanding to inform intervention design. Predictor variables that did not map to the COM-B model were included as control variables.

Outcome variable (behaviour)

Hearing aid use

The outcome variable was hearing aid use, ascertained by responses of the study partner to the question 'Does the person currently use a hearing aid?' (Yes / No)

Predictor variables (capability, opportunity, motivation, control)

Capability: Cognitive ability, vision impairment, health status, and functional dependence

Cognitive ability was determined by the total score achieved on the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005). The MoCA is a clinician- / researcher-administered 30-point cognitive screening tool with high sensitivity and specificity. Higher scores denote better cognitive ability.

Vision impairment was ascertained through the PEEK acuity app

(https://peekvision.org/en_GB/peek-solutions/peek-acuity/). This is a researcher-administered validated Android smartphone-based test that provides a measure of distance visual acuity (Bastawrous et al., 2015). We categorised participants with scores ≥ 0.2 LogMAR as visually impaired, and those with scores < 0.2 LogMAR as not visually impaired (Regan et al., 2019).

Health status was evaluated by the study partner's response to the question, 'In general, would [person with dementia's name] say his/her health is excellent, very good, good, fair, or poor?' This question is taken from the proxy 12-item Short Form survey (SF-12) (Ware, Kosinski and Keller, 1996), which is a valid and reliable measure of health-related quality of life (Huo et al., 2018).

Functional dependence was measured by the Bristol Activities of Daily Living Scale (BADLS) (Bucks et al., 1996), which was completed by the study partner. The BADLS evaluates the person with dementia's level of function across 20 activities of daily living (ADLs). We categorised scores of 0-14 as lower dependence and scores of 15-60 as higher dependence, using a categorisation reported in previous research (Leroi et al., 2024).

Opportunity: Living situation, country of residence, and access to subsidised hearing aid provision

Living situation was dichotomised as living with someone versus living alone. Country of residence was categorised according to which of the five European trial sites the participant lived (Cyprus, England, France, Greece, Ireland). Access to subsidised hearing aid provision was categorised as low-medium or high-full subsidy for each country using information from the 'State of provision of hearing aids in Europe' report for England, France and Greece (EFHOH, 2022), publicly available information for Ireland ([Hearing aids - HSE.ie](https://www.hse.ie/eng/health/earandhearing/hearing_aids.htm)), and information from an audiologist in Cyprus (Thodi, 2023). Subsidy levels were lower (maximum €900 stereo subsidy) and / or subject to means testing in Cyprus, Greece, and Ireland. We therefore categorised these countries as low-medium subsidy. Subsidy levels were higher (€1900 stereo subsidy) or fully subsidised without means testing in England and France, and so we categorised these countries as high-full subsidy.

Motivation: Hearing acuity, self-perceived hearing difficulty, engagement in social activities, and depression

Hearing acuity was measured using the researcher-administered Siemens HearCheck™ Screener. This validated device screens hearing acuity at the 1kHz and 3kHz frequencies at decreasing fixed intensities (75, 55 and 35 dBHL at 3kHz and 55, 35 and 20 dBHL at 1kHz) (Parving et al., 2008) and has good sensitivity and specificity (Abes, Reyes-Quintos and Tantoco, 2011). The score represents the number of tones heard from a possible maximum of 6 tones. Higher numbers represent better hearing acuity. For our analysis we used the total better ear score.

Self-perceived hearing difficulty was evaluated by the researcher-administered Hearing Handicap Inventory for the Elderly (HHIE) (Ventry and Weinstein, 1982). This assesses self-perceived emotional and situational impact of hearing loss in older adults. Following comparison of self- and study partner-reported outcomes for the HHIE, the self-report from the person with dementia was

included in the analysis as this relates more closely into the motivation component of the COM-B model and was significantly correlated with the study partner score ($r(4) = .51, p < .001$). In alignment with previous studies (Kawata et al., 2021; Leroi et al., 2024), we categorised total scores of 0-16 as no or minimal perceived difficulty, 18-42 as mild to moderate perceived difficulty, and >42 as significant perceived difficulty.

Frequency of engagement in social activities was established from the person with dementia and their study partner's report of engagement in the following health and social care activities: cognitive rehabilitation, cognitive stimulation therapy, dementia café or memory café, music therapy, befriending service, exercise / mobility class, animal assisted therapy, day centre, lunch club, education group, other. We assigned a binary value of 1 (yes) if they participated in any of the listed activities at least monthly, or 0 (no) if they did not engage in any activities.

Depression was evaluated according to the Neuropsychiatric Inventory (NPI) (Cummings et al., 1994). This is a validated study partner-rated measure that assesses the presence, frequency, and severity of neuropsychiatric symptoms across ten different domains of behaviour. For our analysis we calculated a composite total from the frequency x severity scores of the depression domain. In alignment with previous studies (Zhang et al., 2012) we categorised composite scores of ≥ 4 as being indicative of clinically significant depression.

Control variables: Age and gender

Age (in years) was added as a continuous variable. Self-reported gender (man or woman) was added as a categorical variable.

Analysis

We undertook our analysis using IBM SPSS Version 29. Descriptive statistics were examined for dispersion and central tendencies. To determine which variables to include in a multivariate logistic regression model, we first evaluated associations between each predictor variable and hearing aid use through a series of bivariate logistic regression analyses. Using a significance level of $p \leq .05$, we identified the predictor variables that were independently associated with hearing aid use and included these in a multivariate logistic regression analysis model. We took this approach to guard against model instability due to the sample size and number of variables included (Stoltzfus, 2011).

Results

Participant characteristics

Table 1 shows the baseline characteristics of the participants (n=239) stratified by hearing aid use. The mean age of the sample was 79.8 years (SD 5.8), and 53% were women. Within the sample, 73

participants (30.5%) reported using a hearing aid. The median duration of hearing aid ownership was 60 months. Data were available for 68 (92%) of the hearing aid users in relation to their hearing aid acquisition and dementia diagnosis dates. Of these, the vast majority (n=62; 91%) had hearing aids prior to receiving their diagnosis of dementia.

Table 1. Characteristics of the sample

COM-B component	Variable	Total (n=239)	Used a hearing aid	
			No	Yes
Capability	Cognitive ability ^a , mean (SD)	16.7 (3.9)	16.2 (4.0)	17.8 (3.6)
	Vision impairment, n (%)			
	No impairment	146 (61)	104 (71)	42 (29)
	Impairment	93 (39)	62 (67)	31 (33)
	General health, n (%)			
	Excellent	13 (5)	12 (92)	1 (8)
	Very good	53 (22)	35 (66)	18 (34)
	Good	100 (42)	73 (73)	27 (27)
	Fair	63 (26)	41 (65)	22 (35)
	Poor	10 (4)	5 (50)	5 (50)
	Functional dependence, n (%)			
	Lower dependence	169 (71)	114 (68)	55 (33)
	Higher dependence	69 (29)	52 (75)	17 (25)
Opportunity	Living situation, n (%)			
	With someone	180 (75)	128 (71)	52 (29)
	Alone	59 (25)	38 (64)	21 (36)
	Country of residence, n (%)			
	England	86 (36)	45 (52)	41 (48)
	Greece	28 (12)	17 (61)	11 (39)
	Cyprus	32 (13)	20 (63)	12 (38)
	France	54 (23)	47 (87)	7 (13)
	Ireland	39 (16)	37 (95)	2 (5)
	Level of hearing aid subsidy, n (%)			
	Low-medium	99 (41)	74 (75)	25 (25)
	High-full	140 (59)	92 (66)	48 (34)
	Motivation	Hearing acuity ^b , mean (SD)	3.2 (1.2)	3.5 (1.2)
Self-perceived hearing difficulty, n (%)				
None or minimal		156 (65)	120 (77)	36 (23)
	Mild to moderate	46 (19)	29 (63)	17 (37)

	Significant	37 (16)	17 (46)	20 (54)
	Engagement in social activities, n (%)			
	None or less than monthly	186 (78)	130 (70)	56 (30)
	At least monthly	53 (22)	36 (68)	17 (32)
	Clinically significant depression, n (%)			
	No depression	195 (86)	136 (70)	59 (30)
	Depression	32 (14)	20 (63)	12 (38)
Control	Age, mean (SD)	79.8 (5.8)	79.6 (5.8)	80.2 (5.7)
	Gender, n (%)			
	Man	113 (47)	73 (65)	40 (35)
	Woman	126 (53)	93 (74)	33 (26)

^a MoCA total score; ^b HearCheck total score

Correlates of hearing aid use

The bivariate logistic regression analyses showed that cognitive ability, country of residence, hearing acuity and self-perceived hearing difficulty were independently associated with the likelihood of using a hearing aid (Table 2). Better cognitive ability was associated with an increased likelihood of hearing aid use, whilst better hearing was associated with reduced likelihood. Greater odds of hearing aid use were associated with living in England relative to France or Ireland, and in participants with significant self-perceived hearing difficulty relative to those with no or minimal perceived difficulty. The other variables were not significantly associated with hearing aid use, and so were not included in the multivariate analysis.

Table 2. Bivariate and multivariate associations with hearing aid use

		Bivariate analysis		Multivariate analysis	
COM-B component	Variable	Hearing aid use OR (95% CI)	p-value	Hearing aid use OR (95% CI)	p-value
Capability	Cognitive ability	1.11 (1.04, 1.20)	.004	1.19 (1.08, 1.31)	<.001
	Vision impairment	1.24 (.71, 2.17)	.46	-	-
	General health	1.28 (.95, 1.73)	.11	-	-
	Functional dependence	.68 (.36, 1.28)	.23	-	-
Opportunity	Living situation	1.36 (.73, 2.54)	.33	-	-
	Country of residence				
		England (ref)		<.001	<.001
		Greece	.71 (.30, 1.69)	.44	1.13 (.42, 3.00)
	Cyprus	.66 (.29, 1.51)	.33	.36 (.14, .96)	.04

	France	.16 (.07, .40)	<.001	.12 (.04, .34)	<.001
	Ireland	.06 (.01, .26)	<.001	.05 (.01, .27)	<.001
	Level of hearing aid subsidy	1.54 (.87, 2.74)	.14	-	-
Motivation	Hearing acuity	.54 (.42, .70)	<.001	.39 (.27, .56)	<.001
	Self-perceived hearing difficulty				
	No or minimal (ref)		.001		.046
	Mild to moderate	1.95 (.97, 3.96)	.06	2.24 (.98, 5.13)	.057
	Significant	3.92 (1.86, 8.27)	<.001	2.61 (1.04, 6.55)	.042
	Engagement in social activities	1.10 (.57, 2.11)	.78	-	-
	Depression	1.38 (.64, 3.01)	.41	-	-
Control	Age	1.02 (.97, 1.07)	.47	-	-
	Gender (F)	.65 (.37, 1.13)	.12	-	-

The multivariate logistic regression model was statistically significant: Chi squared (DF, n = 8) = 86.731, $p < .001$, explaining between 30% (Cox & Snell R square) and 43% (Nagelkerke R square) of the variance in the dependent variable, and correctly classifying 78.2% of cases.

In the multivariate logistic regression analysis, cognitive ability, country of residence, hearing acuity and self-perceived hearing difficulty remained significantly associated with the likelihood of hearing aid use. This represents one variable in each of the capability and opportunity components, and two variables in the motivation component of the COM-B model (Table 2).

Self-perceived hearing difficulty was the strongest correlate of hearing aid use. The odds of hearing aid use for participants with significant self-perceived difficulty were 72% greater than for those who reported no or minimal self-perceived difficulty (OR 2.61 [CI = 1.04 - 6.55]). There was no significant difference in odds of hearing aid use between those with mild-moderate and no or minimal self-perceived difficulty. For cognitive ability, the odds of hearing aid use were greater in participants with higher cognitive ability. Every unit increase in the MoCA assessment score was associated with an 19% increase in the odds of using a hearing aid (OR 1.19 [CI = 1.08 - 1.31]). For hearing acuity, the odds of hearing aid use decreased in participants with better hearing, corresponding to a 61% decrease in the odds of using a hearing aid with every ~20 dB improvement in hearing acuity (OR .39 [CI = .27 - .56]).

In relation to country of residence, the odds of hearing aid use were significantly lower for participants living in Cyprus, France, or Ireland relative to those living in England. Those living in

England had 72% increased odds of using a hearing aid compared to Cyprus (OR .36 [CI = .14 - .96]), 89% increased odds of using a hearing aid compared to France (OR .12 [CI = .04 - .34]), and 95% increased odds of hearing aid use compared to Ireland (OR .05 [CI = .01 - .56]). The odds of hearing aid use in Greece were not significantly different to those in England.

Discussion

This study investigated correlates of hearing aid use in a cross-section of community-residing people with dementia and hearing loss within the framework of the COM-B model. This is the first study of this nature to investigate multiple correlates concurrently, and thus to give an indication of their relative importance.

Capability and hearing aid use

Cognitive ability was the only variable within the capability component that was associated with hearing aid use. This adds to existing research that has shown a correlation between cognition and hearing impairment in a general population sample of people aged over 75 (Lupsakko, Kautiainen and Sulkava, 2005) by demonstrating that level of cognitive functioning is also associated with hearing aid use among people with clinically diagnosed dementia. Although investigation into explanatory causes for this was beyond the scope of the present research, lower levels of use in those with more advanced cognitive impairment could be influenced by functional decline associated with progression of dementia. Previous research has reported that deterioration in executive functioning (such as planning and executing actions) predicts impairment in ability to perform activities of daily living (Cipriani et al., 2020); thus, evaluation of the influence of executive functioning on hearing aid use could provide a starting point for further empirical investigation with this population.

Opportunity and hearing aid use

Within the opportunity component country of residence, but not level of hearing aid subsidy, was associated with hearing aid use. For example, participants in our study living in England had significantly higher odds of hearing aid use than those in France, despite both countries being classified as having a high level of hearing aid subsidy. A possible explanation for this is that access to fully subsidised hearing aids through the public National Health Service has been long-established in England, whereas in France the level of reimbursement increased markedly during the recruitment period for our study under the French government's '100% Sante' reforms, now covering the full cost of basic hearing aids (Légifrance, 2019; EFHOH, 2022). A recent European Hearing Instrument Manufacturers Association (EHIMA) Euro Trak survey reported that hearing aid uptake in France increased to 45.7% in 2022 from 41% in 2018 following the introduction of the reforms

(EHIMA/ANOVUM, 2022), suggesting that they may be having a positive effect. Re-evaluation of hearing aid uptake among people with dementia in France may therefore be advantageous in time. Nevertheless, despite Greece being identified as having a ‘worryingly low’ level of subsidy by the European Federation of Hard of Hearing People (EFHOH) (2022, p. 2) the odds of hearing aid use there were not significantly different to those in England, suggesting that cultural factors beyond the economics of hearing aid provision may be influencing use (Zhao et al., 2015).

Motivation and hearing aid use

Hearing acuity was negatively associated with hearing aid use in our study, suggesting that people with more severe hearing loss are more likely to use hearing aids. This aligns with findings for both the general population (Knoetze et al., 2023) and people with dementia (Nirmalasari et al., 2017; Kim et al., 2021). Given that people with mild-moderate hearing loss also benefit from using hearing aids (Ferguson et al., 2017), it is concerning that we found that the odds of hearing aid use decreased by 61% with every ~20 dB improvement in hearing acuity.

Further, and in line with findings for the general population (Knoetze et al., 2023), greater self-perceived hearing difficulty was the strongest correlate of hearing aid use among people with dementia. To our knowledge, the association between self-perceived hearing difficulties and hearing aid use has not previously been investigated among people with dementia. We had postulated that self-recognition of hearing difficulties may be particularly important among people with dementia due to the lower self-awareness and insight associated with dementia (Mograb, Huntley and Critchley, 2021). However, as there was no comparison group of people with healthy cognition in the present study, we were not able to investigate whether lower levels of insight might result in less likelihood of reporting hearing difficulties among people with dementia.

Implications for practice

Although our results are not able to demonstrate causal relationships, they suggest that the COM-B components *psychological capability* (cognitive ability), *physical opportunity* (country of residence) and *reflective motivation* (hearing acuity and self-perceived hearing difficulty) are potential areas that could be targeted to support hearing aid use among people with dementia.

To address psychological capability, firstly it is important to increase understanding of why lower cognitive ability might be associated with reduced hearing aid use, and then to address these factors through interventions. Cognitive rehabilitation is an intervention approach that has been demonstrated to improve ability to complete targeted activities among people with mild to moderate dementia (Kudlicka et al., 2023), and could therefore provide an evidence-based way to improve capability in hearing aid use. According to Kudlicka et al. (2023), cognitive rehabilitation

interventions may include a focus on developing habits and routines (such as designating a place to store hearing aids and their maintenance equipment) and implementation of compensation strategies (such as external prompts to use hearing aids) as part of the approach. Research suggests that structured support is key in enabling successful outcomes in cognitive rehabilitation (Clare et al., 2019). Implementation of this approach may therefore necessitate increased frequency of input from hearing health professionals.

To address physical opportunity, it is important to understand what factors might influence use by country. Further research to increase understanding of national differences in hearing aid use among people with dementia is therefore warranted. Zhao et al.'s (2015) paper on the influence of culture on hearing aid uptake and use provides a helpful starting point, through suggesting that cross-cultural psychological factors including stigmatisation and social representation of hearing disability may be relevant factors to consider and investigate.

To address reflective motivation, consideration of ways in which hearing interventions could be targeted towards people with milder hearing loss who may not recognise the need for hearing aids may be warranted. Universal screening for hearing loss may therefore be advantageous. In this regard, implementation of Littlejohn et al.'s (2022) international practice recommendation to include hearing screening within the specialist diagnostic evaluation for dementia may be beneficial, alongside regular screening following a diagnosis of dementia, such as at two-yearly intervals as recommended by the United Kingdom's National Institute for Health and Care Excellence (2018). Evaluation of whether such measures are (a) implemented, and (b) effective in increasing hearing aid uptake and use, is warranted.

It is also important to consider how to address any evident lack of insight that impacts on reduced recognition of hearing difficulties. In this regard, facilitating a trial of hearing aids so that the person experiences aided and unaided hearing may aid acceptance. If it is not possible to address this successfully, alternative interventions such as communication training for people with dementia and their care partners may be worth pursuing as an alternative to hearing aids (Mamo et al., 2017; Meyer et al., 2020).

Limitations

This study has several limitations. First, the sample for this study were recruited for a study of hearing and / or vision loss in people with dementia. Our sample may therefore be biased towards people who recognised that they have hearing difficulties. In this respect our prevalence estimate of 30.5% hearing aid use should be treated with caution as it probably overestimates the level of hearing aid use within the wider population of people with dementia. However, because the sample

included a range of people across key variables, correlational analyses are likely to be reliable. Second, through our use of logistic regression analysis we have identified associations between predictor variables and hearing aid use among people with dementia. We have not investigated causal relationships. Experimental research is warranted in this respect. Third, our use of a cross-sectional design precluded evaluation of the factors that influence hearing aid use over time. Longitudinal studies are therefore warranted. Fourth, our study involved secondary analysis of data that had been collected. This precluded investigation of additional variables that may be associated with hearing aid use in people with dementia, such as perceived hearing aid benefit and level of support. Fifth, our use of a screening measure for hearing aid use limited our understanding of the full audiological profile of the participants. Lastly, it was not possible for us to differentiate between hearing aid uptake and use or to evaluate the frequency of hearing aid use in our study.

Conclusion

For the first time, this study has used a theory-informed framework to investigate predictors of hearing aid use in a sample of people with dementia and hearing loss. Our study revealed that greater self-perceived hearing difficulty, higher cognitive ability, and more severe hearing loss increase likelihood of hearing aid use among people with dementia. Adapting interventions to account for psychological capability, physical opportunity, and reflective motivation may better support hearing aid use in people with dementia.

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Chapter five:

Discussion

In this discussion chapter, influences on hearing aid use arising from the findings of this thesis are presented, and intervention options and implementation options considered. The findings are discussed within Michie et al.'s (2014) Behaviour Change Wheel intervention design process to form insights that may be useful for the development of interventions to support hearing aid use in people with dementia. A broader discussion of the overall findings is also presented, along with consideration of the strengths and limitations of this thesis, areas for future research and overall conclusions.

Chapter 5

Discussion

The studies presented within this thesis aimed to develop understanding of key influences on hearing aid use among community-residing people with dementia and age-acquired hearing loss through evaluating factors that affect hearing aid behaviour. Prior to this thesis, this was under-researched in this population. The objective of gaining this understanding was to develop insights that could inform the development of interventions to support hearing aid use in this population. The methodology that underpinned the research in this thesis has been informed by the COM-B and TDF theories of behaviour change (Cane, Connor and Michie, 2012; Michie, Atkins and West, 2014). This provides a perspective that considers both intrinsic influences on hearing aid use related to the person with dementia's *capabilities* and *motivations* and extrinsic influences, or *opportunities*, arising from the social and environmental context.

This thesis includes three studies: a systematic review (chapter two) and two original research studies (chapters three and four). To collate and systematically evaluate existing evidence about factors that influence hearing aid use among people with comorbid dementia and age-acquired hearing loss, a systematic review was first conducted. Although component constructs for barriers, facilitators, and non-correlates of hearing aid use in dementia were identified through this review, no studies had directly investigated correlates of hearing aid use, limiting understanding of factors affecting hearing aid use. To develop this understanding, a qualitative exploration of enablers and barriers to hearing aid use with eleven people with dementia and their care partners, and a quantitative evaluation of correlates of hearing aid in 239 people with dementia and hearing loss use were completed. These studies are reported in chapters three and four, and a range of factors that may influence the target behaviour of hearing aid use were identified. The samples for the original research studies reported in chapters three and four were drawn from a parent study - the European SENSE-Cog trial, which investigated the effectiveness of a sensory intervention for people with dementia and hearing and/or vision loss (Regan et al., 2019).

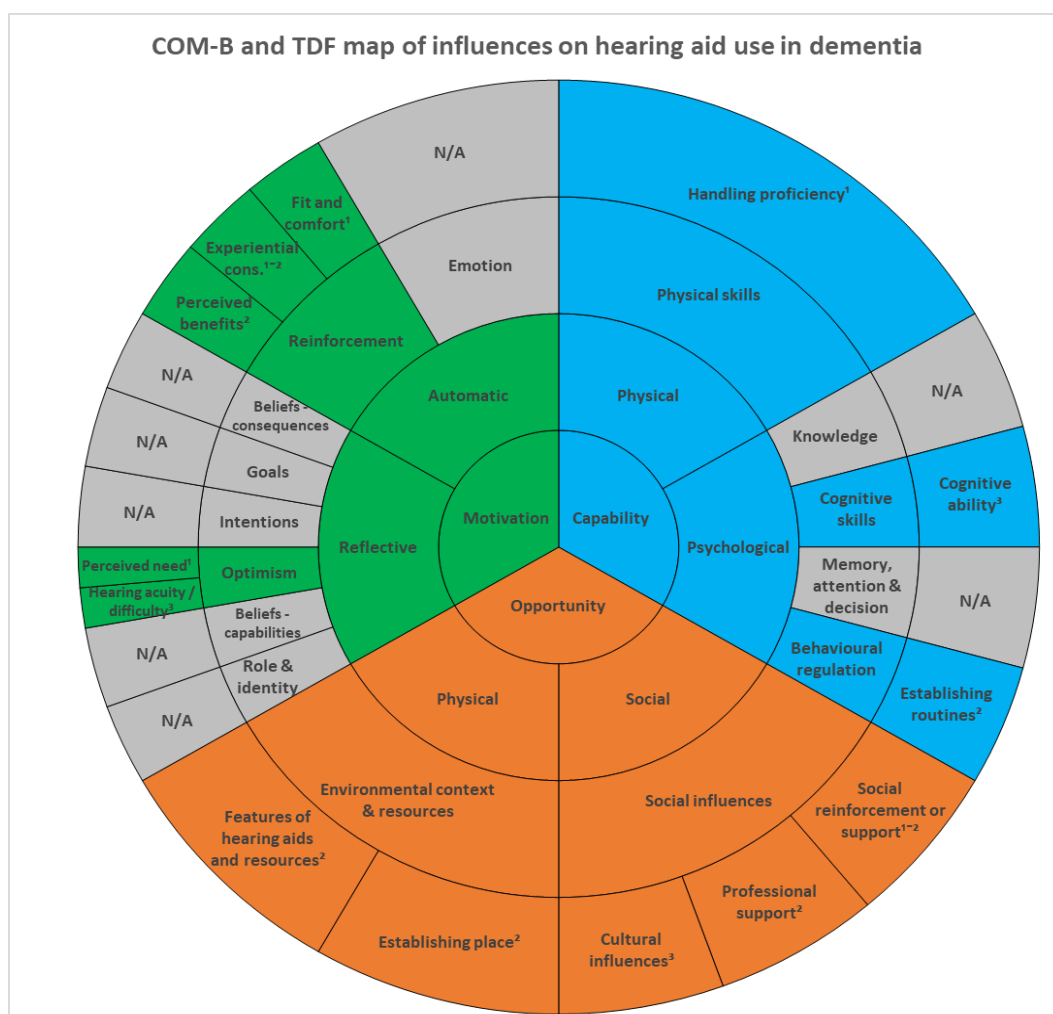
The results of the research reported within this thesis enable analysis of influences on hearing aid behaviour in dementia and identification of areas for change to support hearing aid use in this population. They thereby form the first stage of Michie et al.'s (2014) Behaviour Change Wheel (BCW) process of intervention design. This discussion chapter draws these findings together within the framework of the BCW to formulate insights that could be used to inform interventions for supporting hearing aid use in people with dementia. The first part of this chapter is presented according to Michie et al.'s (2014) three-stage process for designing behaviour change interventions:

(i) Understanding the behaviour; (ii) Identifying intervention options; and (iii) Identifying content and implementation options. Wider discussion, consideration of the strengths and limitations of this thesis, areas for future research, and general conclusions follow.

Stage 1: Understanding the behaviour

Michie et al. (2014) suggest that a thorough assessment of behaviour leads to greater accuracy of formulation and increased effectiveness of intervention. Taken together, the findings of the studies presented within this thesis suggest that several factors within the physical and psychological capability, physical and social opportunity, and reflective and automatic motivation components of the COM-B model are potential drivers for hearing aid use, and these are presented in Figure 1 below and Table A4.1 in Appendix 4.

Figure 1. COM-B and TDF map of influences on hearing aid use in people with dementia



Key: Inner circle = COM-B model components; Second circle = Subdivisions of the COM-B components; Third circle = Linked TDF domains; Outer circle = Mapped findings, derived from:

¹ Systematic review; ² Qualitative study; ³ Quantitative study

Capability

The findings suggest that factors within the *physical* and *psychological* capability components of the COM-B model are associated with hearing aid use in dementia, linking to the TDF domains *physical skills*, *cognitive skills*, and *behavioural regulation*. In relation to physical capability / physical skills, the systematic review findings suggest that hearing aid handling proficiency is important; if a person has the physical skills to insert, remove, adjust, and maintain their aids this supports hearing aid use.

In relation to psychological capability, findings from the quantitative study suggest that the TDF domain *cognitive skills* is relevant to hearing aid use in dementia because people with higher cognitive abilities have greater odds of hearing aid use relative to those with more impaired cognition. Additionally, the findings of the qualitative study suggest that the TDF domain *behavioural regulation* is relevant; where effective routines are established, this supports hearing aid use.

Opportunity

The findings suggest that the COM-B components *social* and *physical* opportunity are both relevant to hearing aid use in dementia. Within the social opportunity COM-B model component and linked TDF domain *social influences*, the findings of the systematic review and qualitative study suggest that receiving social reinforcement and support in the form of prompts, encouragement or assistance enable hearing aid use. Additionally, findings of the qualitative study suggest that professional support to develop hearing aid skills and routines enables their use, provided that this support is timely and responsive. At a macro level, the quantitative study findings suggest that cultural factors are influential because country of residence, but not level of hearing aid subsidy, is associated with hearing aid use, thereby suggesting that there could be barriers relating to social influences rather than the environmental context such as fiscal resources.

Within the physical opportunity component and linked TDF domain *environmental context and resources*, findings from the qualitative study suggest that establishing set places within a person's home environment to store and maintain hearing aids is an enabler for their use. In relation to resources, the findings of the qualitative study suggest that features of hearing aids may support or hinder their use: the quality of sound is important, and when the hearing aids are an appropriate size for the person to handle, the person has greater opportunity for independence in their use. Additionally, when hearing aids have features such as visible and understandable markings to aid differentiation between left and right aids, and a recognisable battery warning alert this supports their use. Hearing aid maintenance resources such as batteries also need to align with the person's handling skills.

Motivation

The findings suggest that factors within the *reflective* and *automatic* motivation components of the COM-B model are associated with hearing aid use in people with dementia. For reflective motivation, findings from the quantitative study and systematic review map to the linked TDF domain *optimism*. Quantitative study findings suggest that self-perceived hearing difficulty and hearing acuity are associated with hearing aid use, with people who have greater self-perceived hearing difficulty and more impaired hearing being more likely to use hearing aids. Conversely, the systematic review findings suggest that perceived listening need is influential; if a person is optimistic that they can hear without their aids they may choose to not use them.

Within the COM-B component automatic motivation, findings from the qualitative study and systematic review map to the TDF domain *reinforcement*. They suggest that consequences of using hearing aids influence their use; when hearing aids are perceived to be beneficial and benefits in daily life are experienced, such as enhanced communication and increased activity engagement, they are more likely to be used. Conversely, when people experience negative reinforcement from using hearing aids, such as auditory discomfort in listening situations such as noisy environments or aural discomfort due to poor fit, they may be less inclined to use them.

Links between COM-B components are evident and warrant consideration. For example, when hearing aids effectively support hearing ability this is a motivator for their use, and when the size of the aids or their maintenance resources are not matched with the person's capabilities there is greater need for effective external support, or social opportunity. Furthermore, the development of routines for hearing aid use and the establishment of place within an environment to both store and maintain hearing aids links behavioural regulation with environmental context.

According to Michie et al. (2014), the first stage of the intervention design process culminates in identification of what needs to change, forming a behavioural diagnosis. In relation to hearing aid use in people with dementia, the findings of the studies within this thesis suggest that the following capability, opportunity and motivation barriers influence the behaviour of hearing aid use:

Capability: difficulty in handling hearing aids, cognitive impairment, and lack of established routines for hearing aid wear and care.

Opportunity: lack of established places to store and maintain hearing aids, ineffective hearing aids, lack of access to – or lack of fit between - maintenance resources and the person's skills, cultural influences, lack of social reinforcement or support, and lack of professional support.

Motivation: lack of recognition of hearing difficulty, lack of awareness of need for hearing aids, lack of perceived benefits of hearing aids, lack of perceived positive experiential consequences from using hearing aids, and uncomfortable or poorly fitting hearing aids.

Michie et al. (2014) suggest that confidence in the analysis of behavioural influences increases when consistency is attained across methods and sources. In this thesis, the findings in relation to social opportunity (social reinforcement and support) and automatic motivation (experiential consequences of hearing aids) are derived from more than one study and methodological approach, suggesting increased confidence in these.

Stage 2: Identifying intervention options

Michie et al. (2014) suggest that once barriers to undertaking a behaviour are understood sufficiently, intervention options can be formulated through the identification of intervention functions and policy categories. These form the outer two layers of the Behaviour Change Wheel and provide a structured way of considering how barriers to behaviour can be addressed. Intervention functions that may best address the barriers to hearing aid use in people with dementia are presented in Table A4.2 in Appendix 4, according to COM-B components / TDF domains.

Evaluation of intervention functions suggests that *training* to build skills through implementing procedural learning techniques (Kudlicka et al., 2019) and *enablement* through implementing compensatory approaches (Gopi, Wilding and Madan, 2022) could optimise physical and psychological capability to use hearing aids. *Enablement* to ensure that resources (both the hearing aids and their associated maintenance resources) have an optimal fit with the person with dementia's capabilities could optimise physical opportunity and support hearing aid use (Dawes et al., 2022), and to establish locations for the storage and maintenance of the aids and provision of environmental cues that reinforce this (Hooper et al., 2024a). Social opportunity may be optimised through *enablement* to increase informal (e.g. care partner) support and *environmental restructuring* to increase formal (professional) support and to enhance cultural norms for hearing aid use (Hooper et al., 2024a; Hooper et al., 2024b). *Education* to increase recognition of hearing loss and awareness of the need for hearing aids may increase reflective motivation to engage in the behaviour of hearing aid use (Littlejohn et al., 2022). *Incentivisation* to create an expectation of positive gains from using hearing aids (Littlejohn et al., 2022), and *enablement* to facilitate timely problem-solving of negative reinforcers may increase automatic motivation to use hearing aids (Hooper et al., 2024a).

Evaluation of intervention functions according to the APEASE criteria

Following identification of potential intervention functions, the next step within the intervention design process is to evaluate these against the APEASE criteria (Acceptability, Practicability, Effectiveness/cost-effectiveness, Affordability, Safety/side-effects, Equity) to judge which might be the most appropriate (Michie, Atkins and West, 2014). Table A4.3 in Appendix 4 outlines APEASE criteria considerations in relation to the context of hearing aid use in people with dementia.

According to these considerations, the most appropriate intervention functions may be *enablement*, *education* and *incentivisation*. The intervention functions *training* and *environmental restructuring* may be less likely to meet the APEASE criteria because evidence suggests that time, training, and resource limitations could impact negatively on the potential to fulfil these within routine clinical practice (Wright et al., 2014; Leroi et al., 2019), necessitating wider service change to be considered practicable. However, stakeholder engagement with people with dementia, their care partners and hearing care providers would be necessary to robustly evaluate the potential intervention functions against the APEASE criteria to inform intervention design.

The next stage of Michie et al.'s (2014) behaviour change intervention design process is to evaluate which policy categories could potentially align successfully with the chosen intervention functions, again with consideration of the APEASE criteria. These are presented in Table A4.4 in Appendix 4. Completion of this process suggests that the policy categories *communication / marketing* and *service provision* may be the most appropriate to select. Although the policy category *guidelines* aligned with many of the suggested intervention functions, it could be less likely to meet the APEASE criteria for inclusion because although practice recommendations for the management of hearing impairment in dementia have been proposed in recent years (Dawes et al., 2022; Littlejohn et al., 2022), current guidelines fall short of addressing the needs of people with dementia.

Stage 3: Identification of content and implementation options

Michie et al. (2014) indicate that once stage two of the intervention design process is complete and the intervention functions and policy categories that seem most appropriate have been identified, the third and final stage of the intervention design process can be considered. The first step within this stage is to link the chosen intervention functions with behavioural change techniques (BCTs) (Michie, Atkins and West, 2014). BCTs represent distinct, replicable strategies that may be implemented to alter behaviour (Michie et al., 2013; Cane et al., 2015). The most frequently used BCTs for each COM-B component / TDF domain were identified by Cane et al. (2015) through expert consensus. To identify which BCTs may be most appropriate to support hearing aid use in people with dementia, the most frequently used BCTs for the intervention functions *enablement*, *education* and *incentivisation* were appraised. These are presented in Table A4.5 in Appendix 4. The frequently

used BCTs that may be most appropriate were *social support (unspecified)*, *social support (practical)*, *adding objects to the environment*, *problem solving*, *goal setting and review (behaviour)*, *action planning*, *prompts/cues*, *restructuring the physical environment*, *information about social and environmental consequences*, *feedback on behaviour*, and *feedback on outcomes of the behaviour*. Less frequently used BCTs were also reviewed, and the following was selected as being potentially appropriate: *restructuring the social environment*.

Formulation of a draft intervention strategy

Considered together, the intervention functions and selected BCTs could inform a potential intervention strategy to support hearing aid use in people with dementia, as outlined in Table 1 below. In relation to mode of delivery, the potential intervention may be most effectively delivered within audiology appointments. It is suggested that, if possible, these appointments could include both the person with dementia together with their care partner, and that the audiologist could facilitate the intervention functions with both parties. It may be appropriate to evaluate whether scheduling of more frequent appointments is beneficial in supporting hearing aid use, as suggested by Souza (2014) and Dawes et al. (2022). Information from the appointments could potentially be reinforced through the provision of written information, such as checklists, that are produced in accordance with guidelines for communicating effectively with people with dementia (Dawes et al., 2022), and offered in a range of formats (Littlejohn et al., 2022), to aid with recall and continued learning (Souza, 2014). The development and provision of accessible information could also inform a marketing strategy that aims to educate and motivate people with dementia about the benefits of addressing hearing loss and using hearing aids.

Table 1. Intervention insights arising from the BCW process

COM-B component	TDF domain	Barrier / problem	Evidence source	Intervention functions	Policy categories	BCTs	Potential intervention strategy
Psychological capability	Physical skills	Difficulty in handling hearing aids	Systematic review	Training*	Guidelines* Service provision	Social support Adding objects to the environment Problem solving Restructuring the physical environment	Inclusion of care partners of people with dementia in audiology appointments. Service provider to advise care partner about ways to support the person with dementia to use their hearing aids, including the following: Care partner to provide practical support and encouragement. This could include bringing the person with dementia’s hearing aids to them, being on hand to problem-solve, and ensuring that the environment is free of distractions and well lit.
				Enablement			
	Behavioural regulation	Lack of established routine for hearing aid wear and care	Qualitative study	Training* Enablement			
Physical opportunity		Lack of established place to store and	Qualitative study	Training*			

	Environmental context and resources	maintain hearing aids		Enablement	Service provision	Action planning Restructuring the physical environment	Inclusion of action planning with the person with dementia and their care partner in audiology appointments to identify and agree places to store and maintain hearing aids. This may include restructuring the environment to ensure that the hearing aids and maintenance resources are stored in a set and suitable place for the person with dementia, and the introduction of visible prompts such as labelling.
		Lack of access to effective hearing aids and resources	Qualitative study	Enablement	Service provision	Problem solving	Inclusion of review of the effectiveness of the hearing aids and their associated resources within audiology appointments, ensuring that the 'fit' with the person with dementia's capabilities is optimal and replacing hearing aids/ resources with more suitable alternatives where necessary.
Social opportunity	Social influences	Lack of social reinforcement or support	Systematic review Qualitative study	Enablement	Service provision	Social support Restructuring the social environment	Inclusion of establishment of whether support is (a) available and (b) effectively provided during audiology appointments. Service provider to advise care partner about ways to support the person with dementia to use their hearing aids through prompts and cues. Where a person with dementia is unsupported or sub-optimally supported, the service provider should address this, for example through onward referral to social care / support services.
		Lack of professional support	Qualitative study	Environmental restructuring*			
		Stigmatisation / poor social representation of hearing disability	Quantitative study	Environmental restructuring*			

Reflective motivation	Optimism	Lack of recognition of hearing difficulty and / or awareness of need for hearing aids	Systematic review Quantitative study	Education	Communication / marketing Guidelines* Service provision	Information about social and environmental consequences Feedback on behaviour Feedback on outcomes of the behaviour Prompts/cues	Inclusion of provision of information within audiology appointments to raise awareness about the consequences of hearing loss and use / non-use of hearing aids that is at a level that is suitable for the person with dementia to comprehend. Audiologist to encourage care partners to: (a) Reinforce the social and environmental consequences of using hearing aids through providing feedback to the person with dementia. (b) Prompt hearing aid use. Audiologist to provide written information (e.g. leaflets) about the benefits of using hearing aids and the risks of non-use that include testimony about the differences that hearing aids can make in daily life.
Automatic motivation	Reinforcement	Lack of perceived benefits of hearing aids and / or lack of perceived experiential consequences of hearing aid use	Systematic review Qualitative study	Incentivisation	Service provision	Feedback on behaviour Feedback on outcomes of behaviour	Audiologist to encourage care partners to give feedback to the person with dementia about their hearing aid use and the outcomes of this in everyday situations.
		Uncomfortable or poorly fitting hearing aids	Systematic review	Enablement	Service provision	Problem solving	Audiologist to review the comfort and fit of hearing aids and replace where indicated.

* Unlikely to meet the APEASE criteria for inclusion

Because the potential intervention strategy suggested here may be most practicably delivered within the framework of established audiology services, there are several limitations that warrant consideration. First, the potential intervention could be limited in its scope to build the skills of the person with dementia to handle and maintain their hearing aids independently. This training approach, which may be best informed by the principles of cognitive rehabilitation (Kudlicka et al., 2023), would require structured specialist support (Clare et al., 2019). This is likely to fall outside the scope of current practice.

Second, it does not address the problem of under-presentation to audiology services for people with dementia (National Institute for Health and Care Excellence, 2018) because it sits downstream of this. A universal screening approach may be beneficial but is outside the scope of the insights that are drawn from this thesis.

Third, it is reliant upon the person with dementia having either manual dexterity to manipulate the aids independently or compensatory support through a willing and able care partner. However, research has demonstrated that fine motor skills become increasingly impaired as dementia progresses (Liou et al., 2020), indicating that the potential to handle and manipulate hearing aids independently is likely to become increasingly problematic over time. Furthermore, almost 1/5th of people with dementia living in the community receive little or no support (Clare et al., 2020). The viability of the potential intervention may therefore be reduced in people with dementia who are more severely functionally impaired and unsupported.

Finally, it has not been co-produced with people living with dementia or their care partners at this juncture. Inclusion of people with this lived perspective is warranted (Powell et al., 2023), along with service providers. A co-production approach with these stakeholders, using the emerging evidence and resulting intervention insights that are presented in this thesis, would form a logical next step in the design and implementation of a theory-informed intervention to support hearing aid use in people with dementia.

General discussion

Within this chapter, the findings of the three research studies undertaken for this thesis have been applied within Michie et al.'s (2014) BCW framework to formulate intervention insights that could inform an intervention to support hearing aid use in people with dementia and hearing loss.

Developing evidence-informed interventions forms the first stage of the Medical Research Council's guidance on complex interventions (Skivington et al., 2021), and this thesis provides evidence that could inform an intervention that aims to support hearing aid use in people with dementia.

Undertaking a programme of co-production with key stakeholders to formulate a draft intervention,

and then piloting this, would provide the opportunity for evaluation of feasibility and viability and further refinement, prior to wider implementation and evaluation.

Furthermore, the studies presented in chapters three and four of this thesis have extended understanding of the enablers and barriers to hearing aid use in dementia that were presented in the systematic review in chapter two (Hooper et al., 2022), enabling a stronger understanding of influencing factors (Michie, Atkins and West, 2014). As such, there is now stronger evidence for the following four systematic review findings for which the GRADE-CERQual (Lewin et al., 2018) confidence ratings were moderate or low in the systematic review: (i) the establishment of routines enables hearing aid use. This was evident in the qualitative study presented in chapter three and supports the findings of previous research (Gregory et al., 2020); (ii) the establishment of a set place to store hearing aids is an enabler. This was also evident in the qualitative study presented in chapter three and supports the findings of previous research (Palmer et al., 1999; Gregory et al., 2020); (iii) the level of self-perceived hearing difficulty influences hearing aid use; people with greater self-perceived hearing difficulty are more likely to use them. This was evident in the quantitative evaluation presented in chapter four and supports the findings of previous research (Palmer et al., 1998; Hutchison, Covan and Bogus, 2012a; Hutchison, Covan and Bogus, 2012b; Leroi et al., 2020b; Sheikh et al., 2021); (iv) perceiving hearing aids to be beneficial is a motivator for their use. This was evident in the qualitative study presented in chapter three and supports the findings of previous research (Gregory et al., 2020).

Two findings from the research presented within chapters three and four add further confirmatory evidence to systematic review findings for which the GRADE-CERQual (Lewin et al., 2018) confidence ratings were high: First, social reinforcement is an enabler for hearing aid use. This was evident in the qualitative study presented in chapter three and supports the findings of previous research (Palmer et al., 1999; Gregory et al., 2020; Leroi et al., 2020b). The research presented in chapter three extends this further through additionally elucidating the benefits of receiving social support (a finding rated as low confidence in the systematic review) and timely professional support in enabling hearing aid use. Second, experiencing positive consequences of hearing aids is a motivator for their use. This finding from the qualitative study presented in chapter three aligns with a significant body of research that informed high confidence in this finding in the systematic review (Palmer et al., 1998; Palmer et al., 1999; Hutchison, Covan and Bogus, 2012a; Dupuis et al., 2016; Nguyen et al., 2017; Gregory et al., 2020; Leroi et al., 2020b; Sheikh et al., 2021).

Some evidence from the research presented in chapter four is contrary to the findings of previous research. First, the finding that severity of cognitive impairment is associated with hearing aid use

contrasts with previous research which suggested that it may not be (Palmer et al., 1999; Nguyen et al., 2017; Nieman et al., 2018). There was low confidence in this finding within the systematic review presented in chapter two. Heterogeneity exists between these studies, including the research presented in chapter four, in relation to measures of cognition and hearing aid use, and the hearing loss thresholds for inclusion, which could contribute towards this contradictory finding. Second, the finding that level of hearing acuity is associated with hearing aid use contrasts with the evidence that informed the systematic review finding which suggested that it may not be associated (Palmer et al., 1999; Hutchison, Covan and Bogus, 2012a; Hutchison, Covan and Bogus, 2012b; Nguyen et al., 2017; Leroi et al., 2020b), but aligns with the findings of Nirmalasari et al. (2017). These contradictory findings suggest that further empirical investigation into the influence of severity of cognitive impairment and hearing acuity on hearing aid use in people with dementia are warranted.

Several novel findings arise from the research presented within chapters three and four of this thesis. First, establishing set places for undertaking hearing aid maintenance tasks is an enabler for their use. Second, although having lower financial resources has been identified as a barrier to hearing aid use in dementia (Hutchison, Covan and Bogus, 2012b; Nieman et al., 2018; Powell et al., 2023), the findings presented within chapter four suggest that cultural factors beyond the financing of hearing aids may be influential. Lastly, the findings of the research presented in chapter three provide qualitative evidence to underpin practice recommendations which suggest that there needs to be an alignment between the style and features of hearing aids and the abilities of the recipient with dementia (Souza, 2014; Dawes et al., 2022), and expand this further to include hearing aid maintenance resources.

Strengths and Limitations

The theoretical frameworks of the COM-B (Michie, Atkins and West, 2014) and TDF (Cane, Connor and Michie, 2012) have underpinned this thesis throughout, and this is a strength of this research. This has enabled a theory-informed approach to understanding the behaviour of hearing aid use in people with dementia that provides the basis for developing an intervention designed to address influences on behaviour and support hearing aid use in this population. Use of the TDF in addition to the COM-B model has enabled a more detailed understanding of these influences to be gained than through use of the COM-B model alone. For example, even though influencing factors were identified within each area of the COM-B model, there was no evidence that some TDF domains were relevant, enabling a more nuanced interpretation. Furthermore, approaching these studies from a mixed-methods perspective has enabled triangulation of the findings, strengthening understanding of influencing factors.

There are also limitations to the work presented in this thesis. First, in relation to the target behaviour, a pragmatic decision was taken to define this as '*daily use of hearing aids by people with dementia and acquired hearing loss in their home and community environments*'. However, the parameters for optimal hearing aid use to support quality of life in people with dementia are not known. This is a key uncertainty (Skivington et al., 2021), and it is possible that the target behaviour as defined within this research may require adjustment according to the outcomes of future research.

Second, there are limitations within the empirical studies included in this thesis in relation to measures of hearing aid use. The impact of the COVID-19 pandemic on data collection within the parent research trial was an influencing factor in this. Thus, cross-sectional binary caregiver report of hearing aid use was utilised in the quantitative study reported in chapter four, giving no indication of the frequency or duration of hearing aid use. Although dyad-reported frequency of hearing aid use was included in the qualitative study in chapter three, this sample size is small compared to that of the quantitative study. Longitudinal research that investigates influences on the frequency and duration of hearing aid use in people with dementia is warranted to address this limitation.

Third, the sample in the empirical studies within this thesis were drawn from a parent research trial of a sensory intervention. They may therefore have had an increased awareness of hearing loss and greater motivation to use hearing aids than the wider population with dementia. As these factors are known determinants of hearing aid use in the general population (Salonen et al., 2013; Knoetze et al., 2023), it is possible that participation in the parent trial positively influenced the target behaviour. Therefore, although this thesis has included a hard to reach and under-researched population, the findings of the empirical studies should be viewed as best-case scenarios, and caution about the generalisability of the findings should be exercised. Furthermore, the sample for the empirical studies was European, thereby limiting generalisability beyond this demographic, social and cultural setting. However, the mean age of participants was akin to that of the population-based studies reported within Mooldijk et al.'s review of diversity in dementia research (2021), the gender representation was nearly equal between men and women, and the mean level of cognitive impairment was moderate. This suggests that aspects of the sample's demographic features could be considered adequately representative of the wider population with dementia.

Future research

The research presented within this thesis has developed understanding of influences on hearing aid use in dementia. Whilst the findings have provided much-needed evidence, further research is needed to address the limitations and considerations outlined in this discussion. This includes (i)

evaluation of the frequency of hearing aid use, influencing factors on hearing aid use, and parameters of optimal hearing aid use in people with dementia that access standard audiology pathways; (ii) further investigation into the influence of hearing acuity, severity of cognitive impairment, and level of support upon hearing aid use in people with dementia; and (iii) piloting of the potential intervention outlined in this chapter to support hearing aid use in people with dementia, underpinned by a programme of co-production with experts by experience.

Overall conclusions

This thesis has utilised a theory-informed approach to develop understanding of factors that influence the behaviour of hearing aid use in community-residing people with mild-moderate dementia and age-acquired hearing loss. The findings suggest that influences of this target behaviour are multifaceted, incorporating a range of factors in the COM-B model components of capability, opportunity, and motivation, and their associated TDF domains. Capability factors include hearing aid handling skills, the extent of cognitive impairment, and establishment of hearing aid routines. Motivation factors include recognition of hearing difficulty, perceived need for hearing aids, and consequences of using hearing aids. Social opportunity factors include social and professional support, and cultural influences on hearing aid use. Environmental opportunity factors include features of hearing aids and their resources, and establishment of set places to store and maintain hearing aids.

The findings suggest that enhanced support pathways that tailor to the capabilities and motivations of the individual with dementia whilst also accounting for their environment and social support systems may represent the best opportunity to optimise hearing aid use. The findings have been consolidated within Michie et al.'s (2014) Behavioural Change Wheel intervention design process to formulate insights that could inform an intervention that aims to support hearing aid use in dementia.

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Appendices

Appendix 1: Introduction

Table A1.1. The capability, opportunity and motivation demands of hearing aid use in dementia.

COM-B component	Linked TDF domain	Application to hearing aid use
Physical capability	Physical skills	Have the manual dexterity, grip, muscle strength and range of movement to manipulate / handle and insert hearing aids.
Psychological capability	Knowledge	Understand the benefits of hearing aid use. Know how to use hearing aids.
	Cognitive skills	Have the cognitive ability to use hearing aids. Have the visuospatial skills to manipulate and insert hearing aids effectively. Have the executive function skills to use hearing aids (e.g. organisation and planning skills, problem solving skills to overcome obstacles).
	Memory, attention, and decision processes	Remember to use hearing aids. Remember where they are stored. Remember to undertake maintenance tasks to keep them in working order (e.g. changing batteries). Maintain attention to complete hearing aid tasks.
	Behavioural regulation	Possess the ability to decide to use hearing aids. Develop habits that support hearing aid use (e.g. relating to storage, maintenance tasks and patterns of use). Be willing to try using hearing aids and to persevere if facing difficulties.
Physical opportunity	Environmental context and resources	Have access to resources (e.g. batteries, cleaning materials). Have an environmental context that supports use (e.g. sufficient lighting / solid surface). Have sufficient funds / access to subsidised provision of hearing aids.
Social opportunity	Social influences	Have support from others – prompting, reinforcement, encouragement, help with maintenance and insertion / removal. Have societal acceptance / pressure for use of hearing aids (cultural norms). Have positive role models for hearing aid use.
Reflective motivation	Social / professional role and identity	Possess personal acceptance of being a hearing aid user.
	Beliefs about capabilities	Have confidence in ability to use hearing aids.
	Optimism	Have an expectation that hearing aids will be useful. Be optimistic about the usefulness of hearing aids. Be optimistic about overcoming any problems with hearing aids.
	Intentions	Have a clear intention to use hearing aids.
	Goals	Have a plan in place for achieving hearing aid use.
Automatic motivation	Beliefs about consequences	Have a stronger sense that hearing aids will help rather than hinder. Have a clear sense of outcome – i.e. what hearing aid use will help to achieve.
	Reinforcement	Find it rewarding / helpful to use hearing aids. Experience benefits / tolerable detrimental effects of hearing aids in different contexts.
	Emotion	Feel pleasure or satisfaction from using hearing aids.

Table A1.2. Links between domains of the TDF and components of the COM-B model (Collated from Cane et al. (2012, pp. 14,15))

COM-B component		TDF domain	TDF domain definition	
Capability	Physical	Skills	An ability or proficiency acquired through practice	
		Psychological	Knowledge	An awareness of the existence of something
		Skills	An ability or proficiency acquired through practice	
		Memory, Attention and Decision Processes	The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives	
Opportunity		Behavioural Regulation	Anything aimed at managing or changing objectively observed or measured actions	
	Physical	Environmental Context and Resources	Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour	
Motivation	Social	Social influences	Interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours	
		Reflective	Social/Professional Role and Identity	A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting
			Beliefs about Capabilities	Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use
			Optimism	The confidence that things will happen for the best or that desired goals will be attained
		Beliefs about Consequences	Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation	
		Intentions	A conscious decision to perform a behaviour or a resolve to act in a certain way	
		Goals	Mental representations of outcomes or end states that an individual wants to achieve	
	Automatic	Reinforcement	Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus	
	Emotion	A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event		

Appendix 2:

Systematic review of factors associated with hearing aid use in people living in the community with dementia and age-related hearing loss

Supplementary File S1: Methods

Inclusion and exclusion criteria

	Inclusion Criteria	Exclusion Criteria
Population	Diagnosed dementia Age-related hearing loss Living in the community Has air conduction hearing aids	Mild Cognitive Impairment / no dementia Congenital Deafness Living in long-term care Does not have air conduction hearing aids
Phenomenon of interest	The use of air conduction hearing aids	Other audiological devices including cochlear implants, bone conduction hearing aids, or assistive listening devices
Outcome	Hearing aid use Factors that influence use	Other outcomes not related to the present review
Study type	Quantitative studies Qualitative studies Mixed methods studies	

Search strategy

Electronic databases: Ovid MEDLINE, Scopus, PsychINFO, and Cumulative Index to Nursing and Allied Health Literature (CINAHL).

Additional searches: Cochrane Databases of Systematic Reviews, reference lists of relevant papers, trial registers ClinicalTrials.gov and the World Health Organisation international clinical trials registry platform (ICTRP), and unpublished 'grey' literature via OpenGrey and Evidence Search.

The full search syntax used for the Ovid MEDLINE search was: (exp DEMENTIA/ OR dement* OR Alzheimer* OR Vascular* OR 'Lewy Bod*' OR (Parkinson* AND (dementia* or disease)), OR Frontotemporal dement* OR ((cogniti* OR memory) AND (impair* OR deficit* OR disord*))) AND (exp HEARING/ OR 'hearing loss' OR 'hearing disord*' OR 'hearing deficit*' OR 'hearing impair*' OR 'auditory impair*' OR presbycusis OR presby*) AND (exp 'HEARING AIDS'/ OR 'hearing aid*' OR 'correction of hearing impairment').

Study selection

A sample of 12% of the titles and abstracts were independently screened by the first author and a second reviewer (H.C.), resulting in moderate inter-rater agreement (Cohen's $k = 0.44$). These were reassessed following consensus discussion and clarification of the inclusion criteria, and substantial agreement was reached (Cohen's $k = 0.63$). During this process, we retained any papers that remained unclear for further appraisal. Screening of a further 6% of the returned search resulted in

perfect agreement (Cohen's $k = 1.00$). The first author then screened the remaining titles and abstracts.

Once the title and abstract screening was complete, the first author and second reviewer independently appraised the full text of all potentially relevant studies against the full inclusion and exclusion criteria. Disagreements between the two reviewers were resolved through discussion, and with the input of another member of the review team (P.D.).

Data extraction

The primary researcher performed the data extraction using a bespoke form. The second reviewer checked this for accuracy. The primary researcher contacted authors of the two included conference abstracts to request missing data, which was provided by one of these.

Quality assessment

The first author and second reviewer independently critically appraised the quality of the selected studies using the Mixed Methods Appraisal Tool (MMAT).^{37, 38} The same reviewers then used the Johns Hopkins Nursing Evidence-Based Practice (JHNEBP)³⁹ framework to appraise and categorise the studies according to the level of research evidence. Throughout this process, any discrepancies were resolved through discussion, and with the input of another member of the research team (L.B.).

Data synthesis

Because this is a mixed methods review, quantitative and qualitative data were treated with equal status and analysed concurrently, according to the A-QUAL + QUAN framework.⁴⁰ An interpretive data synthesis was undertaken by mapping extracted findings to the 14 domains of the Theoretical Domains Framework.^{31,41} Any determinants of hearing aid use that did not fit into the domains of the TDF were categorised as 'other' to ensure completeness of the synthesis.

Confidence in the findings was assessed according to the Grading of Recommendations Assessment, Development and Evaluation Confidence in the Evidence from Reviews of Qualitative Research (GRADE-CERQual) approach.⁴² For this, the first author and second reviewer independently assessed each finding in relation to methodologic limitations, coherence, adequacy, and relevance. The outcomes of these appraisals informed an overall assessment of confidence in the findings, according to the GRADE-CERQual criteria of high, moderate, low, or very low.

Supplementary Table S1. Characteristics of included studies

Author (year), country of origin	Type of publication	Study design*	Evidence level† / quality rating*	Inclusion criteria	Participant characteristics	Study description	Hearing aid use	Correlates of hearing aid use
Dupuis et al. (2016) Canada	Conference abstract & poster	Quantitative non-randomised intervention	Level II / Low	Not reported	<p><u>Sample size:</u> n=4 dyads</p> <p><u>Age:</u> Mean 90 years (range 80-92)</p> <p><u>Gender:</u> 50% male</p> <p><u>Cognitive status:</u> Mean MoCA 16.75 (SD 4.03) – indicative of moderate cognitive impairment / mild dementia.</p> <p><u>Dementia type:</u> 25% diagnosed with AD; 25% other dementia variant; 50% MCI variants</p> <p><u>Hearing status:</u> Mean BEA = 40.4 dB (SD 5.58)</p> <p><u>Living circumstances:</u> 50% cohabiting with spouse; 25% cohabiting with adult child; 25% alone</p> <p><u>Socioeconomic status:</u> Not reported</p> <p><u>Ethnicity:</u> Not reported</p>	<p><u>Aim:</u> To examine the impact of including significant others in audiologic rehabilitation of people with cognitive impairment</p> <p><u>Intervention:</u> Hearing aids (mixture of ITE and BTE, monaural and binaural) and audiologic rehabilitation</p> <p><u>Control:</u> No control condition</p> <p><u>Duration:</u> 3 months</p>	<p><u>Data source:</u> Researcher report</p> <p><u>Data type:</u> Qualitative (descriptive)</p> <p><u>Outcome:</u> “Successful use” for all participants</p>	<p><u>Enablers:</u> Identification of goals relating to listening and communication; Positive consequents of use (reduced listening and communication difficulties, increased safety in the home, increased engagement in participatory activities).</p> <p><u>Barriers:</u> Lack of procedural knowledge (difficulty differentiating, naming and comprehending parts); Difficulty with handling skills (incorrect battery insertion).</p> <p><u>Non-correlates:</u> None reported</p>
Gregory et al. (2020) UK	Peer reviewed journal	Qualitative phenomenological	Level III / High	Aged 50+ Diagnosed mild AD or MCI (sMMSE ≥21)	<p><u>Sample size:</u> n=10</p> <p><u>Age:</u> Range 75-86 years</p> <p><u>Gender:</u> 60% male</p>	<p><u>Aim:</u> To explore the experiences of hearing aid use in people with dementia / mild cognitive impairment</p>	<p><u>Data source:</u> Participant report</p> <p><u>Data type:</u> Qualitative (descriptive)</p>	<p><u>Enablers:</u> Incorporation into everyday routine; Keeping aids in a set location when not in use;</p>

				Confirmed hearing loss Provided with hearing aids	<u>Cognitive status:</u> sMMSE range 21-28 – indicative of mild cognitive impairment / mild dementia	via semi-structured interview	<u>Outcome:</u> Selective use related to situations, motivation and consequences	Perseverance; Welcoming visibility of hearing aids in aiding communication awareness of others; Optimism about efficacy; Positive consequents of use (increased confidence, feeling protected, finding them helpful) Comfortable fit; Support of care partner to insert aids; Social reinforcement (reminders / encouragements from family)
				Exclusion: Not fluent in English Lack capacity to consent	<u>Dementia type:</u> 80% AD; 20% MCI <u>Hearing status:</u> Not reported <u>Living circumstances:</u> Not reported <u>Socioeconomic status:</u> Not reported <u>Ethnicity:</u> 50% White British, 50% White Irish / Black / Asian / Punjabi			<u>Barriers:</u> Lack of knowledge and handling skills (hearing aid insertion); Misplacing / losing aids; Forgetting to use them; Stigma related to visibility; Belief that hearing aid use could lead to over-reliance on them; Ambivalence about need; Influence of environmental factors (excessive noise, demands of the listening situation) <u>Non-correlates:</u> None reported
Hawkins (2011) USA	Practitioner Magazine	Qualitative case report	Level V / Low	Not reported	<u>Sample size:</u> n=1 <u>Age:</u> 89 years <u>Gender:</u> Male <u>Cognitive status:</u> Moderate – advanced dementia. Cognitive	<u>Aim:</u> To report difficulties encountered in the provision of replacement hearing aids for a person with dementia	<u>Data source:</u> Researcher report <u>Data type:</u> Qualitative (descriptive)	<u>Enablers:</u> None reported <u>Barriers:</u> Deterioration of knowledge and skills (affecting comprehension of hearing

					assessment score not reported <u>Dementia type:</u> Mixed dementia <u>Hearing status:</u> Mild-moderate hearing loss <u>Living circumstances:</u> Cohabiting with spouse <u>Socioeconomic status:</u> Not reported <u>Ethnicity:</u> Not reported		<u>Outcome:</u> Rejection of replacement hearing aids	aid controls and device maintenance); Manufacturer manual triggering anxiety about complexity of aids; Immovable mind-set precipitating resistance to changing aids; Lack of confidence in capabilities, agitation arising from this <u>Non-correlates:</u> None reported
Hutchison et al. (2012 a and b) USA	Peer reviewed journal	Mixed methods intervention	Level III / Low	Aged 65+ Diagnosed mild-moderate dementia (MMSE 14-24) Mild-moderate hearing loss (determined by HHIE-S) No cerumen blockage No history of middle ear surgery Little to no hearing aid experience Living independently or with family within commuting distance of the research facility	<u>Sample size:</u> n=10 <u>Age:</u> Median 86.5 (Range 82-94) years <u>Gender:</u> 20% male <u>Cognitive status:</u> MMSE not reported. Researcher determined 70% with 'moderate dementia'; 30% 'no dementia' <u>Dementia type:</u> Not reported <u>Hearing status:</u> 50% moderate-severe hearing loss; 50% mild-moderate <u>Living circumstances:</u> 60% alone; 30% cohabiting with spouse; 10% cohabiting with other family <u>Socioeconomic status:</u> Not reported	<u>Aim:</u> To ascertain the viability of treatment, impact of hearing loss treatment on behavioural symptoms and psychosocial factors for people with dementia, and willingness of caregivers to provide support <u>Intervention:</u> Binaural BTE hearing aids <u>Control:</u> No control condition <u>Duration:</u> 4 weeks	<u>Data source:</u> Caregiver log <u>Data type:</u> Quantitative (continuous) <u>Outcome:</u> Data for n=7: Median 211.5 hours over 4 weeks (range 114-419.5) n=1 rejected hearing aids	<u>Enablers:</u> Positive consequents of hearing aid use (improved ability to engage in social/leisure/religious activities, increased connection with the internal or external auditory environment; improved participation in communication); Improved affective state (increased morale – Hedges' g 1.47 on Lawton Morale Scale – large effect, signs of decreased depression and joy); Care partner assistance (successfully supported hearing aid use in 9/10 participants) <u>Barriers:</u> Lack of awareness of hearing loss; Resistance to using hearing aids;

					<u>Ethnicity:</u> Not reported			Difficulty with hearing aid insertion; Concerns about affordability (2 out of 10 participants believed they were affordable) <u>Non-correlates:</u> Hearing threshold was not associated with use (Hedges' g 0.07) <u>Enablers:</u> Hearing aid use was inversely associated with both the number and severity of NPS <u>Barriers:</u> None reported <u>Non-correlates:</u> None reported
Kim et al. (2021) USA	Peer reviewed journal	Quantitative descriptive observational	Level III / Moderate	Attendees at a community memory assessment clinic Completed audiometric and neurocognitive testing	<u>Sample size:</u> 101 <u>Age:</u> Mean 76.3 (range 49-93) years <u>Gender:</u> 44% male <u>Cognitive status:</u> Mean MMSE 23.1 (SD 4.4) – indicative of mild dementia <u>Dementia type:</u> 52% AD or related dementias; 27% MCI; 21% other cognitive disorders <u>Hearing status:</u> Mean BEA 31.4 dB HL (SD 13.3) 34% unimpaired hearing; 44% mild loss; 20% moderate loss; 3% severe loss <u>Living circumstances:</u> Not reported <u>Socioeconomic status:</u> Not reported <u>Ethnicity:</u> 82% White; 18% Black	<u>Aim:</u> Chart review to examine the association between objective hearing loss and neuropsychiatric symptoms (NPS) among people with varying degrees of cognitive impairment	<u>Data source:</u> Clinical records <u>Data type:</u> Quantitative (categorical binary) <u>Outcome:</u> 20% of sample used hearing aids; 5.9% of those with no hearing loss (n=2); 16% of those with mild hearing loss (n=7); 48% of those with moderate-severe hearing loss (n=11)	
Leroi et al. (2020)	Peer reviewed journal	Mixed methods intervention	Level III / High	Aged 60+ Diagnosed mild-moderate dementia (AD,	<u>Sample size:</u> n=19 dyads <u>Age:</u> Median 76 (range 63-88) years	<u>Aim:</u> To field trial a prototype hearing and vision intervention in dementia	<u>Data source:</u> Caregiver report <u>Data type:</u>	<u>Enablers:</u> Improvement in knowledge, and skills in hearing aid use;

Cyprus,
France and
UK

VaD, mixed)
(MoCA ≥12)
Hearing loss
>35dB HL over 1-
3kHz in better ear
Community
dwelling
Study partner
available
Capacity to
consent

Exclusion:
Congenital
hearing loss
Unstable medical
or psychiatric
condition

Gender: 63% male
Cognitive status:
Mean MoCA 17.3
(range 12-23) –
indicative of
moderate cognitive
impairment / mild
dementia
Dementia type: 47%
diagnosed with AD;
47% VaD; 5% mixed
Hearing status:
Mean Better ear
Hearcheck score =
3.8
Living circumstances:
79% cohabiting with
study partner
Socioeconomic
status: Not reported
Ethnicity: Not
reported

Intervention: Binaural
digital BTE hearing
aids, troubleshooting
support. Glasses for
comorbid vision loss
n=4 dyads received an
additional extended
'sensory intervention'
from a Sensory
Support Therapist
(SST)
Control: No control
condition
Duration: 4 weeks
(basic intervention) /
12 weeks (extended
intervention)

Quantitative
(continuous)
Outcome: Data
for n=4: 4-12
hours/day; 4-7
days/week

Becoming confident in
hearing aid wear and care;
Setting goals related to
device use, device care,
communication, function,
and social inclusion;
Positive consequences of
hearing aid use (increased
confidence, increased
engagement in social and
leisure activities, improved
communication);
Fostering of positive affect;
Building care partner
device knowledge and skills
(8% improvement in
knowledge and 24%
improvement in skills on
HASK assessment);
Care partner
encouragement
Barriers:
Lack of awareness of the
presence of hearing loss
(HHIE-S mean baseline
score 7.87, indicative of no
perceived hearing loss);
Extraneous information
within manufacturer
manual;
Experiencing problems
with device fit
Non-correlates:
None reported

Nguyen et al.
(2017)
France

Peer reviewed
journal

Quantitative RCT
intervention with
semi-crossover design

Level I /
Moderate

Aged 65+
Diagnosed mild-
moderate AD
(MMSE 10-28)
Bilateral
sensorineural

Sample size: n=51
(randomised)
Age: Mean 82.6 (SD
6.69) years
Gender: 40% Male
Cognitive status:
Mean MMSE 19.52

Aim: To assess the
efficacy of hearing aid
provision on the
cognitive status of
people with
Alzheimer's disease
and hearing loss

Data source:
Caregiver log
Data type:
Quantitative
(continuous and
categorical)
Outcome:

Enablers:
Younger age was
associated with good
compliance (mean age was
80.3 for good/very good
users and 86 for bad/very

				<p>hearing loss (21-80dB HL) No hearing aids in last 2 years Able to tolerate HAs for at least 1 hour/day Living with caregiver.</p> <p>Exclusion: Not AD Recent introduction or dose change of AD treatment Break / lose HA twice or more during the study</p>	<p>(SD 4.51) – indicative of moderate dementia <u>Dementia type:</u> AD <u>Hearing status:</u> Mean hearing threshold 48.75dB (SD 10.48) <u>Living circumstances:</u> All cohabiting <u>Socioeconomic status:</u> Not reported <u>Ethnicity:</u> Not reported</p>	<p><u>Intervention:</u> Binaural digital hearing aids and audiologic rehabilitation <u>Control:</u> Dummy hearing aids which were activated at 6 months in a semi-crossover design <u>Duration:</u> 12 months. (Primary outcomes at 6 months)</p>	<p>Of the total sample 31.6% were categorised as bad and moderate users and 68.4% as good / very good users at 6 months Of the bad/moderate users, 66.7% were control group; of the good/very good users, 46.2% were control group. Daily use for 73.7% of active group and 59.1% of control group at 6 months.</p>	<p>bad – Hedges’ g 0.88 - large effect) <u>Barriers:</u> Insufficient audiological gain (66.7% of the bad/moderate hearing aid users were in the control group) <u>Non-correlates:</u> Stage of cognitive decline was not associated with compliance (Hedges’ g 0.1); Hearing threshold was not associated with hearing aid compliance (Hedges’ g 0.19)</p>
Nieman et al. (2018) USA	Conference abstract	Quantitative descriptive observational	Level III / Low	<p>Meet diagnostic criteria for dementia Community-dwelling Reliable study partner</p>	<p><u>Sample size:</u> n=647 <u>Age:</u> ≥65 years <u>Cognitive status:</u> Mild cognitive impairment / mild dementia (MMSE 21-30) 38%; Moderate dementia (MMSE 11-21) 40%; Severe dementia (MMSE 0-10) 18%. <u>Dementia type:</u> Not specified. <u>Hearing status:</u> Not reported <u>Living circumstances:</u> Not reported</p>	<p><u>Aim:</u> To establish the prevalence of proxy-rated hearing loss and hearing aid use of community-dwelling people with dementia</p>	<p><u>Data source:</u> Proxy report <u>Data type:</u> Quantitative (categorical binary) <u>Outcome:</u> <u>Use according to age:</u> 0% of 65-75 years; 17% of 75-85 years; 31.3% of 85+ years. <u>Use according to cognition:</u></p>	<p><u>Enablers:</u> None reported <u>Barriers:</u> Use was lower amongst participants with lower socio-economic status (effect size calculation not possible); Use was lower amongst younger participants (effect size calculation not possible); Use was lower amongst non-White participants (effect size calculation not possible) <u>Non-correlates:</u></p>

Nirmalasari et al. (2017) USA	Peer reviewed journal	Quantitative descriptive observational	Level III / Moderate	Aged 50+ Diagnosed cognitive impairment Hearing screened English speaking	<p><u>Socioeconomic status:</u> 15% low income (<\$11,000); 28% middle income (\$11-24,999); 57% high income (>\$25,000) <u>Ethnicity:</u> 44% White, 50% African American, 6% other</p> <p><u>Sample size:</u> n=100 <u>Age:</u> mean 76 (SD 9.3) years <u>Gender:</u> 42% male <u>Cognitive status:</u> Mean MMSE 21.8 (SD 5.4) – indicative of mild dementia <u>Dementia type:</u> 68% unspecified dementia; 32% MCI / other <u>Hearing status:</u> Mild loss 32%; moderate 25%; severe 3% <u>Living circumstances:</u> Not reported <u>Socioeconomic status:</u> Not reported</p>	<u>Aim:</u> Chart review to establish the prevalence of hearing loss in a memory clinic, and to investigate rates of hearing aid use and demographic associations within this	<p>25.6% of mild dementia; 16% of moderate dementia; 21.7% of severe dementia. <u>Use according to income:</u> 0% of <\$11,000; 23.5% of \$11-24,999; 23.7% of >\$25,000. <u>Use according to ethnicity:</u> 27.5% of white; 5.6 % of African-American; 0% of Other.</p> <p><u>Data source:</u> Clinical records <u>Data type:</u> Quantitative (categorical binary) <u>Outcome:</u> 21% of sample used hearing aids: 8% of those with no loss (n=3); 9% of those with mild loss (n=3); 54% of those with moderate-severe loss (n=15)</p>	Stage of cognitive decline was not associated with compliance (effect size calculation not possible)
							<p><u>Data source:</u> Clinical records <u>Data type:</u> Quantitative (categorical binary) <u>Outcome:</u> 21% of sample used hearing aids: 8% of those with no loss (n=3); 9% of those with mild loss (n=3); 54% of those with moderate-severe loss (n=15)</p>	<p><u>Enablers:</u> People with greater severity of hearing loss were more likely to use hearing aids (effect size calculation not possible) <u>Barriers:</u> None reported <u>Non-correlates:</u> None reported</p>

					<u>Ethnicity:</u> 68% White; 32% non-white			
Palmer et al. (1998) USA	Peer reviewed journal	Qualitative case study	Level III / Moderate	Not reported	<u>Sample size:</u> n=1 <u>Age:</u> 78 years <u>Gender:</u> Male <u>Cognitive status:</u> MMSE 18 – indicative of moderate dementia <u>Dementia type:</u> Mixed dementia <u>Hearing status:</u> BEA 58dB HL over 0.5,1,2 kHz <u>Living circumstances:</u> Cohabiting with spouse <u>Socioeconomic status:</u> Not reported <u>Ethnicity:</u> White	<u>Aim:</u> To report the impact of a hearing intervention on a person with dementia <u>Intervention:</u> Monaural ITE hearing aid, audiological training support and troubleshooting <u>Control:</u> No control condition <u>Duration:</u> 6 weeks pre-intervention; 8 weeks post-intervention	<u>Data source:</u> Caregiver log <u>Data type:</u> Quantitative (continuous) <u>Outcome:</u> 15 hours/day	<u>Enablers:</u> Awareness of hearing loss (baseline HHIE score 35); Identification of listening situation goals; Positive consequents of use (reduced hearing-related disability – significant reduction in HHIE score to 11 at follow-up, increased enjoyment in listening situations, increased communication); Care partner support with maintenance and use <u>Barriers:</u> Lack of troubleshooting knowledge for care partner <u>Non-correlates:</u> None reported
Palmer et al. (1999) USA	Peer reviewed journal	Quantitative non-randomised intervention	Level II / Low	Diagnosed mild-moderate AD (MMSE 12-24) HHIE-P >18% Bilateral sensorineural hearing loss appropriate for amplification Living at home with spouse / adult child Exclusion: Significant h/o alcohol abuse, schizophrenia,	<u>Sample size:</u> n=8 dyads <u>Age:</u> Mean 79 (range 71-89) years <u>Gender:</u> 62% male <u>Cognitive status:</u> Mean MMSE 14 (range 5-18) – indicative of moderate dementia <u>Dementia type:</u> AD <u>Hearing status:</u> Mean 40.4 dB HL over 0.5, 1, 2 KHz (range 21.7-56.6) <u>Living circumstances:</u> All cohabiting - 50%	<u>Aim:</u> To ascertain the impact of hearing aid provision on caregiver-identified problem behaviours of people with dementia <u>Intervention:</u> Monaural ITE hearing aid, audiological training support and troubleshooting <u>Control:</u> No control condition <u>Duration:</u> 6-10 weeks pre-intervention; 8 weeks post-intervention	<u>Data source:</u> Caregiver log <u>Data type:</u> Quantitative (continuous) <u>Outcome:</u> Median 9 hours/day (range 4-13)	<u>Enablers:</u> Severity of cognitive impairment (participants with greater impairment wore aids for longer per day – Hedges' g 0.28 - small effect); Positive intention for use; Positive consequents of use (Reduced hearing-related disability – significant positive change scores on HHIE for 3 / 4 participants, improved ability to engage in social and leisure activities, improved

				Parkinson's, head trauma, or CVA English not first language	with spouse; 50% with adult child <u>Socioeconomic status</u> : Not reported <u>Ethnicity</u> : Not reported			communication in 6 / 8 participants); Severity of hearing loss (participants with greater severity of hearing loss wore hearing aids for longer - Hedges' g 0.58 – medium effect) <u>Barriers</u> : Difficulty with handling skills (evident in 2/3 of sample); Misplacing hearing aids; Incomplete adaptation <u>Non-correlates</u> : Age was not associated with hearing aid use (Hedges' g 0.10) <u>Enablers</u> : Awareness of hearing loss (mean baseline HHIE score 66.7 (SD 17.9) – significant perceived hearing disability); Increased confidence in using and handling hearing aids; Positive consequents (reduced hearing-related disability – HHIE change score Hedges' g 3.50 - very large effect, improved ability to engage in social and leisure activities, improved communication); Fostering of positive affect (PHQ-9 Hedges' g 1.62 - large effect, GAD-7 Hedges' g 1.89 - large effect);
Sheikh et al. (2021) Pakistan	Peer reviewed journal	Mixed methods intervention	Level III / High	Aged 60+ Diagnosed with AD, VaD or mixed AD+VaD OR evidence of undiagnosed dementia Mild-moderate cognitive impairment (MoCA ≥10) Adult-acquired bilateral hearing loss worse than 35dB HL at 1000Hz and above in the better ear Capacity to consent Living at home Has a study partner – informal	<u>Sample size</u> : 15 <u>Age</u> : Median 64, range 60-80 years <u>Gender</u> : 47% male <u>Cognitive status</u> : Mean MoCA 15 (SD 2.9) range 10-20 (n=14) – indicative of moderate cognitive impairment / mild dementia 1 participant with score ≥26 (normal cognition) <u>Dementia type</u> : AD (n=1), VaD (n=1), undiagnosed (n=13) <u>Hearing status</u> : Not reported <u>Living circumstances</u> : All cohabiting – 50% with spouse; 40% with other family	<u>Aim</u> : To culturally adapt and evaluate the feasibility, acceptability and impact of a multifaceted hearing support intervention to enhance quality of life for PwD in Pakistan <u>Intervention</u> : Hearing aids (type not reported), training and support in HA use, goal setting, communication training, dementia awareness training (study partner) <u>Control</u> : No control condition <u>Duration</u> : Up to 13 weeks	<u>Data source</u> : Researcher report <u>Data type</u> : Qualitative (descriptive) <u>Outcome</u> : All participants were willing to use their prescribed aids. No report of frequency / duration.	

<p>caregiver ≥18years old</p> <p>Exclusion: Congenital hearing impairment Profound hearing loss Unstable medical or psychiatric condition Participating in trial of cognitive enhancing intervention</p>	<p><u>Socioeconomic status</u>: Not reported <u>Ethnicity</u>: Not reported</p>	<p>Improvement in care partner's device knowledge and skills; Care partner optimism about hearing aids <u>Barriers</u>: Negative perception of hearing loss as a disability; Lack of awareness that hearing aids may help <u>Non-correlates</u>: None reported</p>
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AD, Alzheimer's Disease; BEA, Better Ear Average; BTE, Behind the Ear; GAD-7, Generalised Anxiety Scale-7⁶⁶; HA, hearing aid; HASK, Hearing Aid Skills and Knowledge Test⁶⁷; HHIE-P, Hearing Handicap Inventory for the Elderly – Proxy⁶⁸; HHIE-S, Hearing Handicap Inventory for the Elderly – Screening⁶⁹; ITE, In the Ear; MCI, Mild Cognitive Impairment; MoCA, Montreal Cognitive Assessment⁷⁰; PHQ-9, Patient Health Questionnaire-9⁷¹; sMMSE, Standardised Mini Mental State Examination⁷²; VaD, Vascular dementia.

*Categorised according to the Mixed Methods Appraisal Tool (MMAT).³⁷

†Based on the Johns Hopkins Nursing Evidence-Based Practice framework (JHNEBP).³⁹

Supplementary Table S2. MMAT³⁷ quality and JHNEBP³⁹ quality and evidence levels appraisals

	Dupuis et al. (2016) ²⁸	Gregory et al. (2020) ⁴⁴	Hawkins (2011) ⁵⁵	Hutchison et al. (2012 ⁵¹ , 2012 ⁵²)	Kim et al. (2021) ⁴⁹	Leroi et al. (2020) ⁴⁵	Nguyen et al. (2017) ⁵⁴	Nieman et al. (2018) ⁵⁰	Nirmalasari et al. (2017) ⁴⁸	Palmer et al. (1998) ⁴⁷	Palmer et al. (1999) ⁵³	Sheikh et al. (2021) ⁴⁶
MMAT Checklist												
Screening												
Clear research question?	Yes	Yes	No	Yes	Yes	Yes	Yes	Can't tell	Yes	Can't tell	Yes	Yes
Collected data addresses research question?	Can't tell	Yes	Can't tell	Yes	Yes	Yes	Yes	Can't tell	Yes	Can't tell	Yes	Yes
Qualitative												
Appropriate approach?		Yes	Can't tell								Yes	
Adequate data collection methods?		Yes	Can't tell								Yes	
Findings adequately derived?		Yes	Can't tell								Can't tell	
Results sufficiently substantiated?		Yes	Can't tell								Yes	
Coherence?		Yes	No								Can't tell	
Quantitative RCT												
Randomisation performed appropriately?								Yes				
Groups comparable at baseline?								Yes				
Complete outcome data?								No				
Assessor blinding?								Yes				
Adherence to intervention?								No				
Quantitative nonrandomized												
Participants representative of target?	Yes											No
Measurements appropriate?	Can't tell											Yes
Complete outcome data?	No											No
Confounders accounted for?	Can't tell											Can't tell
Intervention administered as intended?	Can't tell											Can't tell
Quantitative descriptive												
Relevant sampling?							Can't tell		Can't tell	Yes		
Representative sample?							Can't tell		Can't tell	Yes		
Appropriate measurements?							Yes		No	No		
Low risk of non-response bias?							Yes		Can't tell	Yes		
Appropriate statistical analysis?							Yes		Can't tell	Yes		
Mixed methods												
Adequate rationale for mixed methods?				No			Yes					Yes
Effective integration of components?				Yes			Yes					Yes
Adequate interpretation of components?				No			Yes					Yes
Divergencies and inconsistencies adequately addressed?				Yes			Yes					Yes
Adherence to quality criteria?				No			Yes					Yes
JHNEP results												
Evidence level	Level II	Level III	Level V	Level III	Level III	Level III	Level I	Level III	Level III	Level III	Level II	Level III
Quality rating	C	A/B	C	C	B	A	B	C	B	C	C	A
Quality category	Low	High	Low	Low	Moderate	High	Moderate	Low	Moderate	Moderate	Low	High

Supplementary Table S3. GRADE-CERQual⁴² outcomes

TDF Domain	Component Construct	Studies Contributing to the Construct	Assessment of Methodologic Limitations	Assessment of Coherence	Assessment of Adequacy	Assessment of Relevance	Overall Assessment of Confidence	Explanation of Judgement
Knowledge	Awareness of the presence of disabling hearing loss is associated with hearing aid use	45-47, 51, 52	Moderate concerns	Moderate concerns	Moderate concerns	Mild concerns	Low confidence	Low confidence due to moderate concerns in relation to coherence, adequacy, and methodology
	Degree of procedural knowledge influences hearing aid use: lack of knowledge impedes use whereas improvement in knowledge enables use	28, 44, 45, 55	Moderate concerns	Moderate concerns	Moderate concerns	Moderate concerns	Low confidence	Low confidence due to moderate concerns in relation to coherence, adequacy, relevance, and methodology
	Standard manufacturer guidance does not enable hearing aid use	45, 55	Moderate concerns	Minor concerns	Moderate concerns	Minor concerns	Moderate confidence	Moderate confidence due to moderate concerns in relation to adequacy and methodology
Skills	Degree of hearing aid handling proficiency influences hearing aid use: difficulty in handling inhibits use whereas being able to handle aids proficiently enables	28, 44-46, 52, 53, 55	Moderate concerns	Minor concerns	No or very minor concerns	Minor concerns	High confidence	High confidence because despite some methodologic limitations, there was a body of relevant data to support the finding
Memory, attention, and decision processes	Severity of cognitive impairment does not appear to be associated with hearing aid use	50, 53, 54	Substantial concerns	Minor concerns	Moderate concerns	Minor concerns	Low confidence	Low confidence due to substantial methodologic limitations of the studies and moderate concerns about adequacy
	Misplacing hearing aids is a barrier to their use; having a	44, 53	Moderate concerns	Moderate concerns	Moderate concerns	Minor concerns	Moderate confidence	Moderate confidence due to moderate concerns

	set place for storage is an enabler							about adequacy and methodologic quality
	Forgetting to use hearing aids is a barrier to their use; implementing compensatory strategies is an enabler	44	No or very minor concerns	Moderate concerns	Serious concerns	Minor concerns	Low confidence	Low confidence due to substantial concerns about adequacy and moderate concerns about coherence
Behavioural regulation	Developing habitual routines enables hearing aid use	44	No or very minor concerns	Moderate concerns	Serious concerns	Minor concerns	Low confidence	Low confidence due to substantial concerns about adequacy and moderate concerns about coherence
	Degree of adaptation to hearing aids influences their use; perseverance is an enabler	44, 53	Moderate concerns	Minor concerns	Serious concerns	Minor concerns	Low confidence	Low confidence due to substantial concerns about adequacy and moderate concerns about methodology
	Resistance to change is a barrier to hearing aid use	55	Substantial concerns	Minor concerns	Moderate concerns	Minor concerns	Low confidence	Low confidence due to substantial concerns about methodology and moderate concerns about adequacy
Role and identity	Mind-set towards the visibility of hearing aids influences their use: concern about their visibility is a barrier whereas welcoming their visibility is an enabler	44, 46	No or very minor concerns	Moderate concerns	Moderate concerns	Minor concerns	Moderate confidence	Moderate confidence due to moderate concerns about coherence and adequacy
Beliefs about capabilities	Degree of self-confidence in ability to handle hearing aids influences their use: low confidence is a barrier whereas increasing confidence is an enabler	45, 55	Moderate concerns	Moderate concerns	Moderate concerns	Minor concerns	Low confidence	Low confidence due to moderate concerns in relation to coherence, adequacy, and methodology

Optimism	Optimism about efficacy about hearing aids enables their use	44	No or very minor concerns	Moderate concerns	Serious concerns	Minor concerns	Low confidence	Low confidence due to substantial concerns about adequacy and moderate concerns about coherence
Beliefs about consequences	Absence of - or negative – expectancy about the outcomes of hearing aids are barriers to their use	44, 46	No or very minor concerns	Moderate concerns	Moderate concerns	Minor concerns	Moderate confidence	Moderate confidence due to moderate concerns about coherence and adequacy
Intentions	Degree of intent influences hearing aid use: lack of intent is a barrier whereas positive intent is an enabler	44, 53	Moderate concerns	No or very minor concerns	Moderate concerns	Minor concerns	Moderate confidence	Moderate confidence due to moderate concerns about adequacy and methodology
Goals	Identification of goals relating to hearing aids enables their use	28, 45, 47	Moderate concerns	Substantial concerns	Moderate concerns	Moderate concerns	Low confidence	Low confidence due to substantial concerns about coherence and moderate concerns about adequacy, relevance, and methodology
Reinforcement	Experiencing positive consequents of hearing aids is associated with their use	28, 44-47, 51, 53, 54	Moderate concerns	Minor concerns	No concerns	Moderate concerns	High confidence	High confidence because although there were moderate concerns about relevance and methodology, there were only very minor concerns about coherence and adequacy
	Degree of fit /comfort influences hearing aid use: problems with fit are a barrier whereas finding them comfortable is an enabler	44, 45	No or very minor concerns	Minor concerns	Moderate concerns	Minor concerns	High confidence	High confidence because although there were moderate concerns about adequacy due to low quantity, the data were rich enough to support this interpretation

Emotion	Negative emotional responses to hearing aids are a barrier to their use, whereas positive impact on affective state resulting from hearing aid use is an enabler	44-46, 49, 51, 55	Moderate concerns	Minor concerns	No or very minor concerns	Moderate concerns	Moderate confidence	Moderate confidence due to moderate concerns about relevance and methodology
Environmental context and resources	Factors related to person-environment interactions influence hearing aid use: excessive noise or perceived lack of need in differing listening situations lead to reduced use	44	No or very minor concerns	No or very minor concerns	Minor concerns	Minor concerns	High confidence	High confidence because although it was only represented in 1 study, this was a high quality, relevant study and there were no concerns about coherence
	Lack of financial resources negatively influence hearing aid use	50, 52	Substantial concerns	Minor concerns	Minor concerns	Substantial concerns	Low confidence	Low confidence due to substantial concerns in relation to relevance and methodologic quality of the studies
Social influences	Proactive care partner support with handling and maintaining hearing aids enables their use	44, 47, 52	Moderate concerns	Minor concerns	Moderate concerns	Moderate concerns	Low confidence	Low confidence due to moderate concerns in relation to adequacy, relevance, and methodologic quality
	Lack of care partner hearing aid knowledge is a barrier, presence of care partner knowledge, skills and optimism are enablers	45-47	Minor concerns	Moderate concerns	Minor concerns	Moderate concerns	Moderate confidence	Moderate confidence due to moderate concerns about coherence and relevance
	Receiving social reinforcement enables hearing aid use	44, 45, 53	Minor concerns	Minor concerns	Minor concerns	Minor concerns	High confidence	High confidence because there were only minor concerns in each domain
Other	Degree of hearing loss may not influence hearing aid use	48, 52-54	Moderate concerns	Moderate concerns	Minor concerns	Moderate concerns	Low confidence	Low confidence due to moderate threats to coherence, relevance,

Age may not influence hearing aid use	50, 53, 54	Substantial concerns	Moderate concerns	Minor concerns	Minor concerns	Low confidence	and methodologic limitations Low confidence due to moderate threats to coherence and substantial methodologic limitations
Ethnicity influences hearing aid use: non-White ethnic groups are less likely to use hearing aids	50	Substantial concerns	No or very minor concerns	Moderate concerns	Moderate concerns	Low confidence	Low confidence due to moderate concerns about adequacy and relevance, and substantial methodologic concerns

Appendix 3:

Enablers and barriers to hearing aid use in people living with dementia

Supplementary Table 1. COREQ (CONSOLIDATED criteria for REporting Qualitative research) Checklist

Item No.	Item	Guide questions / description	Reported on Page No.
Domain 1: Research team and reflexivity			
Personal characteristics			
1.	Interviewer/facilitator	Which author/s conducted the interview or focus group?	4
2.	Credentials	What were the researcher's credentials?	4 + title page
3.	Occupation	What was their occupation at the time of the study?	4
4.	Gender	Was the researcher male or female?	4
5.	Experience and training	What experience or training did the researcher have?	4
Relationship with participants			
6.	Relationship established	Was a relationship established prior to study commencement?	4
7.	Participant knowledge of the interviewer	What did the participants know about the researcher?	4
8.	Interviewer characteristics	What characteristics were reported about the interviewer/facilitator?	4
Domain 2: study design			
Theoretical framework			
9.	Methodological orientation and Theory	What methodological orientation was stated to underpin the study?	2, 5
Participant selection			
10.	Sampling	How were participants selected?	3
11.	Method of approach	How were participants approached?	3
12.	Sample size	How many participants were in the study?	5
13.	Non-participation	How many people refused to participate or dropped out? Reasons?	5
Setting			
14.	Setting of data collection	Where was the data collected?	4
15.	Presence of non-participants	Was anyone else present besides the participants and researchers?	4
16.	Description of sample	What are the important characteristics of the sample?	5, Table 2
Data collection			
17.	Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested?	3, 4
18.	Repeat interviews	Were repeat interviews carried out? If yes, how many?	4
19.	Audio/visual recording	Did the research use audio or visual recording to collect the data?	5
20.	Field notes	Were field notes made during and/or after the interview or focus group	5
21.	Duration	What was the duration of the interviews or focus group?	4
22.	Data saturation	Was data saturation discussed?	No
23.	Transcripts returned	Were transcripts returned to participants for comment and/or correction?	5
Domain 3: analysis and findings			
Data analysis			
24.	Number of data coders	How many data coders coded the data?	5
25.	Description of the coding tree	Did authors provide a description of the coding tree?	5
26.	Derivation of themes	Were themes identified in advance or derived from the data?	5
27.	Software	What software, if applicable, was used to manage the data?	Not included
28.	Participant checking	Did participants provide feedback on the findings?	5
Reporting			
29.	Quotations presented	Were participant quotations presented to illustrate the themes / findings? Was each quotation identified?	6-10
30.	Data and findings consistent	Was there consistency between the data presented and the findings?	5-10

31.	Clarity of major themes	Were major themes clearly presented in the findings?	5-10
32.	Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes?	5-10

Developed from: Tong A, Sainsbury P, Craig J. (2007) Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care*. 19 (6): pp. 349 – 357

Supplementary Material 1. Enablers and barriers to hearing aid use in dementia qualitative interview schedule

Icebreaker: Could you start by telling me a bit of background about how you came to get hearing aids in the first place?

Optimism: When you found out that you needed hearing aids, what were your expectations of how they could help you?

Did you have any concerns about getting hearing aids?

Knowledge: Next, I would like to find out about any advice that you have received.

What advice or guidance have you been given about your hearing aids?

(e.g. how much to use them, how to care for them)

Who gave you this advice?

Does this advice influence your use of your hearing aids? In what ways?

Is there any aspect of using your hearing aids that you still feel unsure about?

Use and maintenance (Overview): Now we are going to spend some time focusing on how you feel that you are getting on with using your hearing aids.

How do you remember to use your hearing aids?

Is there anything that helps you to remember to use them?

When it comes to using and looking after your hearing aids, what is your responsibility for that?

What do you find easy?

What do you find hard?

How confident are you about looking after and using your hearing aids yourself?

Use (handling, insertion and removal): When it comes to the practicalities of handling your hearing aids,

(a) How well are you able to physically handle your hearing aids?

Is there anything that you find difficult about this?

(b) When it comes to putting your hearing aids in:

How well are you able to tell the right and left hearing aids apart?

What helps with this?

How confident are you with putting your hearing aids in and taking them out?

How well are you able to maintain your concentration when you are putting your hearing aids in and taking them out?

How well do you go on with getting all of the steps in the right order when you are putting your hearing aids in and taking them out?

Maintenance: When it comes to keeping your hearing aids in good working order,

(a) How do you know when you need to change the batteries?

How well are you able to change the batteries?

How confident do you feel about doing this?

How well are you able to maintain your concentration when you are changing your hearing aid batteries?

(b) What do you know about keeping your hearing aids clean?

How well are you able to keep them clean?

How confident are you with this process?

How well are you able to maintain your concentration when you are cleaning your hearing aids?

Use and maintenance (Task completion): Overall, when it comes to the things you do to use and look after your hearing aids,

How well do you go on with getting all of the steps in the right order?

What helps you to see these tasks through?

What gets in the way?

Overcoming problems: How do you manage any problems you have with your hearing aids?

How optimistic are you that you can overcome any problems that you may have with using your hearing aids?

When you come across problems using or maintaining your hearing aids does this influence your likelihood of wearing them?

Skill development: Moving on, you have had your hearing aids for a little while now,

I would like to ask if you feel that your ability to use them has changed since you first got them. In what ways?

What training or support have you received to help you to use your hearing aids?

Has this made a difference to you? In what ways?

Social influences & Interpersonal skills: I would like to ask you now about any help or support that you get from other people.

Does someone else help you to manage your hearing aids? Who?

In what ways do they help you with this?

What is it like for you to have this support?

How well are you able to work with the person who helps you with your hearing aids?

How do you let them know that you need their help with this?

Do they change the way you feel about using hearing aids? In what ways?

More generally, do the views or presence of other people make you any more or less likely to use your hearing aids? Who and why?

Behavioural regulation: We are about half way through my questions now. Next, I would like to ask you some questions about your pattern of hearing aid use.

How do you get yourself into the habit of wearing your hearing aids?

If you think about a typical day, what is your routine for your hearing aid use?

How satisfied are you with this routine?

How do you decide when to wear your hearing aids?

If you take them out during the day, do you choose to put them back in again later on?

Intentions: How much do you intend to use your hearing aids?

Has your intention to use them changed over time? (e.g. think back to when they were recommended to you – how much did you intend to use them at the start?)

What affects these intentions?

Environmental context and resources: The questions so far have focused on you and people around you. Now we are going to explore other things that you have around you that may help or hinder your hearing aid use.

Is there anything about the environment around you that makes it easier for you to use your hearing aids?

Potential areas for exploration:

Is there anything around you that helps you to not lose your hearing aids?

How do you get on with keeping track of the things you need to maintain your hearing aids (batteries, cleaning wires etc.)?

What other things do you have around you that help you to manage or use your hearing aids?

Is there anything about the environment around you that makes it harder for you to use your hearing aids? (e.g. clutter / lighting)

Does anything about the place where you are influence your use of your hearing aids? (e.g. is it different for you at home to when you are in a busy place?)

Beliefs about consequences: My next questions are about the outcomes of wearing hearing aids.

Does wearing hearing aids change your day? In what ways?

In what ways is your hearing different with hearing aids?

In what ways are hearing aids a good thing for you? And for your family or friends?

Are there any other positive effects of wearing hearing aids that makes you more likely to keep using them?

What are the downsides of hearing aids? (For you? For your family or friends?)

Are there any other negative effects of wearing them that make you less likely to use them?

Emotion: Is wearing hearing aids an enjoyable experience for you? Why / why not?

What positive or negative emotions does using hearing aids bring about in you?

Social identity: Do you think of yourself as being a hearing aid user?

How does wearing hearing aids make you feel about yourself?

Goals: We are coming towards the end of my questions now, so I would like to find out about your plans for wearing your hearing aids.

What do you want to achieve by wearing hearing aids?

How important is it to you to wear hearing aids?

What are your longer-term plans for using your hearing aids?

Closing: As we draw to a close,

Are there any other things that might encourage you to wear your hearing aids?

Are there any other things that hold you back from wearing your hearing aids?

Finally, is there anything else that you would like to tell me about how get on with your hearing aids?

Thank you for helping us to find out more about the things that help or hinder you from wearing your hearing aids. This information will help us to plan how best to support people like you in the future.

Appendix 4: Discussion

Table A4.1. Identification of associations with hearing aid use according to TDF domains and COM-B components

COM-B component	Linked TDF domain	Associations with hearing aid use	Evidence Source
Physical capability	Physical skills	Hearing aid handling proficiency	Systematic review
Psychological capability	Knowledge	N/A	-
	Cognitive skills	Cognitive ability	Quantitative study
	Memory, attention, and decision processes	N/A	-
Physical opportunity	Behavioural regulation	Establishing routines	Qualitative study
	Environmental context and resources	Establishing place	Qualitative study
		Features of hearing aids and their resources	Qualitative study
Social opportunity	Social influences	Social reinforcement or support	Systematic review Qualitative study
		Professional support	Qualitative study
Reflective motivation	Social / professional role and identity	Cultural influences	Quantitative study
		N/A	-
	Beliefs about capabilities	N/A	-
Automatic motivation	Optimism	Self-perceived hearing difficulty	Quantitative study
	Intentions	Perceived need in differing listening situations	Systematic review
		Hearing acuity	Quantitative study
		N/A	-
	Goals	N/A	-
	Beliefs about consequences Reinforcement	N/A	-
		Perceived benefits of hearing aids	Qualitative study
Experiential consequences of hearing aid use		Systematic review Qualitative study	
Emotion	Emotion	Fit and comfort of hearing aids	Systematic review
		N/A	-

Table A4.2. Identification of intervention functions to address barriers to hearing aid use in dementia according to COM-B components and TDF domains

COM-B component	Linked TDF domain	Barrier	Intervention functions
Physical capability	Physical skills	Difficulty in handling hearing aids	Training
Psychological capability	Cognitive skills	Greater cognitive impairment	Training Enablement
	Behavioural regulation	Lack of established routine for hearing aid wear and care	Training Enablement
Physical opportunity	Environmental context and resources	Lack of established place to store and maintain hearing aids	Enablement
		Lack of access to effective hearing aids and resources	Enablement
Social opportunity	Social influences	Lack of social reinforcement or support	Enablement
		Lack of professional support	Environmental restructuring
		Stigmatisation / poor social representation of hearing disability	Environmental restructuring
Reflective motivation	Optimism	Lack of recognition of hearing difficulty	Education
		Lack of awareness of need for hearing aids	Education
Automatic motivation	Reinforcement	Lack of perceived benefits of hearing aids	Incentivisation
		Lack of perceived positive experiential consequences from hearing aid use	Incentivisation
		Uncomfortable or poorly fitting hearing aids	Enablement

Table A4.3. Evaluation of intervention functions according to the APEASE criteria

Candidate intervention functions	Does the intervention function meet the APEASE criteria (affordability, practicability, effectiveness / cost-effectiveness, acceptability, side-effects / safety, equity) in the context of hearing aid use in people with dementia?
Training	Not practicable in the current context of service delivery. Would necessitate a bespoke pathway that included increased intervention duration and training in cognitive rehabilitation techniques for audiologists.
Enablement	Yes
Environmental restructuring	Not practicable in the current context of service delivery. Would necessitate a bespoke pathway that included increased intervention duration and availability and / or cultural change that is beyond scope.
Education	Yes
Incentivisation	Yes

Table A4.4. Identification of policy categories to support the implementation of intervention functions

Intervention function	COM-B component	Linked TDF domain	Potentially useful policy categories	Does the policy category meet the APEASE criteria in the context of hearing aid use in people with dementia?	
Enablement	Psychological capability	Cognitive skills	Guidelines	No	
			Fiscal measures	Not relevant	
			Regulation	Not relevant	
			Legislation	Not practicable	
			Environmental / social planning	Not practicable	
		Behavioural regulation	Service provision	Yes	
			Guidelines	No	
			Fiscal measures	Not relevant	
			Regulation	Not relevant	
			Legislation	Not practicable	
	Physical opportunity	Environmental context and resources	Environmental / social planning	Not practicable	
			Service provision	Yes	
			Guidelines	No	
			Fiscal measures	Not practicable	
			Regulation	Not practicable	
		Social opportunity	Social influences	Legislation	Not practicable
				Environmental / social planning	Not practicable
				Service provision	Yes
				Guidelines	No
				Fiscal measures	Not relevant
Automatic motivation	Reinforcement	Regulation	Not relevant		
		Legislation	Not relevant		
		Environmental / social planning	Not relevant		
		Service provision	Yes		
		Guidelines	No		
	Reflective motivation	Optimism	Fiscal measures	Not relevant	
			Regulation	Not relevant	
			Legislation	Not relevant	
			Environmental / social planning	Not relevant	
			Service provision	Yes	
Incentivisation	Automatic motivation	Reinforcement	Yes		
		Communication / marketing	Potentially		
		Guidelines	Not relevant		
		Regulation	Not relevant		
		Legislation	Not relevant		
			Service provision	Yes	

Policy categories selected: Communication / marketing, service provision

Table A4.5. Evaluation of Behavioural Change Techniques to support hearing aid use in people with dementia

Intervention function	COM-B component	Linked TDF domain	BCTs	Does the BCT meet the APEASE criteria in the context of hearing aid use in people with dementia?
Enablement	Psychological capability	Cognitive skills	Social support (unspecified)	Yes (encouragement)
		Behavioural regulation	Social support (practical)	Yes
	Physical opportunity	Environmental context and resources	Goal setting (behaviour)	Potentially
			Goal setting (outcome)	Unlikely to be effective in this context
	Social opportunity	Social influences	Adding objects to the environment	Yes
			Problem solving	Yes
	Automatic motivation	Reinforcement	Action planning	Potentially
			Self-monitoring of behaviour	Unlikely to be effective in this context
			Restructuring the physical environment	Yes
			Restructuring the social environment	Yes
Review behaviour goals			Potentially	
Review outcome goals			Unlikely to be effective in this context	
Education	Reflective motivation	Optimism	Information about social and environmental consequences	Yes
			Information about health consequences	Yes
			Feedback on behaviour	Yes
			Feedback on outcomes of the behaviour	Yes
			Prompts/cues	Yes
			Self-monitoring of behaviour	Unlikely to be effective in this context
			Feedback on behaviour	Yes
Incentivisation	Automatic motivation	Reinforcement	Feedback on outcomes of behaviour	Yes
			Monitoring of behaviour by others without evidence of feedback	Unlikely to be effective in this context
			Monitoring outcome of behaviour by others without evidence of feedback	Unlikely to be effective in this context
			Self-monitoring of behaviour	Unlikely to be effective in this context

BCTs selected:

Social support (unspecified)
 Social support (practical)
 Adding objects to the environment
 Problem solving
 Goal setting (behaviour)
 Action planning
 Goal review (behaviour)
 Prompts/cues
 Restructuring the physical environment
 Restructuring the social environment
 Information about social and environmental consequences

Feedback on behaviour

Feedback on outcomes of the behaviour
