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A Scoping Review of Technology and Infrastructure Needs in the Delivery of Virtual Hearing Aid Services

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Title: A scoping review of technology and infrastructure needs in the delivery of virtual hearing aid services

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Abstract

Purpose: The digital health revolution has brought forward integral technological advancements enabling virtual care as a readily accessible delivery model. Despite this forward momentum, the field of audiology still faces barriers that impede the uptake of virtual services into routine clinical practice. The aim of this study was to gather, synthesize, and summarize the literature around virtual hearing aid intervention studies and the related technology and infrastructure requirements. **Methods:** A scoping review was conducted using MEDLINE, CINHAI, SCOPUS, Nursing and Allied Health, and Web of Science databases. Objectives, inclusion criteria, and scoping review methods were specified in advance and documented in a protocol. **Results:** The 11 studies identified through this review related to virtual hearing aid services delivered by a licensed healthcare provider and/or facilitator(s) specific to hearing aid management, programming, verification, and validation services. Service delivery models varied according to patient population, technology experience, type(s) and time course of care, type of remote location, and technology/support requirements. Barriers and facilitators to implementation related themes including technology access and function, client sociotechnical, convenience, education and training, interaction quality, service delivery, and technology innovation. **Conclusions:** This scoping review provides evidence around the technology and infrastructure required for full integration of virtual hearing aid services into practice and according to care type. Low-tech versus high-tech requirements may be used to guide virtual service delivery triaging efforts. Research and development efforts in the areas of pediatrics, clinical support tools, and hearing aid/app-based solutions will support further uptake of virtual service delivery in audiology.

Introduction

The World Health Organization's recent "World Report on Hearing" highlights an unacceptable number of people living globally with unaddressed hearing loss and ear diseases, stressing the need for timely action to prevent and address hearing loss across the life course (World Health Organization [WHO], 2021). Inequalities related to accessing hearing services are further exacerbated when faced with the effects of global events, such as the COVID-19 pandemic, and the influence of social distancing requirements and other psychosocial consequences. Families are now facing greater challenges considering travel-related resources, access to child-care, stress and anxiety related to personal health, and avoidant behaviours towards in-person appointments in face of COVID-19 (Douglas et al., 2020; Latham et al., 2020; Li et al., 2020). Considering the implications of current global events, people living with hearing loss have experienced service delays related to care required to address hearing needs (Ayas et al., 2020; Moynihan et al., 2021).

Delays in access to audiological care, including rehabilitative or hearing aid care, have the potential to negatively impact individuals who rely on these services for communication and day-to-day functioning. Even if temporary, service delay can impact psychological well-being and may amplify feelings of social isolation (Ciorba et al., 2012; Douglas et al., 2020; Li et al., 2020; Nordvik et al., 2018). Social isolation is one negative outcome of physical distancing and stay-at-home measures, experienced across the globe. Furthermore, individuals with disabilities such as hearing loss may experience feelings of frustration and loneliness, compounding an inability to communicate related to their hearing loss, which may be exacerbated by the use of facial masks (Douglas et al., 2020; Li et al., 2020; Ten Hulzen & Fabry, 2020). The inability to access hearing services can adversely impact well-being and quality of life (Hay-McCutcheon et

al., 2019). These impacts pose risks to both pediatric and adult populations and warrant the need for timely and continuous access to services. When hearing loss is not addressed in older adults, it can lead to cognitive decline and can increase the risk of dementia (Gonzales et al., 2017). In children, limited access to audiological rehabilitative care has been found to have negative impacts on speech and language development, literacy skills, educational success, and social-emotional well-being (Wilson et al., 2017). Beyond extending services remotely, virtual care has the potential to facilitate person-centred care, improving the effectiveness and efficiency of services for those experiencing health disabilities.

The digital health revolution offers innovative information and communication technology advancements, with the potential to offer alternative service delivery models. There are many terms associated with technology-enabled service delivery models, including telehealth, telemedicine, remote care, virtual care, mHealth, eHealth, connected care, tele-audiology, tele-fitting, and eAudiology. The term *virtual care* will be used throughout this study, where *virtual* describes interactions between patients/clients and people involved in the delivery and/or management of care, occurring remotely, using any form(s) of communication or information technologies with the aim of facilitating or maximizing the quality and effectiveness of the care process (Shaw et al., 2018). Virtual care should aim to strengthen overall health service delivery, rather than compete with the in-person care model, a concept dating back to global eHealth initiatives recommended by the WHO in 2010 (WHO, 2010). Audiology delivery models continue to expand with the changing technological landscape. Over the past decade, the field of audiology has experienced greater and more flexible service delivery options for providers and patients/clients, clear opportunities for interdisciplinary collaboration and greater

use of on-site facilitators, and an increased ability to connect individuals to follow-up care and provide educational support (Molini-Avejonas et al., 2015; Muñoz et al., 2021).

Virtual audiology is now considered in a more positive light when compared to stakeholder practices and opinions pre-pandemic. Delivery infrastructures are rapidly evolving for use in practice, but hands-on experience and education opportunities are critical to ensuring further progress (Eikelboom et al., 2021; Saunders & Roughley, 2020). Internet-based interventions for adults with hearing loss, tinnitus, and vestibular disorders have also been found to provide positive patient outcomes for many, while also increasing accessibility to services (Aazh et al., 2021; Beukes et al., 2018). When comparing survey data collected before and during the pandemic, including screening and general phone appointments, videoconferencing, cochlear implant consultations, tinnitus sessions, group sessions, adult rehabilitation, and hearing aid adjustments, an increase in positive attitudes and use towards virtual care in audiology is reported; the adequacy of virtual hearing aid service delivery related to device fitting is reported to be low and device fitting follow-up and fine-tuning is reported to be relatively high (Eikelboom et al., 2021). These findings likely relate to the level of technology required for the specific application in use, including varying amount of skill and knowledge to successfully implement into practice.

Despite recent advancements around the clinical integration of virtual care, the field of audiology is still experiencing barriers to uptake. When considering previous literature reviews, it is apparent that clinical recommendations around remote hearing aid services are evolving with technological advancement that is supported through research (Muñoz et al., 2021; Tao et al., 2018). These interconnected requirements, integral to the uptake of virtual hearing aid care, warrant further investigation to support technology- and infrastructure-specific recommendations

across the varying types of hearing aid care. Also highlighted is the need for repeated efforts to review the evidence, as we continue to experience rapid technological advancement during and following the COVID-19 pandemic.

The clinical uptake of virtual hearing aid care is multi-faceted, relating closely to implementation factors on both the provider and the client side of care. Recent survey data from Eikelboom and colleagues (2021) suggests growth in the attitudes and use of virtual care by international audiologists, although the disparity between high attitudes and lower reported growth in usage suggests the need to examine the barriers and facilitators to implementation more closely. Moderate to extreme barriers related to the delivery of virtual care are reported to include technology and internet access, lack of client-related confidence in using technology, multiple technology platform requirements, limited scope for programming or adjusting hearing aids remotely, lack of training, and the risk of making hearing care impersonal (Eikelboom et al., 2021; Parmar et al., 2021). Literature surrounding the factors thought to influence the use of remote care amongst pediatric audiologists highlight the need for best practice guidelines to support implementation efforts (Glista, O'Hagan, Moodie, et al., 2021). Multi-faceted and multi-level guidance is therefore needed to support successful uptake of virtual care in audiology and will ultimately lead to a clearer understanding of the delivery models/modalities that can be used effectively in practice and in alignment with evidence-based practice. Clinical support tools have the potential to guide both virtual and hybrid care pathways.

A clearer understanding of the required components and implementation factors involved in the delivery of virtual hearing aid services, and across the different service types, is necessary to guide the development of training and education tools and the successful translation of these services into clinical practice. From a health services perspective, further research is required to

fully integrate virtual audiology services into routine clinical practice. The primary objective of this scoping review was to gather, summarize, and synthesize the peer-reviewed literature describing virtual hearing aid services delivered as part of intervention studies. A secondary objective was to synthesize information related to the integral components and implementation factors that contribute to the delivery of virtual hearing aid services, including the models, modalities, and supports required. This scoping review was conducted as part of a study aimed at evaluating the different factors, systems, and processes that affect access to and use of virtual hearing aid care for all stakeholders.

Methods

This scoping review was conducted and reported in accordance with the Joanna Briggs Institute (JBI) methodology for scoping reviews (Aromataris & Munn, 2017; Peters et al., 2020). Systematic and scoping review projects are exempt from the research ethics review process based on the use of secondary and anonymized information (Canadian Institutes of Health Research et al., 2018). A preliminary search using MEDLINE and CINAHL found that there were no published systematic or scoping reviews that provided synthesized data on the components required to enable and integrate virtual hearing aid services into routine clinical care models. This scoping review included studies that were: a) peer-reviewed; b) published in English; c) specific to services delivered to a client/family by a licensed hearing healthcare provider (e.g., an audiologist, otolaryngologist¹, or audiologist-directed facilitator); d) specific to an evaluation of a virtual hearing aid intervention including management, programming,

¹ A hearing aid fitting study included in this review was conducted in Brazil prior to 2021, when an Otolaryngologist was required to complete a hearing aid prescription prior to referring hearing aid selection and fitting process to an audiologist (*Justiça afirma validade de Resolução do CFFa – Conselho Federal de Fonoaudiologia*, n.d.). All other studies were conducted in countries where hearing aid prescription is within the scope of practice of a regulated Audiologist.

verification, and/or validation; and e) including services incorporating technology-enabled interaction between the provider or a facilitator and the client/family. Studies were excluded if they were: a) published in grey literature or outside of a peer-reviewed journal; b) published in a language other than English; c) included services to a client/family that were not delivered or directed by a licensed hearing healthcare provider; d) an evaluation of a virtual hearing aid intervention was not conducted; and e) services did not incorporate technology-enabled interaction between the provider or a facilitator and the client/family or were specific to client-facilitated educational support. There was no limit on the publication date range.

Search Strategy

This scoping review was supported by a librarian from the University of Western Ontario, who assisted in the development of the search strategy and provided guidance throughout the development of the protocol. An initial search of MEDLINE and CINAHL was conducted to identify published studies related to virtual hearing care. Key words from the identified studies' titles, abstracts, and index terms were used to develop a complete search strategy. Table 1 provides the search strategy used for MEDLINE, which was adapted for CINAHL, SCOPUS, Nursing and Allied Health, and Web of Science databases. Database searches were completed on August 7th, 2020. Additional records were identified in the full-text eligibility stage of the review through citation screening and hand-searching. The objectives, inclusion criteria, and methods of analysis for this review were specified in advance and documented in a protocol (DiFabio et al., 2021).

Table 1*Literature Search Strategy*

MEDLINE Search Strategy
(remote OR virtual OR internet-based OR “internet based” OR internet OR tele-audiology OR teleaudiology OR telemedicine OR tele-medicine OR telehealth OR tele-health OR mobile OR eHealth OR mHealth OR eAudiology OR connected OR cyber OR electronic OR online OR virtual) AND (“hearing aids” or Hearing Aids/ OR audiology or Audiology/ OR audiological) AND (intervention OR treatment OR support OR “device programming” OR fitting OR counseling OR counselling OR guidance OR training OR education OR management OR orientation OR monitoring OR troubleshooting)

Note. Search terms were used for all databases. For MEDLINE and CINAHL subject headings, official words, and/or phrases selected to represent concepts (e.g., Audiology) were also searched.

Evidence Selection

Following the literature searches, all identified citations were collated and uploaded into Covidence software (Veritas Health Innovation, n.d.), which was used to manage the study process, study selection, and to automatically remove duplicates. The study selection proceeded in two stages: 1) title and abstract screening and 2) full-text review. Titles and abstracts were screened by two independent reviewers (DD, RO) for assessment against the inclusion criteria and potentially relevant sources were tagged as *Yes* or *Maybe*. The reviewers participated in a calibration exercise with 10 sample studies to verify that inclusion criteria were consistently applied (Levac et al., 2010). Upon consensus of the first screening, full-text studies were then retrieved. During the second stage of the review process, studies were assessed by two reviewers (DD, RO) to ensure they met the inclusion criteria. A rationale for excluding sources of evidence at the full-text eligibility stage was recorded in Covidence (refer to Results section). Any screening conflicts between the two reviewers, at either stage, were discussed with the team (DD, DG, RO). Additional relevant studies were hand-picked from the reference lists of selected studies. Refer to Figure 1 for a display of the results of the study selection phase according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR, Tricco et al., 2018).

Data Extraction

The research team (DD, DG, RO) developed the data extraction tool, followed by a pilot data extraction with two studies, completed by two reviewers (DD, RO). The pilot data extraction process ensured that the extracted information was standardized across reviewers and consistent with the research questions (Levac et al., 2010). Data extraction included a detailed description of each research study's objectives, methods, and outcomes, with particular interest

around the providers' location and training, type and timeline of service(s), delivery model/modalities, technologies/tools/specialized equipment, support personnel/tools, and other relevant implementation factors. A final data extraction tool can be found in Appendix A. Data was synthesized using categorization of primary service types of virtual hearing aid care (Table 2).

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Table 2*Virtual Hearing Aid Care Key Components and Definitions*

Term	Definition
Digital literacy	The ability to operate and understand digital devices of all types, including the technical skills to operate these devices, the conceptual knowledge to understand their functionality, and the ability to creatively and critically use these devices to access, manipulate, evaluate, and apply data, information, knowledge, and wisdom in activities of daily living (Nelson & Stagers, 2018).
Facilitator	A person, or people, who assists the provider in conducting an appointment at the remote location, acts as a liaison between the provider and the client, and who manages the hands-on aspects of a virtual appointment. (Coco et al., 2016).
Provider location	The physical location where the provider is delivering services from and at a distance to the client.
Remote location	The physical location where the client is receiving care; often integrating family members, caregivers, or substitute decision makers as support personnel.
Virtual delivery model	The type of client-provider interaction used to facilitate the delivery of virtual services.
Asynchronous	Service delivery using “store-and-forward” technology to enable non-real-time, two-way exchange of data when stakeholders are not available to interact at the same time. For example, email and cloud-based communication and applications.
Hybrid	Involves a combination of both asynchronous and synchronous service delivery models and/or the combination of in-person and virtual service delivery models.
Synchronous	Real-time delivery of two-way interactive telecommunication technology and/or patient monitoring technologies to connect a healthcare provider to a client/ family for direct care. Common examples include the use of videoconferencing and telephone-based interaction (Nelson & Stagers, 2018).
Time course	The time point(s) in the client care process in which care is offered/provided. For example, an initial hearing aid fitting or a follow-up hearing aid appointment.
Follow-up	Care provided to a client in follow-up to the receipt of a treatment, such as a hearing aid fitting.
Initial	Care provided to a client to enable a new treatment. For example, an initial hearing aid fitting.
Virtual hearing aid services	The provision of direct, technology enabled hearing aid services to a client who is in a different location to the provider. These services include management, programming, validation, and verification.
Management	Hearing aid care related to ongoing device use and management, including the provision of counselling, monitoring, and education services to a client(s), family member(s), and/or substitute decision maker (College of Audiologists and Speech-Language Pathologists of Ontario, 2016).
Programming	The direct act of programming or adjusting the settings of a hearing aid(s). In initial hearing aid care, this involves a hearing aid fitting to ensure adequate physical fit and alignment with a valid fitting formula. In follow-up care, hearing aid programming is often used in response to troubleshooting needs and/or related to hearing aid fitting difficulties.
Validation	Measurement of benefit and/or satisfaction with hearing aids using formal or informal scales, questionnaires, and/or interviewing (College of Audiologists and Speech-Language Pathologists of Ontario, 2016).
Verification	Verification ensures that the hearing aid(s) meets a set of standards and that output values are within safe and comfortable limits, including verification of the hearing aids performance to the prescribed settings using appropriate verification methods such as the

use of probe microphone measurements and hearing instrument test box (CASLPO, 2016).
Virtual verification is often facilitator-led and/or may include simulated verification.

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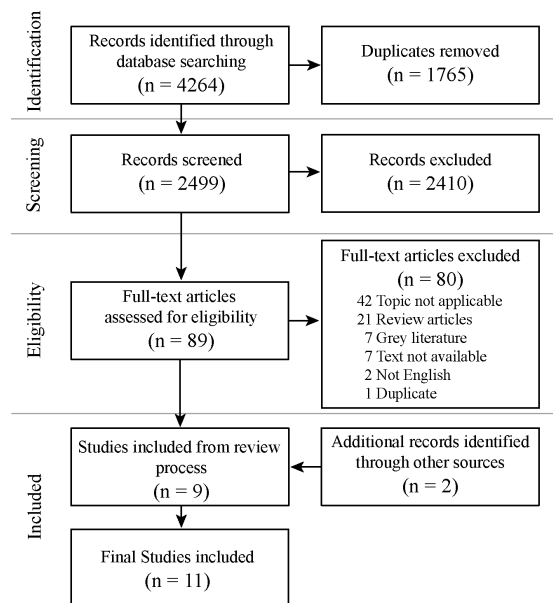
Results

Search Results

The literature search generated a total of 4,264 studies to be screened and imported into Covidence, 1,765 duplicates were automatically removed through Covidence. Of the remaining 2,499 studies, 2,410 studies were removed during the initial title and abstract screening, and a further 80 studies were removed during full-text review. A total of 11 studies were included in the final dataset, including two additional hand-picked studies (Figure 1).

Figure 1

PRISMA-ScR Flow Diagram



A summary of all extracted data is provided in Table 3 and can be used as a supplement to the following reported results.

Participant Populations and Time Course of Virtual Care

Of the 11 included studies, 10 were focused on adult participant populations, with only one study involving pediatric participants and their families. Two studies included new hearing aid users, two studies included experienced hearing aid users (i.e., greater than one year of hearing aid experience), four studies included both new and inexperienced users, and three studies did not specify previous hearing aid use. One adult-focused study included the delivery of initial hearing aid services for new study devices in a virtual manner, three were focused on delivery of follow-up services and included both adults and children, seven studies included adult participants that received both initial and follow-up virtual hearing aid services, and the time course of service delivery for one study is unknown.

Delivery Models and Modalities

When considering the virtual delivery model used, only one study included asynchronous delivery. All others were reported as synchronous virtual delivery, with the inclusion of an in-person component for five hybrid delivery models, across various service types. In-person services were used to deliver initial hearing aid fitting services in three studies, and five studies included initial hearing aid fitting delivered virtually to a remote clinic location with a facilitator. Hearing aid services were delivered to different remote locations including the client's home and workplace ($n = 4$) and remote clinic locations ($n = 9$) that simulated clinic environments and/or provided specialized remote equipment in both urban and rural facilities. Two studies provided an optional in-person supervised instructional set-up of the virtual equipment (Angley et al., 2017; Muñoz et al., 2017).

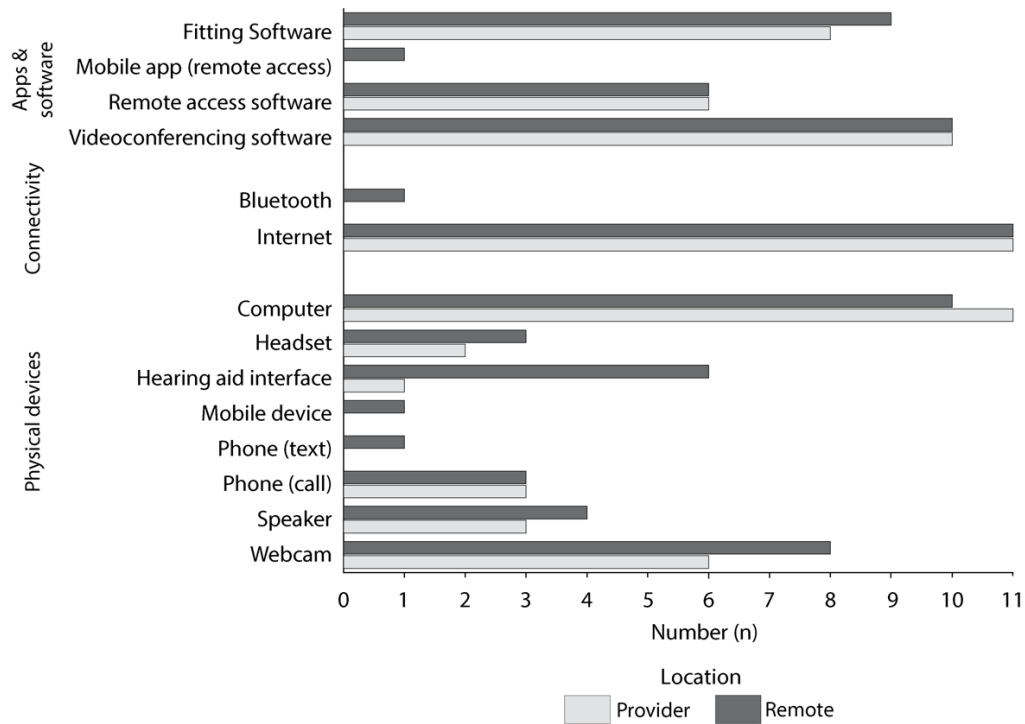
Technological Components in Delivery

Various technological requirements were identified, depending on the type(s) of service and the model and modalities with which it was delivered. Technologies differed according to

the remote and provider location requirements. Figure 2 summarizes the technologies and tools used according to use in the provider location and/or the remote location with a client and/or facilitator. Across all service types, a computing device such as a computer, laptop, or mobile device was used, along with the internet and video conferencing software, with the exception of the one study specific to mobile device use, which did not require videoconferencing to deliver asynchronous services (Convery et al., 2020). Many of the studies required the use of a webcam to enable audio/video interaction during videoconferencing (six in provider locations, eight in remote locations). A high number of studies (9) included fitting software in the delivery model, to connect to hearing devices during service delivery. A hearing aid interface, such as a wired or wireless programming device, was included in six studies in the remote location and in one at the provider location. Remote access software was incorporated in over half of the studies (6), all of which included a facilitator in the delivery of services.

Figure 2

Technological Components Reported According to Location of Service



Hearing Aid Management

A total of seven studies included the delivery of virtual hearing aid management, including counselling services. The pediatric study included direct-to-patient delivery of virtual counselling services to families of children wearing hearing aids. Services in this study were focused on a series of virtual visits to monitor hearing aid use via the remote connection using the datalogging feature; this study identified the ability to collect data logging information more frequently as an important factor in effective problem-solving to increase hearing aid use (Muñoz et al., 2017). Of the remaining six studies that included virtual hearing aid management with adults, most incorporated a facilitator to deliver or assist with services. Virtual hearing aid

management was focused on informational and coaching-based counselling specific to hearing aid use, care and handling, demonstrations, as well as management of hearing aid expectations/limitations (Anglely et al., 2017; Campos & Ferrari, 2012; Muñoz et al., 2017; Novak et al., 2016; Pearce et al., 2009; Penteadó et al., 2014; Tao et al., 2020). All studies that included hearing aid management used synchronous delivery of virtual services and the use of videoconferencing.

Hearing Aid Programming

A total of nine studies included the delivery of initial and/or follow-up hearing aid programming services virtually to a client in a remote location. Three studies included initial hearing aid programming services delivered in-person, whereas only one study included a follow-up in-person programming component. Two of the nine studies incorporated hearing aid programming in both initial and follow-up appointments, three completed only initial programming, and four limited programming to follow-up appointments. A facilitator was incorporated into the delivery model to offer provider-led services in the case of initial virtual programming services and to incorporate remote technologies and specialized equipment into the appointment. Remote technologies, including videoconferencing and remote access software, enabled the provider to oversee or deliver controlled acts via facilitator collaboration and the use of a computer situated in a remote clinic location. Reported virtual programming activities varied across studies and included adjustments to the physical fit, volume, frequency-gain adjustments, program management, and changes to hearing aid features/ settings, such as frequency lowering, occlusion compensation, noise management (Anglely et al., 2017; Campos & Ferrari, 2012; Convery et al., 2020; Penteadó et al., 2012; Tao et al., 2020). Across studies, programming adjustments were motivated by client-related feedback and/or according to a study protocol.

Hearing Aid Verification

Five studies included synchronous virtual hearing aid verification services for initial and/or follow-up hearing appointments. These studies included both provider- and facilitator-led remote verification that took place in a remote clinic using videoconferencing. Remote access software allowed provider control over hearing aid fitting and verification equipment positioned in the remote location for a subset of these studies, with a facilitator completing the insertion of a probe microphone into the client's ear to enable real ear measurements ([REM]; Campos & Ferrari, 2012; Ferrari & Bernardez-Braga, 2009; Novak et al., 2016; Pearce et al., 2009; Pross et al., 2016). Reporting details regarding the delivery model used when verifying hearing aids remotely were inconsistent across studies. In general, virtual verification services confirmed amplification targets and accommodated client feedback. This review did not identify any studies where direct-to-client virtual verification services could be provided outside a remote clinic location with a facilitator present to operate specialized equipment.

Hearing Aid Validation

A total of four studies administered one or more validation measures as part of a virtual follow-up hearing aid appointment; one additional study, not included in this count, used direct mailing to deliver validation tools to participants in their home (Pross et al., 2016). Two of the four studies including validation used both in-person and virtual validation services. The following measures were reported as part of virtual hearing aid validation services: International Outcome Inventory for Hearing Aids (IOI-HA), Glasgow Hearing Aid Benefit Profile (GHABP), Hearing Handicap Inventory for the Elderly (HHIE-S), Psychosocial Impact of Assistive Devices Scales (PIADS), Hearing in Noise Test (HINT), Satisfaction with Amplification in Daily Living (SADL), Client Oriented Scale of Improvement (COSI), and Hearing Aid Issues Instrument

(HAI (Campos & Ferrari, 2012; Novak et al., 2016; Penteado et al., 2014; Tao et al., 2020).

Details pertaining to the virtual administration included a mix of provider- and facilitator-led questioning (read aloud) and client response recording, with three of the four studies using videoconferencing and one study collecting data in-person at the remote location via the facilitator.

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Table 3*Overview of Included Studies*

Study	Design	Participant population	Hearing aid use history	Care type in a virtual or hybrid delivery model (I - initial, F – follow-up, B – both)	Remote location	Facilitator(s)
Angley et al., 2017	Descriptive quasi-experimental group design	Adults, 32-88 years (n= 51)	New and experienced	<i>Virtual-Synchronous</i> ² : management (F), programming (F)	Remote clinic and home (video)	None
Campos & Ferrari, 2012	Prospective randomized study	Adults, 39-88 years (n= 50)	New	<i>Virtual-Synchronous</i> ¹ : management (I), programming (I), verification (I), validation (I) <i>In-person</i> : Validation (F)	Remote clinic (video)	Audiology & SLP students /providers
Convery et al., 2020	Exploratory study	Adults, <86 years (n= 30)	Experienced	<i>Virtual-Asynchronous</i> ¹ : programming (F) <i>In-person</i> : programming (I)	Home (mobile app)	None
Ferrari & Bernardez-Braga, 2009	Repeated measures group design	Adults, 18-84 years (n= 60)	Unknown	<i>Virtual-Synchronous</i> ¹ : verification (F)	Remote clinic (video)	Audiologist
Muñoz et al., 2017	Longitudinal case study	Families, 0-5 years (n= 4)	New and experienced	<i>Virtual-Synchronous</i> ² : management (F)	Home (video)	None
Novak et al., 2016	Descriptive study	Adults (n= 181)	New and experienced	<i>Virtual-Synchronous</i> : management (I), programming (I), verification (I), validation (I) <i>In-person</i> : programming (F), when required <i>Phone</i> : validation (F)	Remote clinic (video and phone)	Nursing & audiology students
Pearce et al., 2009	Pilot case studies	Adults (n= 3 [5 total])	Unknown	<i>Virtual-Synchronous</i> ¹ : management (F), programming (B), verification (I)	Remote clinic (video)	Hearing assistants
Penteado et al., 2012	Case reports	Adults, 61-81 years (n= 3)	Experienced	<i>Virtual-Synchronous</i> : programming (I)	Remote clinic (video)	Audiologist
Penteado et al., 2014	Pilot case studies	Adults, 18-90 years (n= 8)	New	<i>Virtual-Synchronous</i> : management (F), programming (F), validation (F) <i>In-person</i> : programming (I)	Remote clinic (video)	Audiologist
Pross et al., 2016	Retrospective case-control	Adults, mean 75 years (n= 42,697)	Unknown	<i>Virtual-Synchronous</i> ¹ : programming (B), validation (F), verification (B) <i>Mail-in</i> : validation (F)	Remote clinic (video)	Audiology technician

Tao et al., 2020	Single-blinded, crossover, randomized control trial	Adults, 50-93 years (n= 56)	New and experienced	<i>Virtual-Synchronous</i> ¹ : management (F), programming (F), validation (F) <i>In-person</i> : programming (I), validation (B)	Remote clinic, home, and work (video)	Audiology students
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Note. ¹ Indicates a study comparing virtual to in-person service delivery; ² indicates the inclusion of an optional in-person or phone-based equipment set-up model.

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Barriers and Facilitators to the Implementation of Virtual Services

This review identified various delivery components related to the implementation of virtual hearing aid services. Figure 3 illustrates these components as facilitators and/or barriers, and according to the overarching implementation themes. Components located in the middle column could be categorized as either a barrier or facilitator, depending on whether reported in a positive or negative manner. Identified themes consider involvement from all stakeholders in the implementation of virtual services; however, the technology/infrastructure components require greater provider consideration to ensure appropriate integration in provider-led or -directed care scenarios. Factors related to accessing technology/services and related functionality of technologies included were included in the *access and technology function* theme. Overall, technical robustness acted as a barrier when technology functionality was poor and as a facilitator when functioning well. Components reported to be barriers to the implementation of virtual services included: the remote mobile application used in one study, which reported connection difficulties for some users; the internet, found to limit access and/or create a poor quality virtual connection in three studies; and general technology challenges related to equipment set-up, connecting the hearing aid remotely, troubleshooting remote access software, and general computer technology (Anglely et al., 2017; Campos & Ferrari, 2012; Convery et al., 2020; Muñoz et al., 2017; Novak et al., 2016; Penteado et al., 2012; Pross et al., 2016; Tao et al., 2020). The use of alternative communication technology was identified as a facilitator to virtual service delivery in the case of poor technology function (Penteado et al., 2012; Tao et al., 2020).

Under the *client sociotechnical* theme, the client's digital literacy was noted as a factor that influenced whether additional set-up help was required; in one study this was informally assessed prior to deciding on whether support was needed at the start of the appointment (Anglely

et al., 2017; Muñoz et al., 2021). In addition, one study reported on factors thought to relate to client facilitation of virtual services, including motivation to use the technology as part of the care process and having a positive perception around the service delivery model (Muñoz et al., 2017). Sociotechnical considerations also influenced the overall time requirements for each appointment. When considering *convenience* factors, the use of specialized equipment was identified as a significant barrier; this related to added operational and training needs specific to multiple technologies used in the delivery of verification and/or programming services in a remote location (Campos & Ferrari, 2012). Alternatively, the elimination of travel time, overall appointment time, and the use of counselling services (i.e., low-tech) during virtual delivery were reported as facilitators to successful implementation in three studies (Campos & Ferrari, 2012; Novak et al., 2016; Tao et al., 2020).

Included in the *education and training* theme were barriers such as the use of unclear instructions during equipment set-up (Anglely et al., 2017) and poor training to enable rapid clinical decision making and/or affecting the facilitator's ability to follow instructions (Ferrari & Bernardez-Braga, 2009; Novak et al., 2016). Three studies reported on the provider and/or facilitator's digital literacy as either a barrier or facilitator, depending on their technical abilities as demonstrated during the study (Ferrari & Bernardez-Braga, 2009; Novak et al., 2016; Pearce et al., 2009). The most commonly reported facilitator to successful implementation and overall satisfaction with the virtual delivery model was the inclusion of specialized training directed at the provider and/or facilitator (Novak et al., 2016; Pearce et al., 2009; Penteadó et al., 2012; Tao et al., 2020). The use of a facilitator was linked to positive preceptorship, which included interprofessional collaboration with students and professionals across nursing, speech language

pathology, and audiology. Evidence to support the effectiveness of the virtual service and the delivery according to evidence-based-practice was also seen as a facilitator (Pearce et al., 2009).

The virtual *interaction quality* was reported to be influenced by the audio and/or visual quality in five studies, with more reports of poor quality components acting as barriers (Anglely et al., 2017; Campos & Ferrari, 2012; Ferrari & Bernardez-Braga, 2009; Penteado et al., 2012; Tao et al., 2020). Comfort with a facilitator was cited as a potential additional barrier (Tao et al., 2020). Facilitators to virtual interaction also related to high levels of communication and collaboration between professionals and support personnel and the inclusion of a virtual face-to-face component in the interaction (Novak et al., 2016; Penteado et al., 2012).

Many facilitators were reported to influence implementation at the *service delivery* level, such as the inclusion of interactive delivery using videoconferencing; improved overall convenience for the families, including the ability to offer more flexible and timely service delivery; the ability to include multiple people from various locations in one appointment; and provider/facilitator language fluency (Ferrari & Bernardez-Braga, 2009; Muñoz et al., 2017; Novak et al., 2016; Tao et al., 2020). Components relating to technological innovation, such as application limitations in the form of closed-response choices that did not include the ability to report all hearing needs, were seen as a barrier to asynchronous virtual interaction (Convery et al., 2020). The inclusion of minimal equipment to enable efficient and effective information sharing was seen as an overall facilitator to virtual service delivery (Penteado et al., 2014).

Figure 3

Implementation Themes and Related Barriers and Facilitators

	Barriers	←→	Facilitators
Access and Technology Function	Application connection Equipment set-up/troubleshooting Poor internet connection	Reliability and robustness	Alternative communication
Client Sociotechnical		Digital literacy	Attitude Motivation
Convenience	Specialized equipment		Appointment time Counselling services Less travel time
Education and Training	Clinical decision-making Unclear instructions	Digital literacy	Evidence to support use Positive preceptorship Specialized training
Interaction Quality	Comfort with facilitator	Audio quality Visual quality	Collaboration Face-to-face component
Service Delivery	Scheduling		Convenience Flexible support Interactive service delivery Inclusion of multiple people Language fluency Timely access
Technology Innovation	Application limitations (closed/ non-specific response choice)		Equipment streamlining/minimization Universal technology

Discussion

This scoping review was conducted according to JBI methodology to gather, summarize, and synthesize the literature describing provider- or facilitator-led virtual hearing aid services delivered to clients and or families in a remote location. Findings relate to 11 hearing aid intervention studies identified to meet the inclusion criteria. Results differed according to the following main components: participant population, hearing aid experience, type of virtual service, time course, virtual service delivery model, hybrid aspects, remote location, and the use of facilitator(s) to assist in delivery. Virtual services examined as part of this scoping review

included hearing aid management (e.g., counselling), programming, verification, and validation. The benefits of virtual services, compared to in-person, are multifactorial and include the opportunity for greater access to care and more connected patient care pathways; however, implementation challenges still exist in the field of audiology and beyond (Molini-Avejonas et al., 2015). A full integration of virtual and/or hybrid health service delivery systems is yet to be achieved. This is largely due to insufficient technology and infrastructure to support routine virtual services in clinical audiology (Saunders & Roughley, 2020). This review helps fill a gap in the evidence related to the technical components of virtual care, as well as noted barriers and facilitators that were found important in the delivery of virtual hearing aid services.

Virtual hearing aid services were found to be delivered across a wide range of ages (i.e., 0 to 93 years) and differing care needs. Only one study included pediatric hearing aid services, highlighting the need for future research to evaluate virtual service delivery with younger populations. A greater pediatric evidence-base is needed in the development of clinical practice guidance related to virtual audiology care. Integration of virtual service delivery is dependent on technological innovation and best-practice guidance enabling the safe and effective delivery of care. At the time of this review, virtual hearing aid programming/fitting with pediatrics was not integrated into routine clinical care, relating to limited access to technology enabled in pediatric hearing aid devices and applications. The requirement to complete frequent and timely verification procedures, as part of routine pediatric audiology care, further complicates the virtual delivery of hearing aid verification services to pediatrics. Special and/or at-risk populations can increase demand on the care process related to the use of specialized equipment, facilitators, and related training needs in absence of direct-to-client virtual verification solutions.

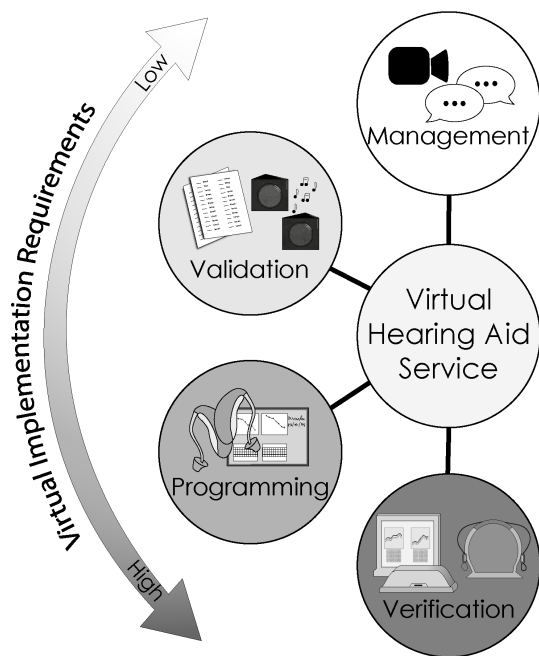
Implementation Considerations

When providing hearing aid care using a virtual delivery model there are many factors for a provider to consider that influence the successful implementation of these services. This review identified technological/infrastructure factors to consider during the integration of virtual hearing aid services. These have been expanded on in the form of a checklist for easy consultation and cover four implementation requirements to consider: need/preference, access, set-up and troubleshooting, and training (Table 4). Need/preference requirements refers to the client and/or provider needs to implement virtual care. Access, as well as set-up and troubleshooting requirements, are dictated by the type and modality of care being provided and relate to technologies and software used in the virtual care delivery. Set-up and troubleshooting will also contain aspects related to interactions with the client and/or facilitators assisting in the virtual appointment. Training requirements should be considered for every stakeholder involved in the appointment, for the client, caregivers, facilitators, and other healthcare professionals.

Table 4*Technology and Infrastructure Checklist for Virtual Care Implementation*

Requirements	Components
Need/preference	<ul style="list-style-type: none"> ✓ Care type and corresponding technology/software ✓ Model of care delivery ✓ Personnel included in appointment ✓ Assistive & accessible technology ✓ Privacy, security, & data management
Access	<ul style="list-style-type: none"> ✓ Required technology/software or loaner options ✓ Sufficient internet ✓ Alternate communication ✓ Adequate physical space ✓ Infection prevention and control
Set-up & troubleshooting	<ul style="list-style-type: none"> ✓ Technology/software installation ✓ Device(s) power supply ✓ Interaction quality (audio/visual) ✓ Supports to optimize delivery
Training	<ul style="list-style-type: none"> ✓ Operational and/or informational ✓ Accessible technology/software-specific resources ✓ Individualized & care-specific

A wide range of technology and infrastructure requirements in the delivery of virtual services were identified across the 11 studies included in this review; these were found to range from low to high implementation requirements (Figure 4). These requirements involve varying levels of stakeholder integration efforts, depending on the type of care and the components required to enable virtual delivery (e.g., technologies and/or use of a facilitator). Technological requirements will evolve with research and development efforts leading to advancements in virtual care. Streamlining of required technology will be one example of a positive outcome; for instance, improving remote capabilities of virtual hearing aid verification could enable the direct verification of the hearing aid response using the device itself, eliminating the need for facilitator-operated specialized equipment and minimizing implementation requirements.

Figure 4*Virtual Hearing Aid Care Implementation Requirements*

Virtual hearing aid management services were found to have a low-level of technological requirements and mainly focused on informational counselling, coaching, and monitoring of hearing use through the hearing aid data logging feature and client/family feedback. Technology needs included the internet, a computer (or smartphone), and videoconferencing equipment (often including the use of a webcam or headset), in both the provider and remote location (Angley et al., 2017; Campos & Ferrari, 2012; Muñoz et al., 2021; Novak et al., 2016; Pearce et al., 2009; Penteadó et al., 2014; Tao et al., 2020). This review highlighted the flexibility with which virtual hearing aid management services could be delivered to all patient populations to remote clinic, home, and work locations, at different time courses in the care process, and with optional use of a facilitator. Facilitators can be incorporated into the management process to deliver hands-on demonstration of device insertion and use and to enable connection (Coco et al., 2020). In the absence of a facilitator with specialized training, efforts directed at training other

support personnel (e.g., parents, other family members, caregivers) may support the delivery of hearing aid management in a remote location.

Implementation requirements specific to virtual validation services were found to be moderate. Technological requirements were reported to be similar those of virtual hearing aid management, with the addition of specialized equipment such as a sound field speaker, as well as the use of a facilitator in a remote clinic, depending on the operationalization of the outcome measurement testing (Campos & Ferrari, 2012; Novak et al., 2016; Penteado et al., 2014; Tao et al., 2018). Whereas virtual hearing aid programming care was found to have greater implementation requirements that varied according to the time course of care. Initial fittings offering fit-to-target information were accompanied by high-tech service delivery options, including specialized equipment positioned in the remote location to enable verification. Virtual hearing aid services reported in this review more commonly incorporated follow-up programming services (a lower tech option), including the internet, computer or mobile device, videoconferencing, hearing aid interface (wired/wireless), fitting software, and optional remote access software (Anglely et al., 2017; Campos & Ferrari, 2012; Convery et al., 2020; Novak et al., 2016; Pearce et al., 2009; Penteado et al., 2012, 2014; Pross et al., 2016; Tao et al., 2020). Technological innovation including mobile devices allows for virtual hearing aid programming services to take place in real-world scenarios, thereby increasing person-centered care.

Verification requirements persist following the completion of significant virtual hearing aid adjustment to confirm audibility and quality needs are met. These services required the most equipment and were considered a high-tech service. This is partly due to the lack of direct-to-patient verification options along with provider desire to complete an in-person/hands-on assessment of devices and patient acceptance; this has been mitigated by facilitator-led service

delivery in the remote location to perform various hands-on tasks (Coco et al., 2020; Saunders & Roughley, 2020). During the pandemic, clinical recommendations for incorporating virtual delivery around the use of hands-on requirements related to triaging appointment needs into no-touch, low-touch, or high-touch, with those identified as high-touch to be supported by a facilitator and/or specialized equipment (Swanepoel & Hall, 2020). Virtual verification service requirements were found to include the internet, computer, videoconferencing, hearing aid interface (wired/wireless), facilitator(s), and specialized equipment to enable REM and electroacoustic measurement of the hearing aid devices (Campos & Ferrari, 2012; Ferrari & Bernardez-Braga, 2009; Novak et al., 2016; Pearce et al., 2009; Pross et al., 2016). Optional technologies included the remote access software. One possible clinical solution enabling provider-led, direct-to-patient virtual verification includes the use of simulated verification measures with the use of specialized equipment positioned in the provider location as well as hearing aid(s) to replicate fitting modification following virtual service delivery. Simulated verification could enable real-time verification for a wider range of clinical scenarios, reducing the technology and facilitator requirements at the remote location as well as the need for in-person follow-up to remote hearing aid programming. Additionally, technological innovation enabling direct-to-patient verification via the hearing aid itself could help streamline the infrastructure, training, and operational demands for this type of service delivery.

Barriers and Facilitators

This review highlighted the barriers and facilitators that emerged as influencing the delivery of virtual services, across all hearing aid care types (Figure 4). Technology reliability and robustness, literacy, and specialized training emerged as the most reported factors. In the case where client digital literacy was low, in-person equipment set up was made available prior

to starting the delivery of virtual services (Anglely et al., 2017; Muñoz et al., 2021). When considering the uptake of virtual services delivered in a hybrid model, recent research specific to in-person and synchronous delivery of many types of hearing care indicates that in adult populations, self-perceived digital proficiency was not found to be a significant predictor; however, lower proficiency did not prevent older adults from seeking and continuing hearing health care in a hybrid model (Ratanjee-Vanmali et al., 2020). As virtual hearing care continues to evolve, further research will help determine the relationship between digital literacy and the uptake of virtual services, across all age groups, and specific to technological innovation.

The use of facilitators in the remote clinic widened the scope of virtual practice, especially in scenarios where controlled acts were being performed. Within the field of audiology, specialized equipment and/or manufacturer-specific technologies are often required to deliver hearing aid care, resulting in the need for specialized training and education efforts to ensure efficient and effective service delivery. In clinical scenarios where provider-led virtual care is directly delivered to clients (without a facilitator), more effective training/education efforts for clients/families will further expand care scenarios and reduce equipment support needs. Furthermore, ensuring the availability of an adequate internet connection at both the provider and remote locations was found to be an important consideration in the success of virtual appointments. This highlights the need to assess accessibility around technologies and supports needed to ensure adequate audio and visual quality for all stakeholders during virtual interactions. Having an alternate communication method available in the case of poor-quality virtual interaction can improve overall access to services. Continuing professional development specific to the technological innovation associated with virtual care, for both care providers and facilitators, will be fundamental to the success of this delivery model.

Privacy and Security Considerations

While risks associated with technology use in virtual service delivery was not identified as a major theme, it is important to consider the risks on a case-by-case basis. This involves the integration of adequate informed consent procedures, as well as robust privacy and security measures. When implementing virtual audiology services, it is important to align data privacy and security practices with regulatory/legislative requirements. This includes the use of technologies and platforms or applications that comply with legislation such as the Personal Information Protection and Electronics Document Act (PIPEDA) or the Health Insurance Portability and Accountability Act (HIPAA). As technology-enabled care evolves, the provider should seek out educational opportunities to remain up to date with the evolving regulatory/legislative requirements specific to digital privacy and security.

Person-Centered Care

Various aspects of this review highlight a shift to person-centered care when incorporating virtual service delivery. Services were found to be delivered to the client's home/work location or to a remote clinic location close to the client's home in many studies. Virtual services were found to decrease travel needs and increase the flexibility and timeliness of care as well as the overall convenience in participation. App-based services have great potential to engage clients while focusing on their specific care needs. Convery et al. (2020) discuss the need to ensure that apps used in the virtual care process are comprehensive and ensure all clients' listening needs are brought to the attention of their provider and are ultimately addressed. This study incorporated asynchronous delivery and may have benefitted from open-response options and/or the option to synchronously connect to their provider. Fully integrated apps also reduce technology requirements on side of the client, thereby streamlining the care process and

increasing accessibility to services, except in areas where access to mobile devices may be limited. Although this review did not cover the use of e-surveys accessed through an app or in an online format to facilitate asynchronous care, these user-directed tools could be used to alert the provider of potential health challenges to ensure a proactive virtual care delivery model (Glista, O'Hagan, Van Eeckhoutte, et al., 2021).

Limitations And Future Directions

Further research specific to virtual hearing aid services delivered to pediatric populations is needed to explore whether technology and infrastructure needs differ from those identified with mainly adult populations. When considering pediatric focused care, the parent and/or caregiver often has a high level of involvement in the appointment. Digital literacy specific to personnel in supporting roles therefore becomes an important factor to consider. Furthermore, technological advancement in pediatric hearing aid solutions and related app-based technology will facilitate hearing aid programming and real-world evaluation of infrastructure needs and overall service delivery effectiveness compared to a traditional in-person care model. Some of the studies included lab-based research scenarios that provided guidance around minimal technology requirements and overall effectiveness of the delivery model. These studies do not model real-world environments or address whether the services can be fully integrated into routine clinical practice. Several of the studies did offer more realistic care scenarios that utilized remote locations to deliver mixed models of hearing aid care into clinically relevant service delivery scenarios (Convery et al., 2020; Novak et al., 2016; Pearce et al., 2009; Penteado et al., 2012; Pross et al., 2016; Tao et al., 2018). Recent research conducted by Ratanjee-Vanmali and colleagues (2019, 2020) demonstrate how hybrid care can be delivered in the field of audiology using real-world settings. A comprehensive look into the factors related to

uptake of virtual care will involve pairing findings related to technology and infrastructure with research centred around stakeholder capabilities, opportunities, and motivations driving success with virtual care.

The studies included in this review did not include details around best practices for obtaining consent, record keeping, infection control, security, privacy, and/or confidentiality measures. Providers should ensure practices align with standards specific to virtual care. Infection prevention and control measures should be adequately considered when loaning technology and equipment to facilitate virtual care, as an example relevant to this review. Overall, safety, security and privacy measures used should be integrated according to best practices and adequately reported in future research studies.

This scoping review also identified the scheduling of virtual appointments to a barrier to implementation. As we transition to a new normal in hearing healthcare, it is important to evaluate the service delivery options available, what worked best, and how best to continue providing care during and post-COVID-19. As a result of the global pandemic driving innovation related to virtual care, evidence around technology and infrastructure needs in the delivery of virtual hearing aid care will continue to evolve. Updated literature reviews following the pandemic will therefore help synthesize emerging research. The development of triaging criteria to be used when scheduling clients/patients for in-person versus virtual appointments, or a hybrid of the two, will help guide clinical practice. In this review, the use of hybrid delivery models mainly depended on previous technology experience and access, the time course of care (i.e., initial versus follow-up fittings), the requirement for specialized equipment, and service type. Future research studies should aim to offer greater details around methods used, including technological, personnel, time course, and modality. Once technical functionality is established,

virtual care needs to be optimized to enable person-centered care and align with the provider's capabilities, needs, and organizational opportunities. Assessment tools are needed to assess stakeholder readiness level to effectively participate in services delivered virtually, furthermore, key indicators are needed to determine care effectiveness on a service delivery level. This review provides valuable information to help guide clinical assessment tools needed to increase uptake of virtual care in audiology. Furthermore, future research and developments efforts should consider current limitations to technology functionality and related infrastructure. Practice-based research methods can help yield evidence to improve operational efficiency of the virtual care delivery model.

ACCEPTED VERSION

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