Remote technologies to enhance service delivery for adults: clinical research perspectives

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Abstract

There are many examples of remote technologies that are clinically-effective, and provide numerous benefits to adults with hearing loss. Despite this, the uptake of remote technologies for hearing healthcare has been both low and slow until the onset of the COVID-19 pandemic, which has been a key driver for change globally. The time is now right to take advantage of the many benefits that remote technologies offer, either through clinical, consumer or hybrid services and channels. These include greater access and choice, and better interactivity, engagement and tailoring of technologies to individual needs, leading to clients who are better informed, enabled and empowered to self-manage their hearing loss. This article provides an overview of the clinical research evidence-base across a range of remote technologies along the hearing health journey. This includes qualitative, as well as quantitative, methods to ensure the end-users' voice is at the core of the research, thereby promoting person-centred principles. Most of these remote technologies are available and some are already in use, albeit not widespread. Finally, whenever new technologies or processes are implemented into services, be they clinical, hybrid or consumer, careful consideration needs to be given to the required behaviour change of the key people (e.g. clients and providers) to facilitate and optimise implementation.

Key words: Remote technologies, connected hearing healthcare, service delivery models, consumer channels, over-the-counter, implementation science

Learning outcomes

1. Provide an overview of research that has used remote technologies along the hearing healthcare journey, and describe three specific remote technologies in terms of what they do, and how they might benefit adults with hearing loss.

2. Demonstrate an understanding of the impact of the COVID-19 pandemic on the use of remote technologies and services.

3. Describe how the COM-B health behaviour change model can be used to describe benefits of, and identify barriers and facilitators to, the use of remote technologies.

Introduction

In the 2000s, there was a slow introduction of telehealth to provide audiology services including screening, diagnosis and interventions[1]. The value of such services then, as with now, is that service delivery models that use remote technologies have the potential to maximise limited global healthcare resources by providing greater, and more flexible, opportunities for clients and healthcare professionals, thereby optimising hearing healthcare[2]. Benefits of telehealth are numerous, most notably greater equity and access to healthcare by overcoming barriers of time, mobility, and geography. The latter is particularly the case in countries with a large land mass, such as Australia, with scattered populations in rural and remote communities. Other benefits include the potential for more individualised and tailored healthcare, greater interactivity that can lead to improved engagement with services, and greater opportunities for self-monitoring and self-evaluation, leading to increased self-management, which is particularly important for chronic conditions such as hearing loss[3].

More recently, the opportunities to gather huge amounts of 'big data' feed into an increasing use of machine learning and artificial intelligence to provide more personalised healthcare[4].

As the field has developed within audiology so has the terminology, whereby telehealth-delivered audiology services can be referred to as connected hearing healthcare, teleaudiology, e-audiology, amongst others[2,5,6]. All these terms encompass the broad use of telehealth and ehealth, of which mhealth is a subcategory that delivers healthcare via mobile technologies. In brief, these terms encompass a combination of people, processes and technology. Here, we use the term 'connected hearing healthcare (CHH)', which has been defined as "access to hearing healthcare that integrates big data, technology and machine learning to individualise services for everyone"[7]. We use the term 'remote technologies' to refer to component parts of CHH.

The use of remote hearing technologies no longer sits solely within clinical audiology. Since 2016, with a focus on priorities for improving accessibility and affordability for hearing healthcare in adults[8], there has been an increase in the number and availability of consumer products. These can be delivered through various consumer models, commonly known as over-the-counter (OTC) or direct-to-consumer (DTC). Despite being the subject of many opinion pieces, there is little clarity on how these technologies are evolving or are likely to evolve over the next decade in terms of service (in-person, clinical, user-led) and channel (e.g. clinical, consumer). Thus, it is timely that a framework to conceptualise these has been proposed (see Brice et al, this issue[9]).

There is also a lack of clarity in the terminology for OTC and DTC models, as well as for the hearing devices that are delivered within these models. For example, OTC and DTC are often

Table 1. Consensus relating to device features for hearable, OTC hearing device, PSAP, self-fitting hearing aid, wearable and hearing aid. ✓✓, >90% agreement; ✓, 80-90% agreement; ✗✗, >90% disagreement; ✗, 80-90% disagreement. For <80% agreement, both percentage and direction (✓ agree; ✗ disagree; ❓ neither agree/disagree) are provided. OTC=over-the-counter; PSAP=personal sound amplification product.

	Hearable	OTC hearing device	PSAP	Self-fitting hearing aid	Wearable	Hearing aid
Provides amplification	75% ✓	✓✓	✓✓	✓✓	45% ❓	✓✓
Has fixed pre-programmes	45% ✓	65% ✓	75% ✓	35% ✗	60% ❓	55% ✓
Can be programmed to a prescriptive target	40% ✗	55% ✓	45% ❓	✓	75% ✗	✓✓
User can adjust frequency/gain using controls on device	50% ✓	✓	✓✓	✓✓	50% ✗	✓✓
User can adjust frequency/gain using remote technologies (e.g. smartphone app)	✓	60% ❓	65% ❓	✓	55% ❓	75% ✓
Device itself can be customised to physically fit user's ear canal	✗	50% ✓	55% ✗	70% ✓	65% ✗	✓✓
Is only for people with hearing-related difficulties	✗✗	✓	50% ✗	✓✓	75% ✗	✓✓
Is considered a medical/healthcare device	✗✗	45% ✓	✗✗	✓	75% ✗	✓✓

used interchangeably, and similarly each is often used interchangeably for both devices and services (e.g. an OTC device, an OTC delivery model). This lack of clarity can lead to confusion. To address this, a three-round electronic Delphi review of 21 leading international hearing healthcare experts was conducted in 2019, with the aim of reaching a consensus on the characteristics and definitions of the terms commonly used (see Table 1). Although there are characteristics that elicited high agreement or disagreement (≥80%), there remains a lack of consensus in just over half (55%) the characterstic/device combinations. As is also discussed by Penno & Zakis (see this issue[10]), while there are areas of shared commonalities, the appropriate application of each device type is informed by a clearer understanding of their functionalities and capabilities. Currently, conventional hearing aids are typically differentiated from 'alternative hearing or listening devices' in that hearing aids are a registered medical product and the alternatives are not.

Despite the proliferation of remote technologies over the last decade, uptake within clinical services has remained low, as has the development of clinical audiology services and new delivery models to implement these new technologies effectively[11]. Three key considerations in developing and implementing such services are, (i) a robust research evidence-base, (ii) input from key stakeholders to ensure new technologies and services are aligned to the needs of end-users (e.g. clients, consumers, hearing care professionals, consumer industry)[12], and (iii) access to the necessary connectivity and infrastructure to deliver these services. The global COVID-19 pandemic that took hold early in 2020 was an unexpected and substantial driver for change. This resulted in a need to consider alternative models of care to the conventional high-touch audiology services because of the need of services to use low-touch and no-touch options[13,14]. The increase in the use of remote technologies and CHH services in the first half of 2020, as clinical services strived to continue to provide for their clients[15-17],

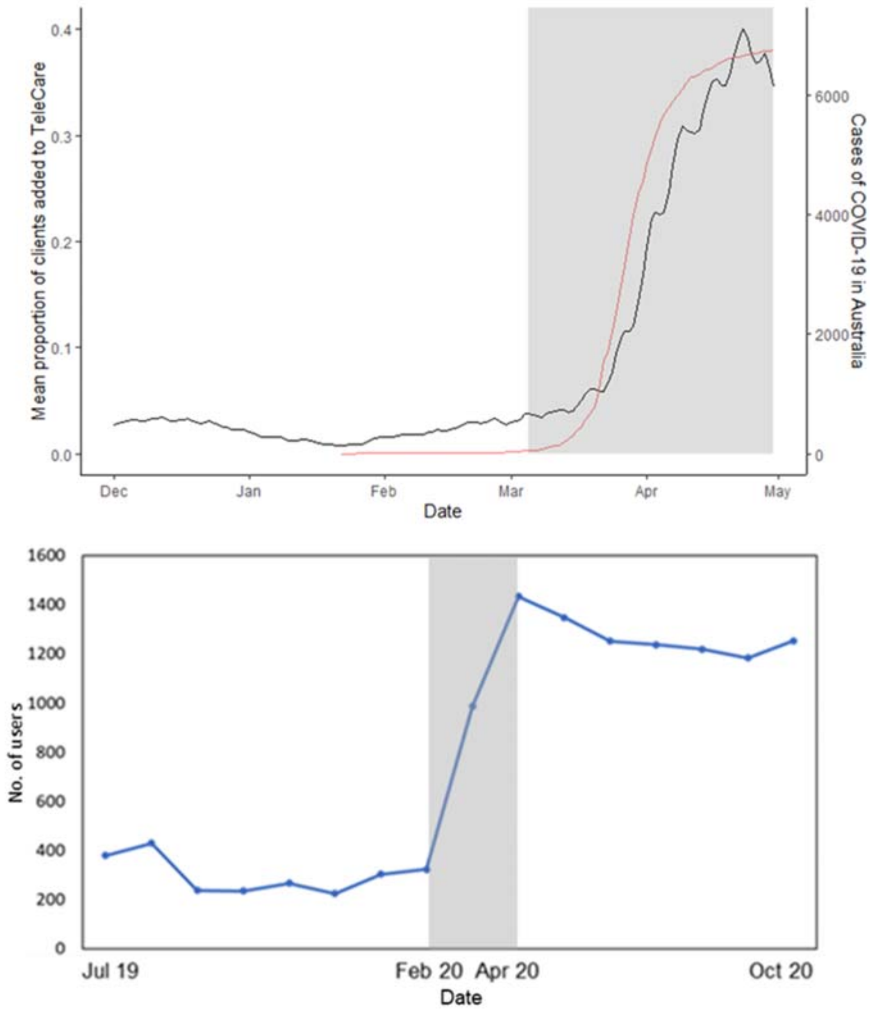

Figure 1. Impact of COVID-19 on the uptake of (a) user-controlled hearing aids in Australia, smooth line = increase in cases of COVID-19, and (b) m2Hear, a remote educational program for hearing aid users, in the UK. Grey area – start of the pandemic in Australia and UK.

As the world has learned to live with the new 'COVID-19 normal', and pandemic-related restrictions have subsided somewhat, there has generally been a subsequent decrease in the use of CHH services[18]. To further support clinicians in adapting to the "new normal" of providing such services, Audiology Australia has developed Teleaudiology Guidelines to support the safe and effective delivery of hearing services through teleaudiology[19]. The guidelines provide practice operations and clinical guidance on the use of teleaudiology practices and are accompanied by a series of consumer resources (written and video) and a resource for audiologists that lists organisations and websites to assist them with skill development and implementation planning.

Research on hybrid service delivery models, whereby there is a combination of, and interplay between, in-person and remote technologies at various points along the client pathway, suggests that hybrid (or blended) models result in positive experiences[20-22]. An example of a hybrid model, described by Ratanjee-Vanmali et al[20], involved online delivery through WhatsApp for hearing screening and motivational engagement, hearing aid trial and fitting were delivered in-person, and aural rehabilitation was delivered using both delivery methods. Arnold et al[22] delivered a hybrid service model through a manufacturer develop app (myPhonak) to obtain outcomes measures and real ear aided responses. As such, it is likely that we will see more focus on hybrid systems in the future with a greater interplay of in-person and remote technology.

To date, there has been limited research on hybrid systems and much of the CHH research has been conducted for specific interventions at various points along the hearing health journey (i.e. awareness, take action, assessment, intervention, ongoing support). Therefore, the aim of this article is to provide an overview of the research evidence for remote technologies along the hearing health journey, consider the effectiveness of these alongside barriers and facilitators, and discuss what works from a clinical, hybrid or consumer perspective. This is of particular relevance to audiologists and service providers because most of the technologies discussed are already available, and some are already in use in clinical, hybrid and consumer services. In short, these technologies have an evidence-base, are a reality, available and ready to use now.

Awareness

Awareness and understanding of hearing loss among the general public is poor[23]. The insidious nature of hearing loss means that many people are not aware they have hearing difficulties, often blaming others for 'mumbling'. However, even if people become aware of having hearing difficulties, they often do not know where to go for advice or where to go to get their hearing tested, and even if they do know what to do, they are not aware of the range of options available to them[24].

In Australia, there have been calls for a national hearing awareness campaign[25] similar to the Australian 'slip slop slap' campaign for skin cancer that showed that it is possible to increase the awareness of public health issues through the media and other routes[26]. Identifying target groups is a first step by using the TARPARE framework (T, number of people in the group; AR, proportion at-risk of a health issue; P, persuasibility of the target group; R, resources required to meet the group's need; and E, equity considerations). A recent study identified six target groups relating to hearing loss, of which the top three were young children and caregivers, people aged 50-75 years, and teenagers and young adults. Three themes were identified (i) accessibility and availability of hearing services, (ii) deciding on a preventative or treatment-focussed approach, and (iii) the difficulty of changing behaviour[27]. Accessibility, availability, and prevention are likely to be increased by the provision of online hearing and screening tests. Changing behaviour is key to most aspects of hearing healthcare[28], which we discuss throughout this article.

Hearing screening programmes have traditionally been used to raise awareness of hearing loss in the community and workplace[29]. Awareness of hearing loss is the first step to changing the behaviour of individuals and taking action for rehabilitation of their hearing loss[30]. Examples of models to reach the population include mobile screening programmes for rural and remote regions[31]; noise awareness programmes for children in their schools[32]; the World Health Organization's app to prevent hearing loss in the 1 billion young people at risk of exposure to entertainment-related noise[33]; and nationally-available screening programmes by phone[34] or online[35]. Screening in primary care centres has also been shown to be a cost-effective way to identify hearing loss in older adults[36].

Take Action

A major challenge is that many people do not seek help for hearing problems even when they are aware of hearing loss[37]. CHH may be a route to address this due to increased convenience and access, greater opportunities to provide important information for decision-making, and reduced time and costs to travel for clinic appointments. But what is the willingness to use CHH?

Experience using connected health amongst the general population has increased due to the COVID-19 pandemic, and clinicians have indicated a high level of willingness to consider CHH for audiology[17]. However, the same levels of use are not seen amongst adults with hearing loss. Our recent online survey exploring telehealth use, experiences and preferences for service provision amongst Australian adults with hearing loss showed only 27% had used telehealth, predominantly over the phone (75%), and only 15% had used CHH for audiology services. Similar results were shown by Saunders and Franki[38]. The uptake of CHH is substantially lower than that seen in the general Australian population aged over 60 years[39]. However, our survey also found that around 40% had a strong interest in accessing audiology services via CHH in the future, with 75% of these people showing interest in remote hearing aid fittings and adjustments, and 25% for counselling and support[40]. Despite clients' interest in CHH, one of the barriers to using CHH lies with inherent biases of healthcare professionals. As seen in other health disciplines, audiologists can be reluctant to offer remote services to older adults due to a perception of poor digital literacy and low confidence to use remote devices and services (the digital divide)[41], which is discussed later.

Identifying individual needs and understanding motivations for help-seeking and taking action are core to person-centred care in audiology[42,43], and motivational engagement is a means to understand and improve motivation to use hearing aids[44-46]. The Ida Institute Motivation Tools, designed to support, engage and coach hearing aid users have been shown to reduce anxiety, improve self-efficacy, and increase engagement with the audiologist early on in the hearing health journey[45]. While this has typically sat within the remit of audiologists in clinic, the online 'Why Improve My Hearing?' (WIMH) tool (https://apps.idainstitute.com/apps/wimh_en), based on the Ida Institute Motivation Tools has been developed to encourage adults with hearing loss to reflect on their individual needs and perceived abilities *prior* to coming into clinic. A randomised controlled trial (RCT) showed improvements in client readiness to use hearing aids (medium to large effect size) in those who used the WIMH tool prior to attending their initial audiology appointment compared to those who received standard care[47]. These results were supported by semi-structured interviews of clients and audiologists, which identified that the online WIMH tool (i) enhanced preparation before the audiology appointment, and (ii) provided a better understanding and acceptance of hearing difficulties, which then led to enriched discussions[48], which are important to encourage clients to take action to improve their hearing difficulties.

Hearing aids are the most common form of management for hearing loss[49], however there is currently very little co-ordinated and trusted information available online about the different hearing aid options available (e.g. range and function) nor other technological and non-technological options[24]. Similarly, there is limited information available about hearing healthcare pathways, how to access them, and the available options, which limits people's ability to make informed decisions, and have choice and control over their personal hearing health. With the many changes taking place currently, and on the HHC horizon, the development of well-designed and co-developed online decision aids to improve knowledge, informed-choice and decision-making is a key need, identified as a priority in national guidelines[25,50].

Assessment

Hearing screening for adults is often conducted using speech tests in background noise. A commonly used test is the Digits-in-noise (DIN), also known as the Digit Triplet Test[51], that can be delivered without calibrated equipment using consumer products, such as a standard telephone, mobile phone or an internet browser on a home computer. The value of the DIN test as a hearing screen has increased in recent years in line with new developments. Advice can now be provided automatically without the need for interpretation by an audiologist, and some applications of the DIN test also incorporate sharing of contact information for nearby audiologists. The DIN test has been shown to be largely insensitive to language proficiency[52], and is available in several languages[53]. This platform is also well-suited to adoption in low-resource settings[54,55], and has been adopted by the World Health Organization who developed a multi-language version delivered via a smartphone app.

In terms of diagnosis, the three primary elements of an audiology assessment are (i) audiometry, (ii) tympanometry, and (iii) otoscopy. The ability to conduct each of these elements remotely has been well-reported, but its importance came to the fore during the COVID-19 pandemic as clinics sought to establish how to continue audiology services.

The feasibility of live remote pure-tone audiometry has been demonstrated[56] but is limited by the need to replicate audiometry facilities and equipment in remote sites. Automated audiometry has been shown to be reliable and accurate[57,58] with variations from the gold standard shown to be within acceptable limits. Automation lessens the demand on audiologists, as testing can be facilitated by health workers [29]. Prominent implementations that have been validated include AMTAS[59,60], KUDUwave[61], Shoebox[62], and HearTest[63]. Both AMTAS and KUDUwave include the facility for bone-conduction audiometry. Extended high-frequency assessment using a smartphone has also been demonstrated[64]. Automating the interpretation may also be useful to screen straightforward audiograms from more complex cases, to triage urgent from non-urgent cases, and may also avoid the variations that occur within and between audiologists[65].

Most of these solutions are attractive to CHH implementations because they include ambient noise attenuation and active noise monitoring that enables testing to be paused until the noise abates[59,61]. The KUDUwave uses insert earphones (alongside headphones) that provide ambient sound attenuation equivalent to a soundproof room. Implementation on mobile devices, such as smartphones or tablets, makes applications such as ShoeBox and HearTest attractive as they are portable, less expensive than standard audiometry equipment, not reliant on a power source or connectivity to the internet for cloud storage of results, and report to the facilitator or client. Although modern electronics are less prone to variations over time than they were previously, standards still demand that calibration is to be done regularly. More recently, alongside smartphone apps for hearing assessment, some internet-browser applications have become available, based on tone, speech or self-report or a combination of these. Evidence to support their use is available for only a few of these, mainly those based on the DIN tests and presentation of words or sentences in quiet or noise[66]. For those responsible for delivering audiology services to clients located remotely, there is now a range of effective tools that are available for screening and assessment, most of them designed to be operated by non-audiologists and even by the client themselves in their own home.

Remote assessment of the middle ear status by tympanometry has been shown to be effective for urban community screening[67]. The incorporation of a tympanometer into the earcups of an automated audiometer, and use of an insert earphone both for pure-tone audiometry testing and for tympanometry has been demonstrated[68]. However, more evidence is required for tympanometry to be recommended for incorporation into a CHH service as it relies on a facilitator to perform the tympanometry.

Video otoscopes are effective for both synchronous and asynchronous delivery[69], and a facilitator can be trained to produce high quality images or videos by an audiologist or ENT. The automatic assessment or classification of video otoscope images using machine learning (or artificial intelligence) has been reported[70,71], which enables images showing no abnormalities to be distinguished from those with wax, tympanic membrane perforation, or otitis media. The accuracy of these approaches is over 80%. This opens opportunities for greater involvement of primary care providers to be involved in the assessment of clients in under-resourced communities. For example, automatic classification can initially be used to ensure that good quality images are captured for later assessment by an audiologist or ENT[72].

It can also assist trained health care workers to interpret otoscopic images as part of an assessment of hearing with a view to fitting hearing aids[73].

Intervention

Fifteen years ago, Arthur Boothroyd wrote a seminal paper on adult aural rehabilitation (AR), asking what is it and does it work?[74] He concluded that combining the four pillars of AR – sensory management, instruction, perceptual training, and counselling – to provide a holistic approach, was the best way to meet the goals of AR. Today, this is still true, however, the field has moved on enormously since then in terms of technology, practice, and philosophy. We reviewed some of the changes across all four pillars a decade on from Boothroyd's paper[75], noting a number of changes, such as emerging technologies to support greater personalisation and interactivity with e- and mhealth, the role of cognition in devices and training, the two-way exchange of information to enhance knowledge, the role of underpinning theories to inform research, and a focus on person-centred care and self-management. We extend that to highlight some key recent developments in online Interventions for *Sensory Management and Auditory Training*, and in the next section on Ongoing Support.

Sensory management

Hearing aids, which form the basis of 'sensory management', now extend to smartphone-connected hearing aids and alternative devices[41,76,77] (see Table 1). Hearing devices can also be self-fit, avoiding the need to involve an audiologist[78], and devices can be fine-tuned remotely without the need to attend an audiology clinic[79]. All three functionalities described below have been shown to be beneficial, but it is important to recognise they also have disadvantages.

Table 2. Barriers and facilitators identified for smartphone-connected hearing aids, based on the COM-B model.

COM-B domain	Facilitator	Barrier
Capability	App increased users' knowledge and understanding of how to control the hearing aid. This encouraged self-management of hearing loss.	Self-perception of poor digital literacy and skills. Increased cognitive burden due to deciding which controls to use.
Opportunity	By controlling the sound quality, participants were more likely to participate in conversations. Greater likelihood of adjusting their device in noisy situations, and so very useful.	Smartphone norms and different listening contexts, where people felt 'rude' using their smartphones in company. Rapid change in environmental sounds led to a reduction in user-control, so set to automatic.
Motivation	User-control to fine-tune hearing aids enabled participants to meet their individual listening and communication needs (i.e. reduce background noise). Led to greater confidence and participation and was also seen as a benefit to others. Smartphone technology helped reduce hearing aid and self-stigma. Empowerment emerged as a key theme as people could control and use their hearing aids how and when they wanted.	Perceived generational smartphone behaviours where smartphone use is more common for younger generation.

Smartphone-connected hearing aids[41] face a number of barriers and facilitators shown in Table 2, classified according to the COM-B model[80]. Similar results were reported by Ng et al[81], in particular the perceived 'digital divide' where older adults self-perceived poor digital literacy skills. However, the benefits clearly overrode the disadvantages in both studies. Perception of poor digital literacy was also seen as a barrier from an audiologist perspective[81,82], reinforcing audiologist's biases for remote technologies in older adults, as discussed earlier. Given the benefits of smartphone-controlled devices, and the high level of success many older hearing aid users have had with them, it would seem that audiologists would be doing clients a disservice by not offering smartphone-connected hearing aids to those who use one. To address this, we are currently developing a validated one-item mhealth digital literacy question for use in clinic, based on the method of Henshaw et al[83]. This may serve as a valuable clinical tool and useful indicator as to a person's digital literacy to help decide which clients might benefit from remote technologies, and who might not.

Self-fitting of hearing devices can be successfully used in the typical hearing aid population[78,84]. Sabin et al[84] showed that self-selected hearing aid parameters were within 1.8 dB of those set by the audiologists, and speech perception and self-reported benefit showed no significant differences between self-fit and audiologist-fit groups. Those who self-fit their hearing aids reported better sound quality than the audiologist-fit group. This was also reported in a recent systematic review, although outcomes from an audiogram-based audiologist-fit method were better than the self-fit outcomes[85].

Convery et al[78] showed that two-thirds (68%) of participants were successfully able to self-fit their hearing aids. However, only one-third (37%) did so without any input from a clinical assistant who was available to provide advice and support to the participants. Seven factors contributed to successful self-fitting: health locus of control, hearing aid self-efficacy, cognitive function, problem-solving skills, age, hearing aid experience and mobile device ownership, of which hearing ownership and mobile device ownership explained 42% of the variance for self-fitting success. Self-fitting resulted in greater feelings of empowerment, also seen in other remote technology studies[41,77,86]. Recently, empowerment along the hearing journey has been conceptualised[87], and a 5-item (clinical) and 15-item (research) measure for empowerment has been developed[88]. Given the improvement in willingness to use remote services by clients, once they have experienced this, greater empowerment could lead to further shifts in attitudes, which could underlie rehabilitation success and adherence.

Remote fine-tuning involves clients being able to provide feedback about their hearing aids, for example via an app, to which audiologists can respond by remotely adjusting the hearing aid prescription, and has been shown to be a feasible clinical tool in terms of usability and client-provider communication[79]. Three-quarters (73%) were able to successfully use this technology and all reported it was easy to use, were satisfied, and preferred their settings to the initial audiologist-settings. There were also no significant differences between speech perception in noise and self-report outcome measures. However, nearly half of the problems could not be addressed by the hearing aid settings (e.g. uncomfortable domes, hearing aids slipping out of ears and itchy ear canals). This highlights the need to better understand remote technologies and it's accessibility within a broad, adaptable model of care[89].

Alternative devices to conventional hearing aids (e.g. PSAPs) have increased in number and type over recent years[76]. One of the key questions is, how effective are these alternative devices in comparison to conventional hearing aids offered by audiologists? A systematic review we published in 2018[90] was not able to answer this question due to a paucity of data on PSAPs. However a more recent review of five studies showed no significant difference for speech perception, sound quality, and listening effort for PSAPs compared to conventional hearing aids[91], suggesting that PSAPs have the potential to be as beneficial as conventional hearing aids.

However, it is important to be mindful that cheaper PSAPs (<USD$150) can have unacceptable electronic characteristics (e.g. input noise, total harmonic distortion) with too little high frequency amplification, and too much low frequency amplification, compared to more expensive PSAPs[76]. Similarly, speech perception appears better with more expensive PSAPs (>US$300)[92], and cosmetic acceptance and willingness to wear also appears greater for more expensive devices[93]. There is also an option for amplification through ‘hearables’ (e.g. NuHeara, Apple Air pods) which are also a potential contender in the PSAP market. Undoubtedly, we will see significant changes in the technologies that come onto the market over the next few years, which is likely to be driven by consumer wants, needs, attitude, and choice.

OTC service models were first investigated in a double-blind RCT by Humes et al[94] who showed that when users self-selected pre-programmes for their hearing aids in an OTC delivery model, the hearing aids were efficacious with moderate to large effect sizes, although satisfaction was slightly lower compared to audiologist best practice hearing aids. Similar results have been shown in other studies[95]. A recent Delphi review on remote hearing health technologies in the UK showed that hearing healthcare professionals were positive about these technologies and introducing them into their adult hearing services[82]. This was particularly the case for adults where communication was their main concern and there were no medical contraindications (e.g. unilateral hearing loss), which can be identified by using the Consumer Ear Disease Risk Assessment (CEDRA) questionnaire[96]. In particular, PSAPs and other technologies were seen as ‘gateway products’ that could be delivered through OTC or DTC channels whereby early use of cheaper alternatives to hearing aids could lead to earlier uptake of hearing aids[82].

In summary, the research evidence for sensory management suggests that relatively new remote technologies are beneficial to a significant number of adults with hearing loss, with numerous benefits in terms of greater participation, satisfaction, self-efficacy and empowerment. However, there are barriers to all these technologies. In particular, self-perception of poor digital literacy was very common and can be deep-rooted, similar to that seen in other health disciplines[97,98] . In particular, there has been little research on identifying what people want from devices purchased via an OTC channel and how they can be best be supported.

Auditory Training

Online, computerised or mobile auditory training programs can provide added value to sensory management interventions by improving listening that extends beyond the clinic, either conducted independently or supported by clinical care. Although hearing aids are clinically effective[49], they do not directly address the role that cognition plays in listening[99], which can be achieved by auditory training[100]. Auditory training programs delivered remotely are interventions that aim to improve and support listening through active engagement with sounds[101]. Early studies showed that computerised auditory training was effective at improving the trained tasks (e.g. phonemes, words, sentences) but not necessarily untrained tasks[102]. A turning point came when auditory training was also shown to improve cognitive function such as working memory and attention, specifically on executive processes such as memory updating and attention switching[100,103]. This suggested that training cognition directly might be an effective method to provide benefit to adults with hearing loss.

However, a high-quality RCT on cognitive training for working memory showed limited improvement in working memory and self-reported hearing benefit[104]. We proposed that a combined auditory-cognitive approach, where cognition embedded within auditory task, is more likely to improve real-world benefits[103,105], which was subsequently confirmed by a systematic review[106]. From a clinical perspective, auditory-cognitive training is not widely used. There is evidence that Brain HQ, which combines auditory and cognitive tasks, can provide improvements in temporal and speech processing, and speech perception[107,108].

Another well-known program is LACE (Listening and Communication Enhancement) that includes some aspects of listening and cognition, although it is not clear which aspects of this program are effective, or not. A well-designed RCT concluded that LACE was not an effective intervention for adults with hearing loss[109], however, it may be that other, more sensitive outcome measures, targeting executive processes may have shown different results. There are a number of current developments to bring auditory and/or-cognitive training into remote clinical care. For example, new training paradigms for involving communication partners[110,111], and we are currently developing an ecologically-valid auditory-cognitive training program to optimise use and adherence in addition to improving listening and cognitive outcomes.

Ongoing support

Interventions that target ongoing *Educational and Rehabilitation Support* and Remote Follow-up and Monitoring are discussed in this section below.

Educational and Rehabilitation Support

Hearing devices alone are not sufficient to address the acoustic, communication and wellbeing impacts of hearing loss. Hearing loss and its consequences are complex, communication is complex, and hearing devices are complex. Hence, there is a need for additional and ongoing support for both first-time and existing hearing device users. High-quality information and education to enhance knowledge and skill is a key component to self-management of hearing loss[112,113], health literacy[114] and empowerment[87], all of which are essential for successful rehabilitation in adults with hearing loss. Patient knowledge and skill are also recognised as core to national clinical guidelines[43,50].

A number of remote, online rehabilitation programmes have been developed and evaluated to support hearing aid users in their hearing-knowledge and rehabilitation needs (e.g. C2Hear/m2Hear[12,15,86,115-118]; Internet-based Aural Rehabilitation (IAR)[119,120]; Support Program (SUPR)[121,122]). These programs provide a mix of interactive videos (or reusable learning objects, RLOs) that cover both practical and psychosocial aspects of hearing loss (for example, see Fig. 2), hearing aids and communication, including acclimatisation, benefits and limitations of hearing aids, client testimonials, as well as directed reading and interaction with peers and audiologists. There were clear benefits to clients in using these supplementary programs, resulting in significant improvements (with medium to large effect sizes) in knowledge, practical and hearing aid handling skills, hearing aid use and self-efficacy, social participation, communication, and hearing disability and participation. It is clear that the benefits are much more than simply knowledge gain, and memorably one of the early participants in our C2Hear RCT commented “if it was not for [C2Hear] I would have given up wearing my hearing aids”. For C2Hear/m2Hear, both co-developed using participatory human-centred design approaches, participants also reported that usability was high and valued by users, which is a likely impact of the co-design approach. m2Hear was viewed more favourably than C2Hear with additional benefits including shorter and more concise RLOs, and being more accessible, convenient, individualised, interactive and easier to use through the mhealth delivery platform, leading to greater confidence, self-efficacy, participation and empowerment[86].

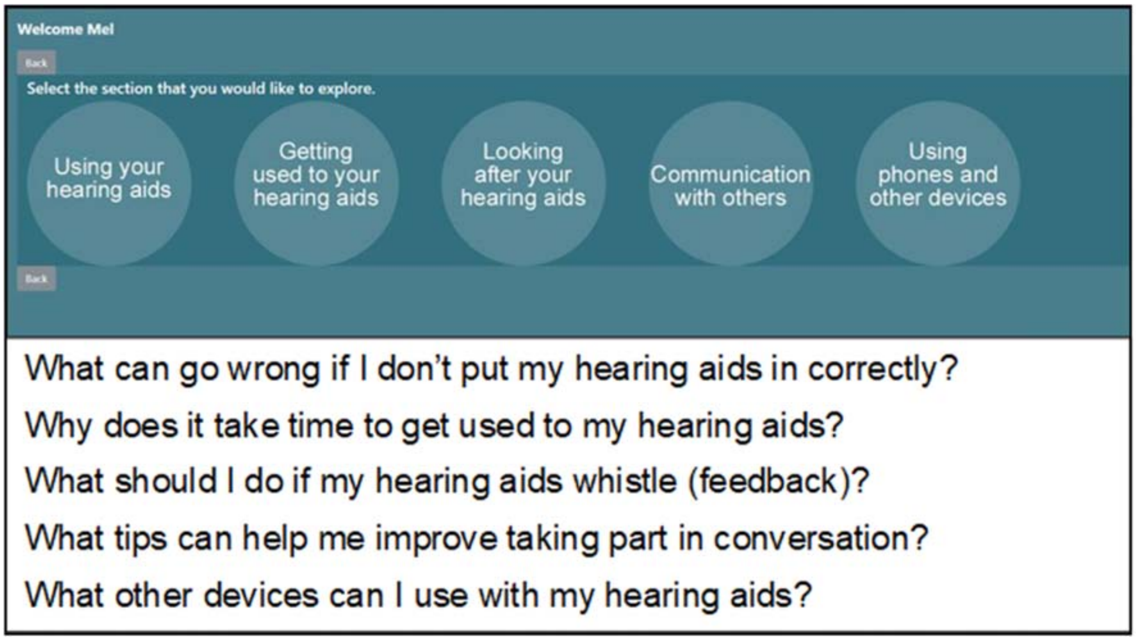

Figure 2. The five overarching themes of m2Hear, and exemplar questions, one from each theme, which is addressed by a short (e.g. 1 min) video clip.

There is a clear need and desire from hearing aid users for good quality information to support them because hearing aids and communication with others are complex, and retention of information given verbally is poor[30,115,123-125]. Accessing this remotely, without the need to attend an audiology clinic was seen as an key advantage of m2Hear, alongside numerous other advantages (Table 3)[86]. While most studies have offered educational support at the time of hearing aid fitting, we trialled the early delivery of C2Hear by offering it at the assessment appointment[117]. The RCT showed that there was a highly significant improvement in both self-efficacy and knowledge of hearing aids (with large effect sizes), and a borderline increase in readiness for hearing aids, in those who received C2Hear compared to the standard care group who received a printed booklet on hearing aids and how to use them. This suggests that online educational resources can prime people even before they obtain their hearing aids, on what hearing aids can do and how hearing aids can benefit them in communicating in everyday life.

Table 3. Benefits of m2Hear, a theoretically-driven, individualised and interactive educational program for hearing aid users delivered through mobile technologies, based on the COM-B model

Capability	Opportunity	Motivation
Comprehensive, facilitating knowledge	Empowering, better self-management	Greater self-efficacy
Concise, easy to retain	Inclusive, shared with others	Better coping
Interactive, improved memory	Personalised, tailored to individual needs	Set expectations

One of the challenges in research when an intervention shows beneficial findings is implementing the intervention into clinical practice. C2Hear was made freely available via YouTube in December 2015 (https://www.youtube.com/c2hearonline), and in 2019, we developed a stand-alone version (https://c2hearonline.com/) to overcome some of the disadvantages of YouTube. Together, there have been around 1 million views globally to date from across more than 50 countries. The benefits of online educational support were clearly obvious during the start of the COVID-19 pandemic when there was a four-fold increase in the number of views (see Fig. 1). Both C2Hear and m2Hear are included in national UK guidelines[14,43], and C2Hear is the Information for Patients in the NICE guidelines[50]. C2Hear is on over 50 UK audiology websites, and we would encourage people to add the link to either C2Hear Online or m2Hear (https://www.nottingham.ac.uk/helm/dev-test/m2hear/) onto their own audiology service website, no permission is required. The benefits of C2/m2Hear also suggest that online educational resources could also be a key element in providing essential support for those accessing hearing devices through OTC or DTC channels[77].

All the education-rehabilitation online programs addressed some aspects of psychosocial consequences of hearing loss, although information retention on this was poorer compared to practical aspects[124]. Furthermore, our understanding of the psychosocial and mental health impacts of hearing loss has grown over recent years, both for adults with hearing loss and their communication partners[126-130]. There are few interventions that focus on psychosocial aspects of hearing loss, one that uses booklet-based cognitive behavioural therapy[131], and another that delivers internet-based Acceptance Commitment Therapy program by a mental health professional[132], with indications that online interventions for psychosocial and emotional support would be valuable[129,133,134]. We are currently conducting some research to address this and improvement of user-engagement with remote technologies.

Remote Follow-up and Monitoring

Follow-up and monitoring of adults who receive hearing devices has considerable potential for both hearing aid and cochlear implant users, and has been identified as a NICE research priority[50]. There are considerable advantages in being able to offer follow-up and monitoring services remotely, either via an audiology clinic or remote support system. Using design thinking principles, the discovery phase of using smartvoice technology (e.g., Alexa, GoogleHome) revealed that post-fitting support would increase motivation of hearing aid users, offer encouragement, assist in joint goal-setting, achieve goals, and record experiences of the hearing aid. All of which could be also be used to monitor after-care and progress by audiologists[135].

A recent pilot study using a manufacturer's myPhonak app was used to conduct internet-based follow-up appointments by collecting outcome measures (COSI, HHIE, QuickSIN and real-ear aided responses)[22]. Most follow-ups were completed, with improvements in the COSI goals, and no significant difference for satisfaction across the in-person and internet-based appointments. As we gain more insights into remote delivery services for hearing aid users from research and clinical practice, these will further guide targeted research and clinical implementation.

There have been similar developments for cochlear implant (CI) users. Remote Check is an app that offers home-based CI testing incorporating subjective and objective assessments in a comprehensive review of CI function[136]. Assessments include the Speech and Spatial Qualities Questionnaire-Short version (SSQ12), impedance testing, aided hearing test, DIN, and datalogging. Users can also upload photos of their implant site for medical review. Studies have shown that use of Remote Check can facilitate high quality, regular review of CI recipient outcomes, with most tests providing equivalent outcomes remotely to those obtained in clinic whilst also facilitating[136,137]. It is important that remote technologies provide services that are at least as good as, and can be easily integrated into, current clinical services. Maruthurkkara et al[136] reported that 94% of all issues arising post-surgery were identified by Remote Check, and there was 99% agreement in cases where there was need to visit the clinic between the clinic and Remote Check. Sucher et al[137] reported that ease of Remote Check use was high, with 100% and 89% rating somewhat/very easy to use at baseline and 6 months, and 90% and 84% highly likely to recommend Remote Check to others. The DIN and standard clinical speech-in-noise tests were significantly correlated, with no clinically significant differences for impedances and aided thresholds measured clinically and via Remote Check. Views of clients and audiologists on Remote Check were also sought, and key themes are shown Table 4.

Table 4. Key themes arising from focus groups of clients and audiologists on the use of Remote Check.

Clients	*Clinician continuity* preferred when reviewing results due to the concern that non-familiar clinicians may miss subtle issues.	*Personalised, hybrid models of care* are preferred, with Remote Check used in conjunction with in-person appointments.
Audiologists	*Training and experience* with Remote Check, and CHH in general, improves ease of use and increases the likelihood of uptake both amongst clinicians and CI users.	*Improved integration* between Remote Check and clinical outcome measures will facilitate tracking of client progress.
Clients and audiologists	*Understanding and trust* of Remote Check outcomes for both clients and audiologist is essential.	*Choice of the client* is key in the use of any remote technology, including Remote Check.

A similar program for personalized long-term follow-up for the management of cochlear implant users is the CHOICE CI home-care program that is manufacturer-agnositc[138]. An RCT showed equivalent, if not better, outcomes for CI users using CHOICE compared to the current in-clinic standard of care for objective and subjective measures of speech recognition. There were also increased levels of empowerment in relation to management of their hearing loss, and most were keen to continue receiving their implant management in this manner.

Studies involving both services clearly reveal a willingness and acceptance of receiving care remotely. Remote CI monitoring enables better management of individuals who are progressing slowly with their implant, as well as removing unnecessary clinic visits if all is going well. Further consideration needs to be given to the necessary integration of outcomes obtained in clinic and remotely to enable direct comparison. As such, we are about to embark on a study to identify a Core Outcome Set to measure outcomes for remote technologies used by CI users.

Generally, the financial implications of remote technologies needs to be better understood. While use of remote technologies for ongoing support has the potential to free up clinic capacity, thus allowing clinicians to see more clients, monitoring must still be reviewed and follow-up assessments may still be needed. At present, from an Australian perspective, there is no funding available for asynchronous CHH. Loss of income from in-person review appointments, in conjunction with the possible need to absorb the cost of monitoring and reviewing results, may make the CHH service cost prohibitive. Unless an acceptable funding model is developed for CHH services, there is a possibility that it will not be implemented. More generally, implementation of remote technologies into clinic systems to provide a hybrid model needs to be understood as implementation science has shown that clinicians and clients need to be ready for change, and optimal conditions are required for an intervention to be taken up and maintained. We cannot simply expect to put new systems into clinics and assume they will work, although this is common, based on a desire to 'get on with it'.

Implementation and behavioural science: from research to practice

Improving healthcare and ensuring that policy on healthcare service delivery is well-grounded requires structured and comprehensive processes for the development, evaluation and implementation of innovative interventions, such as remote technologies. Healthcare interventions are complex, and it is challenging to implement them effectively within healthcare settings. The UK's Medical Research Council (MRC) developed a framework to guide the development and evaluation of complex health interventions[139]. The four key elements are: *Development* (identifying the evidence base and theory); *Feasibility/piloting* (testing procedures, estimating recruitment/retention, calculating sample size); *Evaluation* (assessing clinical- and cost-effectiveness, understanding the change process); and *Implementation* (dissemination, monitoring and long-term follow-up). This framework has guided some of our research[15,115,140,141], and has been recently updated[142] to align with important aspects that have been introduced into research over the last decade. These include stakeholder engagement[12,116,143-145], identifying key uncertainties[146,147], iterative refinement of the intervention[15,116,144,145,148], and economic considerations[115].

While intervention development and evaluation come before implementation, research highlights the benefit of considering implementation needs right from the outset[149]. For example, there is no point developing an effective intervention if the target users are unwilling to use it. This point is crucial, as we see in audiology there are clinically-effective remote tools available to help clients to better self-manage their hearing loss, yet their uptake and use often remains limited.

Implementation science holds the key to unlocking what is needed to motivate, equip and empower clinic staff and service providers so that effective interventions are embedded into routine hearing health care so that all clients can benefit. First, it is imperative to clarify the common confusion between what is the clinical intervention and what is the implementation intervention. The clinical intervention is the *what* (e.g., m2Hear program) and the implementation process is the *how* (e.g., how the m2Hear program becomes embedded within a clinic). Implementation interventions may include, for example, efforts to change behaviour at the client, provider, system, or policy level. Common examples include strategies at the provider level such as education/training, audit-feedback, and performance incentives.

Implementation science is "the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practice into routine practice and, hence, to improve the quality and effectiveness of health services" [150]. There are over 90 implementation theories or conceptual frameworks available to guide research and clinical practice. These can be used to: describe and/or guide the process of translating an evidence-based program for delivery into the clinic (process models); understand and explain what influences implementation outcomes (determinant framework); and evaluate aspects of the implementation process (evaluation frameworks)[151]. Selection of the appropriate theory, model, or framework will depend on the research question and purpose; the context and implementation setting (e.g., targeting person or organisational-level constructs); and the depth of analysis and operationalisation required (e.g., guiding processes, determinants, strategies, evaluation)[152]. Reviews and websites (e.g. https://dissemination-implementation.org/) provide lists of available theories, models and frameworks[153] and the Theory Comparison and Selection Tool (T-CaST) provides guidance on selection criteria[152,154,155]. All models of care would benefit from a better understanding of implementation requirements as implementation science gains more ground and becomes better understood within audiology[156,157].

One implementation theory that has gained attention in the audiology literature is the Behaviour Change Wheel (BCW), an eight-step systematic process guiding intervention development and implementation. The BCW has been widely used to develop interventions that are both acceptable to users and effective in achieving their aims. These include interventions designed to optimise changes in health behaviours, such as audiologists engaging in shared goal planning for adults with hearing loss[158,159], and engaging hearing aid users with smartphone-connected hearing aids [41]. We recently used the BCW to develop an intervention targeting mental wellbeing support behaviours in hearing healthcare clinicians, the AIMER (Ask, Inform, Manage, Encourage, Refer)[141]. This multifaceted intervention was developed to change hearing healthcare clinicians' behaviours relating to provision of mental wellbeing support to adults with hearing loss. A follow-up study evaluated the implementation of the AIMER, guided by the RE-AIM framework[160] providing a theoretical structure for the assessment of implementation pathways, and found that after completing the AIMER program, hearing healthcare clinicians were more likely to engage in the target behaviours. All models of care would benefit from a better understanding of implementation requirements as implementation science gains more ground and becomes better understood within audiology[156,157].

At the core of the BCW is the COM-B model of behaviour change[80]. The COM-B recognises that barriers and facilitators of the target Behaviour may relate to Capability (e.g., skills, knowledge), Opportunity (e.g., social influences, physical environment), or Motivation (e.g., beliefs, intentions, emotional responses, habitual responses). The COM-B model proposes that if a behaviour is not taking place, barriers in one or more of these areas need to be addressed. There is a growing body of work demonstrating the use of the COM-B for identifying barriers and facilitators to implementation of hearing healthcare interventions[41,77,158,159,161]. For example, to address the barriers that users reported for smartphone-connected hearing aids, behaviour change techniques (BCTs) were mapped onto the 10 identified themes (e.g. smartphone literacy) to support use of smartphone-connected hearing aids by audiologists[41]. In this case, smartphone literacy could be addressed by BCTs addressing education (for smartphone skills), training (to demonstrate functions) and enablement (provision of behavioural support).

Conclusions

There are many types of remote technologies that have been developed and evaluated along the hearing health journey to provide an evidence-base. Most of these have been developed for clinical systems and some for consumer systems, although the technologies for these are not mutually exclusive. Here, we provide an overview of some of the technologies that have been evaluated through research, of which many are available and some are being used. Yet there is little research that brings these technologies together to form hybrid or fully-remote service delivery models. One could envisage a 'pick and mix' approach, taking the elements along the hearing journey that best meet individuals' needs, from either a clinical perspective, a consumer perspective, or a mix of the two (see Fig. 3). We anticipate that over the next few years, the need to address the huge unmet need within hearing healthcare will continue to drive the development and implementation of remote technologies and new service delivery models and channels. This will almost certainly include new technologies not specifically addressed here (e.g. artificial intelligence[162] and big data[163]) that are fast moving into our horizon. An evidence-based approach is key for sustainable models, as is the need to implement these models by addressing what works (the facilitators) and what does not (the barriers), which can be at odds with a sense of 'just get on with it'. The opportunities to substantially improve hearing healthcare and person-centred outcomes through remote technologies, service models and channels are great. To quote Matt Mullenweg, founder of WordPress "technology works best when it brings people together".

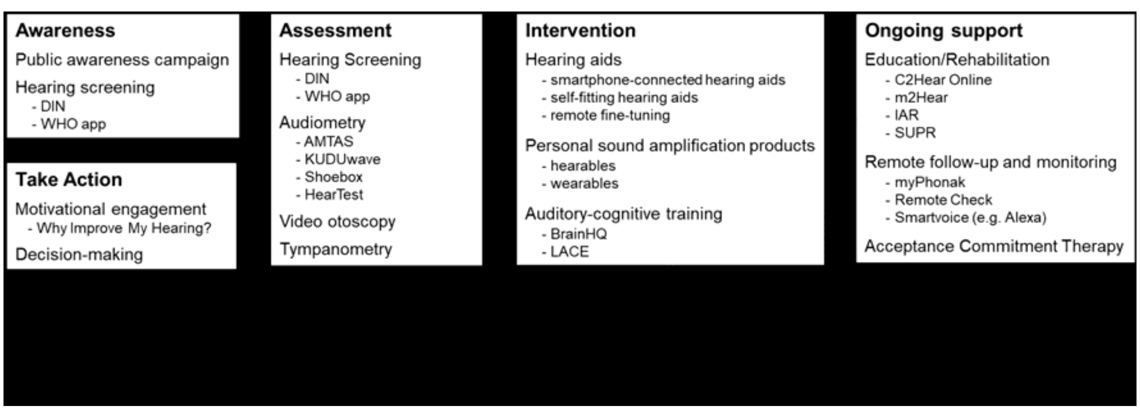

Figure 3. Summary of remote technologies along the hearing health journey, which can be used in clinical, hybrid and consumer services, underpinned by principles of implementation and behavioural science. Specific examples of technologies are shown.

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References

1. Swanepoel DW, Hall JW. A systematic review of telehealth applications in audiology. Telemedicine journal and e-health: American Telemedicine Association. 2010;16(2):181-200.

2. Glista D, Ferguson M, Muñoz K, Davies-Venn E. Connected hearing healthcare: shifting from theory to practice. International Journal of Audiology. 2021; 60: (Sup 1); S1-S3.

3. Ferguson M, Maidment D, Henshaw H, Heffernan E. Evidence-based interventions for adult aural rehabilitation: that was then, this is now. Thieme Medical Publishers; 2019:068-084.

4. Goudey B, Plant K, Kiral I, et al. A multicenter analysis of factors associated with hearing outcome for 2,735 adults with cochlear implants. Trends in Hearing. 2021;25:23312165211037525.

5. Eikelboom R, Bennett R, Brennan M. Tele-audiology: An opportunity for expansion of hearing healthcare services in Australia. Ear Science Institute Australia, Perth, WA. 2021;

6. Montano J, Angley G, Ryan-Bane C, et al. eAudiology: Shifting from theory to practice. Hearing Review. Hearing Review. 2018;25(9):20-24.

7. Ferguson M, Glista D, Davies-Venn E. Connected health in audiology: the future of hearing healthcare. ENT & Audiology News. 2019;28(5):47.

8. NASEM. Hearing healthcare for adults. Priorities for improving access and affordability. 2016.

9. Brice S, Saunders E, Edwards B. Scoping review for a global hearing care framework: matching theory with practice. Seminars in Hearing. In Press;

10. Penno K, Zakis J. Exploring technology domain for the framework from clinical application to technology capability Seminars in Hearing. In Press;

11. Muñoz K, Nagaraj NK, Nichols N. Applied tele-audiology research in clinical practice during the past decade: a scoping review. International Journal of audiology. 2021;60(sup1):S4-S12.

12. Ferguson M, Leighton P, Brandreth M, Wharrad H. Development of a multimedia educational programme for first-time hearing aid users: A participatory design. International Journal of Audiology. 2018;57(8):600-609.

13. Swanepoel DW, Hall JW. Making audiology work during COVID-19 and beyond. The Hearing Journal. 2020;73(6):20-22.

14. AIHHP, BAA, BSA, BSHAA. Audiology and otology guidance during Covid-19. UK2022.

15. Ferguson MA, Maidment DW, Gomez R, Coulson N, Wharrad H. The feasibility of an m-health educational programme (m2Hear) to improve outcomes in first-time hearing aid users. International Journal of Audiology. 2021;60(Sup1):S30-S41.

16. Allen D, Ferguson M, Pang J, et al. Clinical outcomes of Hearing Australia in-person and remote services 2020. https://www.nal.gov.au/wp-content/uploads/sites/2/2020/11/Clinical-outcomes-of-Hearing-Australia-inperson-and-remote-services.pdf

17. Eikelboom RH, Bennett RJ, Manchaiah V, et al. International survey of audiologists during the COVID-19 pandemic: Use of and attitudes to telehealth. International Journal of Audiology. 2022;61(4):283-292.

18. Abrams HB, Callahan CM. Health behavior nad motivational engagement models can explain and mofidy tele-audiology uptake. American Journal of Audiology. In press;

19. Australia A. Teleaudiology Guidelines. https://teleaudiologyguidelines.org.au/teleaudiology-guidelines/

20. Ratanjee-Vanmali H, Swanepoel DW, Laplante-Lévesque A. Patient uptake, experience, and satisfaction using web-based and face-to-face hearing health services: process evaluation study. Journal of Medical Internet research. 2020;22(3):e15875.

21. Tao KF, Brennan-Jones CG, Capobianco-Fava DM, et al. Teleaudiology services for rehabilitation with hearing aids in adults: A systematic review. Journal of Speech, Language, and Hearing Research. 2018;61(7):1831-1849.

22. Arnold ML, Schwartz B, Neil H, Chisolm TH, Sanchez VA. Feasibility and Assessment of a Hybrid Audiology Service Delivery Model for Older Adult Hearing Aid Users: A Pilot Study. American Journal of Audiology. 2022:1-13.

23. Davis A, Smith P, Ferguson M, Stephens D, Gianopoulos I. Acceptability, benefit and costs of early screening for hearing disability: a study of potential screening tests and models. Health Technology Assessment. 2007;11(42):1-294. doi:10.3310/hta11420

24. Woods M, Burgess Z. Report of the Independent Review of the Hearing Services Program. 2021.

25. HHSC. Roadmap for Hearing Health 2019.

26. Montague M, Borland R, Sinclair C. Slip! Slop! Slap! and SunSmart, 1980-2000: Skin cancer control and 20 years of population-based campaigning. Health Education & Behavior. 2001;28(3):290-305.

27. Alperstein S, Beach EF. Prioritizing the target audience for a hearing awareness campaign in Australia using the TARPARE model. Health Promot Int. 2022;

28. Coulson N, Ferguson MA, Henshaw H, Heffernan E. Applying theories of health behaviour and change to hearing health research: Time for a new approach. International Journal of Audiology. 2016;55(S3):S99-S104.

29. Dawood N, Mahomed Asmail F, Louw C, Swanepoel DW. Mhealth hearing screening for children by non-specialist health workers in communities. International Journal of Audiology. 2021;60(sup1):S23-S29.

30. Laplante-Lévesque A, Hickson L, Worrall L. Stages of change in adults with acquired hearing impairment seeking help for the first time: application of the transtheoretical model in audiologic rehabilitation. Ear and Hearing. 2013;34(4):447-457.

31. Brennan-Jones CG, Taljaard DS, Brennan-Jones SE, Bennett RJ, Swanepoel DW, Eikelboom RH. Self-reported hearing loss and manual audiometry: A rural versus urban comparison. Australian Journal of Rural Health. 2016;24(2):130-135.

32. Taljaard DS, Leishman NF, Eikelboom RH. Personal listening devices and the prevention of noise induced hearing loss in children: the Cheers for Ears Pilot Program. 2013;

33. WHO. Check your hearing. https://www.who.int/teams/noncommunicable-diseases/sensory-functions-disability-and-rehabilitation/hearwho

34. Folmer RL, Vachhani J, McMillan GP, Watson C, Kidd GR, Feeney MP. Validation of a computer-administered version of the digits-in-noise test for hearing screening in the United States. Journal of the American Academy of Audiology. 2017;28(02):161-169.

35. RNID. Take our free hearing check. https://rnid.org.uk/information-and-support/take-online-hearing-check/

36. Dubno JR, Majumder P, Bettger JP, et al. A pragmatic clinical trial of hearing screening in primary care clinics: cost-effectiveness of hearing screening. Cost Effectiveness and Resource Allocation. 2022;20(1):1-13.

37. Simpson AN, Matthews LJ, Cassarly C, Dubno JR. Time from hearing aid candidacy to hearing aid adoption: A Longitudinal Cohort Study. Ear and Hearing. 2019;40(3):468-476.

38. Saunders GH, Oliver F. Impact of Hearing Loss on Communication During Remote Health Care Encounters. Telemedicine and e-Health. 2022;

39. Isautier JM, Copp T, Ayre J, et al. People's experiences and satisfaction with telehealth during the COVID-19 pandemic in Australia: cross-sectional survey study. Journal of Medical Internet research. 2020;22(12):e24531.

40. Galvin K, Sucher CM, Bennett RJ, Ebrahimi-Madiseh A, Crosland P, Eikelboom RH. Willingness to consider and to pay for a variety of telehealth services amongst adult hearing clinic clients. International Journal of Audiology. 2022:1-9.

41. Gomez R, Habib A, Maidment DW, Ferguson MA. Smartphone-Connected Hearing Aids Enable and Empower Self-Management of Hearing Loss: A Qualitative Interview Study Underpinned by the Behavior Change Wheel. Ear Hear. 2022;43(3):921-932.

42. Ridgeway J, Hickson L, Lind C. Autonomous motivation is associated with hearing aid adoption. International Journal of Audiology. 2015;54(7):478-84. doi:10.3109/14992027.2015.1007213

43. BSA. Common Principles of Rehabilitation for Adults in Audiology Services. British Society of Audiology. http://www.thebsa.org.uk/wp-content/uploads/2016/10/Practice-Guidance-Common-Principles-of-Rehabilitation-for-Adults-in-Audiology-Services-2016.pdf

44. Aazh H. Feasibility of conducting a randomized controlled trial to evaluate the effect of motivational interviewing on hearing-aid use. International Journal of Audiology. 2015;2:1-9.

45. Ferguson MA, Maidment DW, Russell N, Gregory M, Nicholson NR. Motivational engagement in first-time hearing aid users: A feasibility study. International Journal of Audiology. 2016;Supp 3:S34-S41.

46. Ekberg K, Barr C. Identifying clients' readiness for hearing rehabilitation within initial audiology appointments: A pilot intervention study. International Journal of Audiology. 2020;59(8):606-614.

47. Maidment D, Heffernan E, Ferguson M. A randomised controlled clinical trial to assess the benefits of a telecare tool delivered prior to the initial hearing assessment. International Journal of Audiology. 2022:1-10.

48. Heffernan E, Maidment DW, Ferguson MA. A qualitative study showing that a telecare tool can have benefits before and during the initial hearing assessment appointment. International Journal of Audiology. 2022:1-9.

49. Ferguson MA, Kitterick PT, Chong LY, Edmondson-Jones M, Barker F, Hoare DJ. Hearing aids for mild to moderate hearing loss in adults. Cochrane Database of Systematic Reviews. 2017;(9)

50. NICE. Hearing loss in adults: assessment and management. National Institute for Health and Care Excellence. https://www.nice.org.uk/guidance/ng98

51. Smits C, Kapteyn TS, Houtgast T. Development and validation of an automatic speech-in-noise screening test by telephone. International Journal of Audiology. 2004;43(1):15-28.

52. Potgieter J-M, Swanepoel DW, Myburgh HC, Hopper TC, Smits C. Development and validation of a smartphone-based digits-in-noise hearing test in South African English. International Journal of Audiology. 2016;55(7):405-411.

53. Van den Borre E, Denys S, van Wieringen A, Wouters J. The digit triplet test: a scoping review. International Journal of Audiology. 2021;60(12):946-963.

54. Swanepoel D, Clark JL. Hearing healthcare in remote or resource-constrained environments. The Journal of Laryngology & Otology. 2019;133(1):11-17.

55. Eksteen S, Launer S, Kuper H, Eikelboom RH, Bastawrous A, Swanepoel DW. Hearing and vision screening for preschool children using mobile technology, South Africa. Bulletin World Health Organization. 2019;97(10):672.

56. Lancaster P, Krumm M, Ribera J, Klich R. Remote hearing screenings via telehealth in a rural elementary school. 2008;

57. Mahomed F, Swanepoel DW, Eikelboom RH, Soer M. Validity of automated threshold audiometry: a systematic review and meta-analysis. Ear and Hearing. 2013;34(6):745-752.

58. Wasmann J-W, Pragt L, Eikelboom R, Swanepoel DW. Digital approaches to automated and machine learning assessments of hearing: scoping review. Journal of Medical Internet research. 2022;24(2):e32581.

59. Margolis RH, Glasberg BR, Creeke S, Moore BC. AMTAS®: Automated method for testing auditory sensitivity: Validation studies. International Journal of Audiology. 2010;49(3):185-194.

60. Eikelboom RH, Swanepoel DW, Motakef S, Upson GS. Clinical validation of the AMTAS automated audiometer. International Journal of Audiology. 2013;52(5):342-349.

61. Swanepoel DW, Matthysen C, Eikelboom RH, Clark JL, Hall III JW. Pure-tone audiometry outside a sound booth using earphone attentuation, integrated noise monitoring, and automation. International Journal of Audiology. 2015;54(11):777-785.

62. Thompson GP, Sladen DP, Borst BJH, Still OL. Accuracy of a tablet audiometer for measuring behavioral hearing thresholds in a clinical population. Otolaryngology–Head and Neck Surgery. 2015;153(5):838-842.

63. Van Tonder J, Swanepoel DW, Mahomed-Asmail F, Myburgh H, Eikelboom RH. Automated smartphone threshold audiometry: validity and time efficiency. Journal of the American Academy of Audiology. 2017;28(03):200-208.

64. Bornman M, Swanepoel DW, De Jager LB, Eikelboom RH. Extended high-frequency smartphone audiometry: Validity and reliability. Journal of the American Academy of Audiology. 2019;30(03):217-226.

65. Brennan-Jones CG, Eikelboom RH, Bennett RJ, Tao KF, Swanepoel DW. Asynchronous interpretation of manual and automated audiometry: Agreement and reliability. Journal of Telemedicine and Telecare. 2018;24(1):37-43.

66. Almufarrij I, Dillon H, Dawes P, et al. Web-and app-based tools for remote hearing assessment: a scoping review. International Journal of Audiology. 2022:1-14.

67. Ciccia AH, Whitford B, Krumm M, McNeal K. Improving the access of young urban children to speech, language and hearing screening via telehealth. Journal of Telemedicine and Telecare. 2011;17(5):240-244.

68. Ramatsoma H, Koekemoer D. Validation of a Bilateral Simultaneous Computer-Based Tympanometer. American Journal of Audiology. 2020;29(3):491-503.

69. Alenezi EM, Jajko K, Reid A, et al. The reliability of video otoscopy recordings and still images in the asynchronous diagnosis of middle-ear disease. International Journal of Audiology. 2021:1-7.

70. Myburgh HC, Jose S, Swanepoel DW, Laurent C. Towards low cost automated smartphone- and cloud-based otitis media diagnosis. Biomedical Signal Processing and Control. 2018;39:34-52.

71. Sandström J, Myburgh H, Laurent C, Swanepoel DW, Lundberg T. A Machine Learning Approach to Screen for Otitis Media Using Digital Otoscope Images Labelled by an Expert Panel. Diagnostics. 2022;12(6):1318.

72. Alenezi EM, Jajko K, Reid A, et al. Clinician-rated quality of video otoscopy recordings and still images for the asynchronous assessment of middle-ear disease. Journal of telemedicine and telecare. 2021:1357633X20987783.

73. Frisby C, Eikelboom RH, Mahomed-Asmail F, et al. Community-based adult hearing care provided by community healthcare workers using mHealth technologies. Global Health Action. 2020;15(1).

74. Boothroyd A. Adult aural rehabilitation: what is it and does it work? Trends in Amplification. 2007;11(2):63-71.

75. Ferguson M, Maidment D, Henshaw H, Heffernan E. Evidence-Based Interventions for Adult Aural Rehabilitation: That Was Then, This Is Now. Seminars in Hearing. 2019;40(01):068-084.

76. Maidment DW, Amlani AM. Argumentum ad ignorantiam: Smartphone-connected listening devices. Thieme Medical Publishers, Inc.; 2020:254-265.

77. Maidment DW, Ali YH, Ferguson MA. Applying the COM-B Model to Assess the Usability of Smartphone-Connected Listening Devices in Adults with Hearing Loss. Journal of the American Academy of Audiology. 2019;30(5):417-430.

78. Convery E, Keidser G, Hickson L, Meyer C. Factors associated with successful setup of a self-fitting hearing aid and the need for personalized support. Ear and Hearing. 2019;40(4):794-804.

79. Convery E, Keidser G, McLelland M, Groth J. A smartphone app to facilitate remote patient-provider communication in hearing health care: usability and effect on hearing aid outcomes. Telemedicine and e-Health. 2019;26(6):798-804.

80. Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implementation Science. 2011;6(1):42.

81. Ng SL, Phelan S, Leonard M, Galster J. A qualitative case study of smartphone-connected hearing aids: Influences on patients, clinicians, and patient–clinician interactions. Journal of the American Academy of Audiology. 2017;28(06):506-521.

82. Olson A, Maidment DW, Ferguson MA. Consensus on connected hearing health technologies and service delivery models in the UK: a Delphi review. International Journal of Audiology. 2021:1-8.

83. Henshaw H, Clark D, Kang S, Ferguson M. Computer Skills and Internet Use in Adults Aged 50-74 Years: Influence of Hearing Difficulties. Journal of Medical Internet Research. 2012;4(4):e113,1-14.

84. Sabin AT, Van Tasell DJ, Rabinowitz B, Dhar S. Validation of a self-fitting method for over-the-counter hearing aids. Trends in Hearing. 2020;24:2331216519900589.

85. Almufarrij I, Dillon H, Munro KJ. Do we need audiogram-based prescriptions? A systematic review. International Journal of Audiology. 2022:1-12.

86. Maidment D, Heyes R, Gomez R, Coulson NS, Wharrad H, Ferguson MA. Evaluating a theoretically informed and co-created mHealth educational intervention for first-time hearing aid users: a qualitative interview study. Journal of Medical Internet Research. 2020;8(8):e17193.

87. Gotowiec S, Larsson J, Incerti P, et al. Understanding patient empowerment along the hearing health journey. International Journal of Audiology. 2022;61(2):148-158.

88. Ferguson M, Gotowiec S, Larsson J, Incerti P, Bennett R, Andrich D. Development of an outcome measure for empowerment for hearing loss. presented at: Hearing Across the Lifespan; June 2022 2022; Cernobbio, Italy.

89. Schnittker J-A, Brice S, Glista D. Remote fitting methods as appears across the framework. Seminars in Hearing. In Press;

90. Maidment DW, Barker AB, Xia J, Ferguson MA. A systematic review and meta-analysis assessing the effectiveness of alternative listening devices to conventional hearing aids in adults with hearing loss. International Journal of Audiology. 2018;57(10):721-729.

91. Chen C-H, Huang C-Y, Cheng H-L, et al. Comparison of personal sound amplification products and conventional hearing aids for patients with hearing loss: A systematic review with meta-analysis. EClinicalMedicine. 2022;46:101378.

92. Reed NS, Betz J, Kendig N, Korczak M, Lin FR. Personal sound amplification products vs a conventional hearing aid for speech understanding in noise. Journal of the American Medical Association. 2017;318(1):89-90.

93. Almufarrij I, Munro KJ, Dawes P, Stone MA, Dillon H. Direct-to-consumer hearing devices: Capabilities, costs, and cosmetics. Trends in Hearing. 2019;23:2331216519858301.

94. Humes LE, Rogers SE, Quigley TM, Main AK, Kinney DL, Herring C. The effects of service-delivery model and purchase price on hearing-aid outcomes in older adults: A randomized double-blind placebo-controlled clinical trial. American Journal of Audiology. 2017;26(1):53-79.

95. Urbanski D, Hernandez H, Oleson J, Wu Y-H. Toward a new evidence-based fitting paradigm for over-the-counter hearing aids. American Journal of Audiology. 2021;30(1):43-66.

96. Klyn NA, Robler SK, Bogle J, et al. CEDRA–a tool to help consumers assess risk for ear disease. Ear and Hearing. 2019;40(6):1261.

97. Kuerbis A, Mulliken A, Muench F, Moore AA, Gardner D. Older adults and mobile technology: Factors that enhance and inhibit utilization in the context of behavioral health. 2017;

98. Wu Y-H, Damnée S, Kerhervé H, Ware C, Rigaud A-S. Bridging the digital divide in older adults: a study from an initiative to inform older adults about new technologies. Clinical Interventions in Aging. 2015;10:193.

99. Loughrey DG, Kelly ME, Kelley GA, Brennan S, Lawlor BA. Association of age-related hearing loss with cognitive function, cognitive impairment, and dementia: a systematic review and meta-analysis. JAMA Otolaryngology–Head & Neck Surgery. 2018;144(2):115-126.

100. Ferguson MA, Henshaw H, Clark D, Moore D. Benefits of Phoneme Discrimination Training in a Randomized Controlled Trial of 50–74 Year Olds With Mild Hearing Loss. Ear and Hearing. 2014;35(4):e110-21. doi:10.1097/AUD.0000000000000020

101. Schow R, Nerbonne M. Introduction to Audiologic Rehabilitation. 5th Edition ed. Pearson Education; 2006.

102. Henshaw H, Ferguson MA. Efficacy of Individual Computer-Based Auditory Training for People with Hearing Loss: A Systematic Review of the Evidence. PLoS One. 2013;8(5):e62836. doi:10.1371/journal.pone.0062836

103. Ferguson MA, Henshaw H. Auditory training can improve working memory, attention and communication in adverse conditions for adults with hearing loss. Perspective. Frontiers in Psychology. 2015-May-28 2015;6:1-7. doi:10.3389/fpsyg.2015.00556

104. Henshaw H, Heinrich A, Tittle A, Ferguson M. Cogmed Training Does Not Generalize to Real-World Benefits for Adult Hearing Aid Users: Results of a Blinded, Active-Controlled Randomized Trial. Ear and Hearing. 2021;

105. Ferguson M, Henshaw H. How does auditory training work? Joined up thinking and listening. Seminars in Hearing. 2015;36(4):237-249.

106. Lawrence BJ, Jayakody DM, Henshaw H, et al. Auditory and cognitive training for cognition in adults with hearing loss: a systematic review and meta-analysis. Trends in Hearing. 2018;22:2331216518792096.

107. Anderson S, White-Schwoch T, Choi HJ, Kraus N. Training changes processing of speech cues in older adults with hearing loss. Frontiers in Systems Neuroscience. 2013;7:97.

108. Anderson S, White-Schwoch T, Parbery-Clark A, Kraus N. Reversal of age-related neural timing delays with training. Proceedings of the National Academy of Sciences. 2013;110(11):4357-4362.

109. Saunders GH, Smith SL, Chisolm TH, Frederick MT, McArdle RA, Wilson RH. A randomized control trial: Supplementing hearing aid use with listening and communication enhancement (LACE) auditory training. Ear Hear. 2016;37(4):381-396.

110. Tye-Murray N, Spehar B, Sommers M, Barcroft J. Auditory training with frequent communication partners. Journal of Speech, Language, and Hearing Research. 2016;59(4):871-875.

111. Lowe SC, Henshaw H, Wild J, Ferguson MA. Evaluation of home-delivered live-voice auditory training for adult hearing aid users involving their communication partners: a randomised controlled trial. International Journal of Audiology. 2022:1-11.

112. Convery E, Hickson L, Meyer C, Keidser G. Predictors of hearing loss self-management in older adults. Disability and Rehabilitation. 2019;41(17):2026-2035.

113. Barker F, Mackenzie E, Elliott L, Jones S, de Lusignan S. Interventions to Improve Hearing Aid Use in Adult Auditory Rehabilitation. The Cochrane Library. 2016;

114. Bahramian M, Najimi A, Omid A. Association between health literacy with knowledge, attitude, and performance of health-care providers in applying health literacy education strategies for health education delivery. Journal of Education and Health Promotion. 2020;9

115. Ferguson MA, Brandreth M, Leighton P, Brassington W, Wharrad H. A randomized controlled trial to evaluate the benefits of a multimedia educational programme for first-time hearing aid users. Ear and Hearing. 2016;37(2):123-136. doi:10.1097/AUD.0000000000000237

116. Maidment DW, Coulson NS, Wharrad H, Taylor M, Ferguson MA. The development of an mHealth educational intervention for first-time hearing aid users: combining theoretical and ecologically valid approaches. International Journal of Audiology. 2020;59(7):492-500.

117. Gomez R, Ferguson M. Improving knowledge and self-efficacy for hearing aid self-management: the early delivery of a multimedia-based education program in first-time adult hearing aid users. International Journal of Audiology. 2020;59(4):272-281.

118. Malmberg M, Sundewall Thorén E, Öberg M, Lunner T, Andersson G, Kähäri K. Experiences of an Internet-based aural rehabilitation (IAR) program for hearing aid users: a qualitative study. International Journal of Audiology. 2018;57(8):570-576.

119. Thorén ES, Öberg M, Wänström G, Andersson G, Lunner T. A randomized controlled trial evaluating the effects of online rehabilitative intervention for adult hearing-aid users. International Journal of Audiology. 2014;53(7):452-461.

120. Malmberg M, Anióse K, Skans J, Öberg M. A randomised, controlled trial of clinically implementing online hearing support. International Journal of Audiology. 2022:1-9.

121. Meijerink JF, Pronk M, Lissenberg-Witte BI, Jansen V, Kramer SE. Effectiveness of a web-based SUpport PRogram (SUPR) for hearing aid users aged 50+: two-arm, cluster randomized controlled trial. Journal of Medical Internet research. 2020;22(9):e17927.

122. Meijerink JF, Pronk M, Kramer SE. Experiences with and lessons learned from developing, implementing, and evaluating a support program for older hearing aid users and their communication partners in the hearing aid dispensing setting. American Journal of Audiology. 2020;29(3S):638-647.

123. Kelly TB, Tolson D, Day T, McColgan G, Kroll T, Maclaren W. Older people's views on what they need to successfully adjust to life with a hearing aid. Health and Social Care in the Community. 2013;21(3):293-302.

124. Ferguson MA, Brandreth M, Brassington W, Wharrad H. Information retention and overload in first-time hearing aid users: An interactive multimedia educational solution. American Journal of Audiology. 2015;24:329-332.

125. Bennett RJ, Eikelboom RH, Sucher CM, Ferguson M, Saunders GH. Barriers and facilitators to delivery of group audiological rehabilitation programs: a survey based on the COM-B model. International Journal of Audiology. 2022;61(2):130-139.

126. Heffernan E, Coulson N, Henshaw H, Barry J, Ferguson M. Understanding the psychosocial experiences of adults with mild-moderate hearing loss: a qualitative study applying Leventhal's self-regulatory model. International Journal of Audiology. 2016;55(S3):S3-S12.

127. Barker AB, Leighton P, Ferguson MA. Coping together with hearing loss: A qualitative meta-synthesis of the psychosocial experiences of people with hearing loss and their communication partners. International Journal of Audiology. 2017;56(5):297-305.

128. Bennett RJ, Saulsman L, Eikelboom RH, Olaithe M. Coping with the social challenges and emotional distress associated with hearing loss: a qualitative investigation using Leventhal's self-regulation theory. International Journal of Audiology. 2022;61(5):353-364.

129. Heffernan E, Withanachchi CM, Ferguson MA. 'The worse my hearing got, the less sociable I got': a qualitative study of patient and professional views of the management of social isolation and hearing loss. Age and Ageing. 2022;51(2):afac019.

130. Bott A, Saunders G. A scoping review of studies investigating hearing loss, social isolation and/or loneliness in adults. International Journal of Audiology. 2021:1-17.

131. Garnefski N, Kraaij V. Effects of a cognitive behavioral self-help program on emotional problems for people with acquired hearing loss: a randomized controlled trial. Journal of Deaf Studies and Deaf Education. 2012;17(1):75-84.

132. Molander P, Hesser H, Weineland S, et al. Internet-based acceptance and commitment therapy for psychological distress experienced by people with hearing problems: A pilot randomized controlled trial. Cognitive Behaviour Therapies. 2018;47(2):169-184.

133. Bennett RJ, Donaldson S, Kelsall-Foreman I, et al. Addressing emotional and psychological problems associated with hearing loss: perspective of consumer and community representatives. American Journal of Audiology. 2021;30(4):1130-1138.

134. Bennett RJ, Kelsall-Foreman I, Donaldson S, Olaithe M, Saulsman L, Badcock JC. Exploring Current Practice, Knowledge, and Training Needs for Managing Psychosocial Concerns in the

Audiology Setting: Perspectives of Audiologists, Audiology Reception Staff, and Managers. American Journal of Audiology. 2021;30(3):557-589.

135. Young T, Pang J, Ferguson M. Hearing From You: Design Thinking in Audiological Research. American Journal of Audiology. 2022:1-10.

136. Maruthurkkara S, Allen A, Cullington H, Muff J, Arora K, Johnson S. Remote check test battery for cochlear implant recipients: proof of concept study. International Journal of Audiology. 2021:1-10.

137. Sucher C, Bennett B, Coetzee L, Liew A, Ferguson M. Assessments in The Cloud: Integrating digital technologies into the cochlear implant clinic using implementation science. presented at: Hearing Across the Lifespan; June 2022 2022; Cernobbio, Italy.

138. Cullington H, Kitterick P, Weal M, Margol-Gromada M. Feasibility of personalised remote long-term follow-up of people with cochlear implants: a randomised controlled trial. BMJ open. 2018;8(4):e019640.

139. Medical Research Council. Developing and evaluating complex interventions: new guidance. 2006.

140. Maidment DW, Ferguson M. An application of the Medical Research Council's guidelines for evaluating complex interventions: A usability study assessing smartphone-connected listening devices in adults with hearing loss. American journal of audiology. 2018;27(3S):474-481.

141. Bennett RJ, Bucks RS, Saulsman L, PAchana N, A. , Eikelboom RH, Meyer CJ. Use of the Behaviour Change Wheel to design an intervention to improve the provision of mental wellbeing support within the audiology setting. Preprint;

142. Skivington K, Matthews L, Simpson SA, et al. A new framework for developing and evaluating complex interventions: update of Medical Research Council guidance. British Medical Journal. 2021;374

143. Heffernan E, Coulson NS, Ferguson MA. Development of the Social Participation Restrictions Questionnaire (SPaRQ) through consultation with adults with hearing loss, researchers, and clinicians: a content evaluation study. International Journal of Audiology. 2018;57(10):791-799.

144. Nielsen AC, Rotger-Griful S, Kanstrup AM, Laplante-Lévesque A. User-innovated eHealth solutions for service delivery to older persons with hearing impairment. American Journal of Audiology. 2018;27(3S):403-416.

145. Burden RS, Galloway LN, Rothpletz AM, Glasheen KA, Preminger JE. The development of an internet-based decision coaching guide to encourage audiology care: the results of a participatory design approach. American Journal of Audiology. 2020;29(3S):546-563.

146. Henshaw H, Sharkey L, Crowe D, Ferguson M. Research priorities for mild-to-moderate hearing loss in adults. Lancet. 2015;386:2140-2141.

147. Fackrell K, Stratmann L, Kennedy V, et al. Identifying and prioritising unanswered research questions for people with hyperacusis: James Lind Alliance Hyperacusis Priority Setting Partnership. BMJ open. 2019;9(11):e032178.

148. Ferguson M, Maidment D, Henshaw H, Gomez R. Knowledge is power: improving outcomes for patients, partners, and professionals in the digital age. Perspectives of the ASHA Special Interest Groups. 2019;4(1):140-148.

149. Bauer MS, Kirchner J. Implementation science: What is it and why should I care? Psychiatry Research. 2020;283:112376.

150. Eccles M, Mittman B. Editorial: Welcome to. Implementation Science Implementation Science. 2006;1(1):1-3.

151. Gitlin LN, Baier RR, Jutkowitz E, et al. Dissemination and implementation of evidence-based dementia care using embedded pragmatic trials. Journal of the American Geriatrics Society. 2020;68:S28-S36.

152. Moullin JC, Sabater-Hernández D, Fernandez-Llimos F, Benrimoj SI. A systematic review of implementation frameworks of innovations in healthcare and resulting generic implementation framework. Health Research Policy and Systems. 2015;13(1):1-11.

153. Nilsen P. Making sense of implementation theories, models, and frameworks. Implementation Science 30. Springer; 2020:53-79.

154. Birken SA, Rohweder CL, Powell BJ, et al. T-CaST: an implementation theory comparison and selection tool. Implementation Science. 2018;13(1):1-10.

155. Moullin JC, Dickson KS, Stadnick NA, et al. Ten recommendations for using implementation frameworks in research and practice. Implementation Science Communications. 2020;1(1):1-12.

156. Studts CR. Implementation Science: Increasing the Public Health Impact of Audiology Research. American Journal of Audiology. 2022:1-15.

157. Marrone NL, Nieman CL, Coco L. Community-based participatory research and human-centered design principles to advance hearing health equity. Ear and Hearing. 2022;43(Supplement 1):33S-44S.

158. Barker F, Lusignan Sd, Deborah C. Improving collaborative behaviour planning in adult auditory rehabilitation: development of the I-PLAN intervention using the behaviour change wheel. Annals of Behavioral Medicine. 2018;52(6):489-500.

159. Barker F, Atkins L, de Lusignan S. Applying the COM-B behaviour model and behaviour change wheel to develop an intervention to improve hearing-aid use in adult auditory rehabilitation. International Journal of Audiology. 2016;55(sup3):S90-S98.

160. Glasgow RE, Harden SM, Gaglio B, et al. RE-AIM planning and evaluation framework: adapting to new science and practice with a 20-year review. Frontiers in Public Health. 2019;7:64.

161. Nickbakht M, Meyer CJ, Saulsman L, et al. Barriers and facilitators to asking adults with hearing loss about their emotional and psychological well-being: a COM-B analysis. International Journal of Audiology. 2022:1-9.

162. Lesica NA, Mehta N, Manjaly JG, Deng L, Wilson BS, Zeng F-G. Harnessing the power of artificial intelligence to transform hearing healthcare and research. Nature Machine Intelligence. 2021;3(10):840-849.

163. Saunders GH, Christensen JH, Gutenberg J, et al. Application of big data to support evidence-based public health policy decision-making for hearing. Ear and Hearing. 2020;41(5):1057.