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Connected Audiological Rehabilitation: 21st Century Innovations

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Abstract

Background—Tele-audiology provides a means to offer audiologic rehabilitation (AR) in a cost-, resource-, and time-effective manner. If designed appropriately, it also has the capability of personalizing rehabilitation to the user in terms of content, depth of detail, etc., thus permitting selection of the best content for a particular individual. Synchronous/real-time data collection, store and forward telehealth, remote monitoring and mobile health using smartphone applications have each been applied to components of audiologic rehabilitation intervention (sensory management, instruction in the use of technology and control of the listening environment, perceptual and communication strategies training, and counseling). In this article, the current state of tele-audiological rehabilitation interventions are described and discussed.

Results—The provision of AR via tele-audiology potentially provides a cost-effective mechanism for addressing barriers to the routine provision of AR beyond provisions of hearing technology. Furthermore, if designed appropriately, it has the capability of personalizing rehabilitation to the user in terms of content, depth of detail, etc., thus permitting selection of the best content for a particular individual. However, effective widespread implementation of tele-audiology will be dependent on good education of patients and clinician alike, and researchers must continue to examine the effectiveness of these new approaches to AR in order to ensure clinicians provide effective evidence-based rehabilitation to their patients.

Conclusions—While several barriers to the widespread use of tele-audiology for audiologic rehabilitation currently exist, it is concluded that through education of patients and clinicians alike, it will gain greater support from practitioners and patients over time and will become successfully and widely implemented.

Keywords

audiological rehabilitation; auditory training; aural rehabilitation; rehabilitation of hearing impairment; tele-audiology; telemedicine

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Adults who acquire a hearing loss often experience a reduction in their quality of life resulting from the impact of the hearing loss on the person's ability to understand speech, so communication becomes difficult and stressful. As a result, a person's participation in social interactions and leisure activities may decrease and they may be unable to enjoy the everyday sounds, which connect them to the world around them (Strawbridge et al, 2000; Arlinger, 2003). Thus, the over-arching goal of comprehensive audiological rehabilitation (AR) intervention for adults is to restore a person's quality of life (Boothroyd, 2007). In this article, the current state of tele-audiological rehabilitation interventions are described and discussed. As specified in Krupinski (2015), the practice of tele-audiology covers a variety of clinical applications, from testing and diagnosis through therapeutic interventions.

AR intervention involves several interrelated components. Typically, it begins with sensory management via the use of hearing aids to optimize access to the auditory world. In some instances, other assistive listening technologies and/or cochlear implants are used. Systematic instruction in use of the technology and about topics such as controlling the listening environment is an integral component of a comprehensive AR program. Some individuals benefit from perceptual training aimed at improving auditory and/or auditory–visual speech perception. Training in the use of communication strategies is also very helpful. Finally, a comprehensive AR program will include counseling aimed at supporting the individual's emotional adjustment to the hearing loss and coping with any residual participation limitations. Ideally, the hearing-impaired adult's communication partner will be included in the rehabilitation process (Preminger and Meeks, 2010) so that he/she can better cope with the ramifications of hearing impairment, be educated about how to best communicate with their hearing-impaired partner, and to ensure they have appropriate expectations about the outcomes of AR.

The components of comprehensive AR intervention are not new—the processes involved were first used in the programs established to meet the hearing health-care needs of U.S. veterans of World War II. These early military AR programs were provided on an in-patient basis over a period of weeks, and involved the fitting of hearing aids, speech perception training, and vocational and psychological counseling (Bergman, 2002). AR is no different today, except that we have the ability to deliver many of the components in a time-, resource-, and cost-effective manner, using telehealth techniques. In the context of intervention for adults with hearing loss, "tele-audiology" allows for the provision of individualized services from afar, many of which can be engaged in at the convenience of the recipient, and can be completed without the need for a provider.

As described in Jacobs and Saunders (2014), there are at least four models of telemedicine that have been applied to tele-audiology: (a) synchronous/real-time data collection—in which face-to-face video conferencing between patients and providers takes place, (b) store and forward telehealth—in which data are acquired and stored by a technician at a remote facility and later forwarded to a specialist for interpretation and diagnosis, (c) remote monitoring—in which mobile devices are used to collect data that can be monitored by health-care providers, and (d) mobile health—in which smartphone applications (apps) or other software are used for self-management of health conditions independent of a practitioner. These have been applied to the components of AR intervention noted above (sensory management, instruction in the use of technology and control of the listening environment, perceptual and communication strategies training, counseling, and inclusion of communication partners) and are described and discussed below.

SENSORY MANAGEMENT

Tele-audiology delivery of sensory management can be achieved using a variety of techniques. For example, hearing aid and/or cochlear implant programming and fitting can be accomplished remotely using synchronous/real-time data collection. Data about listening environments can be captured while the devices are being used in the real world, stored, and then forwarded to the audiologist for subsequent programming adjustments. Remote monitoring can be used to collect hearing aid usage information. Finally, there are a variety of mobile health applications that can provide amplification in lieu of a hearing aid and/or serve as a remote control of devices.

Overall, studies show that remote hearing aid and cochlear implant programming and fitting are not only feasible, but also the outcomes do not differ from the standard clinical face-to-face encounter. For example, Campos and Ferrari (2012) compared reported hearing aid outcome and measured speech understanding and real-ear hearing aid output for two groups of individuals. One group was fitted with hearing aids at a conventional face-to-face appointment and the other was fitted via a synchronous teleconsultation session. At 1-mo postfitting, there were no significant between-group differences for any of the outcome measures. Similarly, Ramos et al (2009) and Wesarg et al (2010) compared synchronous teleconsultation and face-to-face sessions for cochlear implant programming. In both studies, no differences between the two methods were found in the final cochlear implant parameters or in patient satisfaction. Other studies, such as those of Gladden and Beck (2015), Penteado et al (2012), and Kuzovkov et al (2014) have also confirmed the equivalence of hearing aid and cochlear implant outcomes when devices are fitted via tele-audiology or through conventional face-to-face clinical encounters.

Convery, Keidser, Dillon, et al (2011), Convery, Keidser, and Hartley (2011), and Convery, Keidser, Hartley, et al (2011) took remote hearing aid fitting a step further, by developing and assessing the feasibility of a "build your own" self-fitting personal amplification device. To build the hearing aid, the user would follow written instructions to select and attach the appropriate length of hearing aid tubing from three precut lengths to a behind-the-ear hearing aid, select and attach the appropriate size of open dome tip from three different sizes, and insert a hearing aid battery. Once assembled, the hearing aid can generate tones for conducting automated in situ audiometry. These thresholds are then automatically applied via a hearing aid fitting algorithm to set the initial hearing aid output. Finally, there is a trainable algorithm for self-adjusted fine tuning. The perceptions about the "build your own" device were assessed in a group of 80 older adults (median age = 73 yr, SD = 11 yr), who lived in an urban area of a developed country. Almost all participants (83%) thought that the concept was a good idea and 63% believed that they would gain a personal benefit. Although 25% reported that they would like professional guidance during the fitting process, almost all (90%) thought that they would likely be capable of managing the process. This same group of individuals was then asked to build the hearing aid (i.e., select the tubing and dome, and insert the battery) while following written instructions. Twenty-six percent of the group were able to complete the assembly process independently without making any errors, a further 50% made just one error when completing the task independently, and another 5% made no errors, but required assistance from a partner. However, this group of individuals had relatively high health literacy; therefore, Convery et al (2013) conducted a subsequent study with individuals from culturally and linguistically diverse backgrounds with a range of health literacy levels. Success varied across cultural/linguistic groups, with health literacy, age, and occupation being predictors of task completion. Not surprisingly, those with greater health literacy were more successful in completing the task, as were those who were younger and who had a “more prestigious” (Convery et al, 2013, p. 390) occupation. The authors concluded that individuals of diverse backgrounds can manage to assemble the self-fitting hearing aid using written instructions, but that health literacy in particular must be taken into consideration.

Mobile health opens up the possibility of using smartphones to conduct hearing aid related functions via down-loadable apps. Some of the currently available apps are distributed by major hearing aid manufacturers, while others are from smaller enterprises. For example, most of the major hearing aid manufacturers have apps that turn a smartphone into a hearing aid remote control, and that permit the phone to stream audio signals directly to both hearing aids. Smaller enterprises have developed apps that turn a smartphone into an amplifier that sends the amplified signals to headphones (e.g., BioAid, HearYouNow, SoundAMP, EarMichine). Many sound amplification apps can be downloaded for free or at very little cost. These apps vary in the features they incorporate. At their most basic, they provide single channel amplification, and at their most sophisticated they incorporate multichannel amplification, compression/ expansion, and noise suppression algorithms. The impact of these apps on population hearing health is unknown. Easy access to low-cost amplification may be a viable alternative for those individuals who cannot afford or who do not wish to use hearing aids. On the other hand, the usability, signal integrity, and amplification parameters of some of these apps have not been validated. Although it can be argued that some form of amplification is better than no amplification at all, individuals using less than optimal amplification may become disillusioned, which may act as a further barrier to the seeking of professional help in the future.

INSTRUCTION AND EDUCATION

Information about hearing, hearing loss, and treatment options is critical for making informed decisions. As with other health conditions there is a plethora of information available through the Internet. An important endeavor for hearing health-care professionals is to ensure that their patients are accessing information from accurate and reliable sources. The quality and readability of Internet information for adults with hearing impairment was evaluated by Laplante-Lévesque et al (2012). They examined the content of 66 English-language Web sites identified following Google searches. They documented the type of organization posting the materials (commercial, government, nonprofit), the date materials were last updated, the quality of the content using Health On Net (HON) certification (Boyer et al, 1998) and DISCERN scores (Charnock et al, 1999), and they calculated readability from established metrics. The majority (64%) of Web sites were commercial, one-third had been updated within the prior 6 mo, 17% had not been updated for ≥18 mo, and 23% were undated. DISCERN scores were low, indicating that the content did not meet quality criteria, and most Web sites (86%) did not have HON certification. Mean reading level assessed with the Flesch–Kinkaid Grade Level Formula was 11.1, suggesting that users would need >11 yr of education to read and comprehend the content. From this, it can be concluded that caution should be used when recommending Web sites to patients. The top-ranked Web sites identified by Laplante-Lévesque et al were nihseniorhealth.gov/hearingloss, chha.ca, en.wikipedia.org/wiki/Hearing_aid, hearingloss.org, mayoclinic.com/health/hearing-loss/DS00172, hiddenhearing.co.uk, www.listenupcanada.com, www.naturalhearing.co.uk, and speechhearingaid.com/speechhearingaid/hearing-aids.html. These Web sites were rated in the top third of all assessed for quality on the DISCERN scale and on all three readability measures. The Mayo Clinic and National Institutes of Health Web sites also have HON certification. They all provide clearly written in-depth information and advice about communication, optimizing the listening environment, and assistive technology. Multimedia online hearing aid and cochlear implant instructional videos are available from a variety of sources, such as the Washington University Adult Audiology Department (hearing.wustl.edu/InstructionalVideos), the National Center for Hearing Assessment and Management at Utah State University (infanthearing.org/videos/#featured), private audiology clinics, and almost all of the major hearing aid manufacturers.

While providing information is critically important, it is well accepted that actively engaging an individual in the learning process leads to better outcomes. Such an approach was taken by Thorén et al (2011) who developed an online rehabilitation education program. In the original version of the program users learned about the ear, hearing, hearing testing, hearing aids, and coping strategies. They were expected to spend~1.5 h per week reading, performing specified tasks (e.g., finding out how well they can identify where sounds are coming from), writing about their experiences, and answering short quizzes to which they received immediate feedback. Twenty-nine individuals with hearing loss (mean age = 63.5 yr, SD=13.3 yr) who reported significant communication difficulties, had been using hearing aids for at least 1 yr and who had access to a computer and the Internet participated. Of the 29 individuals who began the program, four withdrew, because they did not consider the login system to be sufficiently secure (n = 2), they felt the program was too demanding or they encountered technical problems with their computer/Internet (n = 2). All 25 who completed the program used it actively, completed the written assignments and answered the quizzes. Following use of the program the group reported fewer participation restrictions, activity limitations, depression, and anxiety. It would thus seem that when individuals encounter sufficient communication problems they are willing to engage in a fairly intensive online AR intervention.

Although the majority of instructional and educational tele-audiology applications are aimed at the person with the hearing loss, hearing health-care providers can also benefit from online training to enhance rehabilitative audiological knowledge and skills. A prime example of an initiative which focuses on improving the journey of the person with the hearing loss comes from the work of the Ida institute—an independent, nonprofit organization that aims to foster a better understanding of the human dynamics of hearing loss—which through worldwide collaboration, has created tools for use by hearing health-care professionals that are freely accessible online at http://idainstitute.com/toolbox/. One of the tools most applicable to the topic of AR tele-audiology is the Group Rehabilitation Online Utility Pack (GROUP) AR Guide. The GROUP provides the information needed to develop and implement a multisession GROUP AR program through a series composed of videos and written materials (Montano et al, 2013). Another tool in which interactive multimedia is used is the E-Learning Laboratory, an online program for teaching professionals about patient-centered Ida AR tools and their clinical application via interactive multimedia presentations in the form of animated screens, videos, questions, and answer options and narrations.

There is certainly room for more forms of remote instruction for patients and clinicians. Some examples include apps offering real-time communication strategies advice based on the current listening environment, or interactive learning opportunities via app-simulated listening situations. These could be helpful to new or struggling hearing aid users unsure of how to optimize listening strategies.

PERCEPTUAL TRAINING

Perceptual training for adults with hearing loss is aimed at increasing the individual's ability to compensate for degradation in the auditory signal due to internal (hearing loss) or external (noise) factors (Sweetow and Palmer, 2005). When first fitted with new hearing aids, cochlear implants and/or other hearing assistive devices, the individual must learn to use the auditory input that is not only impoverished but also different from that experienced previously. Training can facilitate the reorganization of neurons in the brain leading to improved perceptual skills. While the training may occur under an auditory alone condition, there may also be a need for a focus on the integration of the auditory sensations with the visual speech signal via completing speechreading exercises. Formal perceptual training, then, can provide the listener with increased opportunities to engage in perceptual learning, which in turn may lead to higher ultimate speech understanding and improved communication ability (Boothroyd, 2007). Although there is evidence that face-to-face auditory and auditory–visual training can lead to improvements in speech understanding (Sweetow and Palmer, 2005; Chisolm and Arnold, 2012), there is limited reimbursement for adult AR. When the lack of reimbursement is combined with the time-, resource-, and cost-constraints associated with clinician-driven intervention models, there appears to be little incentive for clinicians to offer perceptual training. A more viable approach would be to provide training at home through the use of computer-based programs.

Perhaps it is not surprising, given the rapid improvements in computer-based technologies over the last decade that several commercially available training auditory and or auditory–visual training programs have been developed (Pichora-Fuller and Levitt, 2012). Many hearing aid/cochlear implant manufacturers provide auditory training apps and/or DVDs to their customers and numerous others are available from other sources. Some focus on auditory skills, some combine auditory training with “brain training,” and others address speech reading also. Because of the rapid change in programs available, a list is not provided here; however, see Pichora-Fuller and Levitt (2012) or www.asha.org/aud/articles/auditory-training-adults-cochlear-implants for information about specific programs.

Despite the rapid development of computer-based auditory and auditory–visual training programs, questions remain regarding their efficacy. Furthermore, it is unknown whether there are specific characteristics or traits that could be used as predictors of benefit from these programs. For example, the results of a well-designed systematic review by Henshaw and Ferguson (2013) indicated that the evidence for on-task learning was robust (i.e., users show improvement on the tasks on which they train), but there was inconsistent evidence of generalization to off-task measures of speech understanding and/or functional benefits, with only small improvements noted. Indeed, research in our laboratories (Chisolm et al, 2013; Saunders et al, 2016; Smith et al, 2016), examining the efficacy of the Listening and Communication Enhancement program (Sweetow and Sabes, 2006) as a supplement to hearing aid intervention in 279 veterans who were optimally fitted with amplification, supported the findings reported by Henshaw and Ferguson. Furthermore, our analyses examining individual differences in outcome following training showed the only robust predictor of outcome to be baseline performance. However, it explained just 11–17% of the variance (Smith et al, 2016). One possible reason for the lack of robust findings to date, may be that we do not have diagnostic tools that allow us to clearly identify who would benefit from training on specific cognitive-perceptual tasks. For example, Ferguson and Henshaw (2015) found that off-task benefits only occurred for complex tasks, such as divided attention and challenging working memory tasks, but not on less challenging measures such as understanding sentences in noise, simple working memory, or a single-attention task. Perhaps only individuals who do poorly on more complex cognitive-perceptual tasks are the ones who should be receiving the training. It is also important to note that while evidence may not be strong for the effectiveness of computer-based training programs, many adults with hearing loss appear to enjoy using the programs (Tye-Murray et al, 2012). It is possible that the greatest benefit of engaging in perceptual training is increased self-confidence and/or a reduction in the effort an individual is expending in speech recognition and conversations (Boothroyd, 2010). Furthermore, there is nothing to suggest the costs, both in time and money, of engaging in a computer-based auditory training program outweigh either measured or self-perceived benefits.

COUNSELING

Online support groups and chat rooms for individuals with hearing loss are widely available through national organizations, such as Hearing Loss Association of America and AlexanderGrahamBell Association for the Deaf and Hard of Hearing. The advantages of online support groups are many. They can provide the opportunity for users to share ideas, thoughts, and feelings with others like themselves. Users can remain anonymous and thus a person may feel safer in participating. Although the groups can be useful to all, they may be particularly valuable for individuals who are isolated, stigmatized, or lack supportive friends, family, or professionals. In addition, because there are no geographic limitations, the diversity of participants is increased (Sproull and Kiesler, 1986).

Cummings et al (2002) surveyed members of an online support group for individuals with hearing loss who wanted to overcome the barriers of hearing loss between themselves and others. They determined that those individuals who participated the most in the online support group perceived less support from family and friends, had a greater ability to cope, used more professional support in the prior year, and perceived more benefit from participating in the group. The researchers also found that many participants (46%) invited family or friends to join the group and that having family and friend participate was positively associated with greater self-reported benefit—thus emphasizing the advantages of including a communication partner in the AR process.

Counseling can be provided alone, or it can be combined with other aspects of an AR program. Recall the education program developed by Thorén et al (2011). After their initial success, the program was modified to incorporate aspects of counseling providing support to the user in terms of coping with the emotional and practical impacts of residual hearing-related limitations. Support was provided in the form of weekly interactions with an audiologist via e-mail and weekly participation in an online discussion forum with peers. In addition, individuals engaged in communication strategies training focused on use of repair strategies, anticipatory strategies, and relaxation exercises using components of the Active Communication Education Program of Hickson et al (2007; http://www.shrs.uq.edu.au/active-communication). For further details, see Thorén et al (2014). The programs of Thorén et al (2011, 2014) resulted in decreased participation restrictions, activity limitations, depression, and anxiety, in both the short term (immediately following use of the program) and longer term. However, the improvements measured following use of the Thorén et al (2014) program were greater. In addition, examination of the content of messages in the discussion forum indicated that users benefited through sharing communication tips, and that they often included their spouse in the interactions. It was also seen that users logged into the forum more often than they posted something, suggesting that they were more interested in the posts of others than in posting content themselves. Based on these findings, it was concluded that the Internet provides a valuable mechanism through which individuals can learn from others, without having to attend a time- and location-specific group meeting.

An important lesson about Internet-based rehabilitation can be learned from the work of Manchaiah et al (2014). These researchers sought to conduct a controlled trial in which 158 individuals with self-reported hearing disability were to be randomly assigned to a 30-day Internet-based pre–hearing aid fitting counseling program or a wait list control group. The Internet-based counseling program was based on the “patient journey” model (Manchaiah and Stephens (2011) with consideration of health behavior change models (Saunders et al, 2012). The patient journey model focuses on the lived experiences of the person with a hearing loss, addressing hearing disability, depression, anxiety, readiness for change, and acceptance of hearing loss. The Internet-based program consisted of a series of videos, text-based information, and reflection and problem-solving exercises. In addition, participants received a daily e-mail from an audiologist with whom they communicated their progress through the program, and from whom they could seek advice. However, the investigators had problems recruiting participants, compliance with the intervention was very poor, and many individuals dropped out of the study before completing outcomes questionnaires. The authors provided a number of explanations for these problems including low Internet and computer usage among older individuals, counseling content that many participants did not like, and resistance among the target population toward hearing rehabilitation.

The experience of Manchaiah et al is quite different to that of Thorén et al. A possible explanation is the participant group's readiness for AR. Manchaiah et al excluded hearing aid users, whereas Thorén included only experienced hearing aid users. Perhaps clinicians should consider patient readiness for AR when recommending an intensive online AR program to their patients. However, as discussed below, readiness is not the only potential barrier to the acceptance and use of tele-audiology in the rehabilitative purposes although, with careful planning and innovation, many of these barriers can be effectively addressed.

POTENTIAL BARRIERS TO INTERNET USAGE

Age

Older age is often cited as a reason for lack of computer use. However, the issue of low Internet usage among older individuals is changing rapidly over time. According to the PEW Research Center, as of January 2014, 88% of adults aged 50–64 and 57% aged >64 used the Internet, this is in contrast to 52% and 32%, respectively, in December 2012. Similar data are available from the US Census that showed that 79% of households with adults aged 45–64, and 58% of households with adults aged ≥65 yr had Internet access in 2013, as compared to 52.1% and 27.9% in 2010 (http://www.census.gov/hhes/computer/). Furthermore, Thorén et al (2013) investigated whether Internet and e-mail use in 158 adults with hearing loss differed across age groups and from the general population in Sweden (where the study took place). They determined that 60% of participants used computers and the Internet and that indeed usage was higher among the younger age group (25–64 yr) than the older age group (75–96 yr). But they also learned that Internet usage was greater among the participants with hearing loss, especially the elderly, when compared with the general population of Sweden, thus emphasizing the applicability of online rehabilitation for hearing loss.

Computer and Internet Security

Lack of trust in Internet and computers and the information provided is a common concern —particularly among older adults (Zulman et al, 2011). Indeed, Thorén et al encountered this is some of their participants, as did Saunders et al (2015) in their evaluation of a self-administered computerized hearing loss prevention program. In the Saunders et al study, although most of the 29 participants reported that learning from the use of a computer-based program was positive, some found it impersonal, and reported that they did not trust information they received from a computer. Clearly, computer and Internet security are very real concerns for many forms of online AR. As noted by Hall and McGraw (2014), the success of telehealth could be undermined if serious privacy and security risks are not addressed when sensitive health and personal information is being transmitted via apps, sensors, or other devices. The American Speech Language Hearing Association (ASHA) provides information about privacy and security regulations of which audiologists should be aware (www.asha.org/PRPSpecificTopic.aspx?folderid=8589934956&section=Key_Issues). ASHA recommends that to manage risk, clinicians should obtain informed consent from the patient in advance of telepractice, and describes technologies, such as encryption, virtual private networks, and firewalls, that have privacy protections. An in-depth discussion of the topic is beyond the scope of this article but bringing attention to the topic is worth mention.

Acceptance of Tele-audiology for Rehabilitation

Patient and clinician acceptance of tele-audiology is of course critical to its success. To the best of our knowledge, only one study has specifically sought to assess patients' perceptions of tele-audiology. That study was conducted by Eikelboom and Atlas (2005) who surveyed 116 individuals to determine their willingness to use telemedicine for hearing-related appointments. The majority (75%) were aware of telemedicine, with only 30% indicating that they would not be willing to have a hearing-related appointment via a telemedicine approach. Although 28% of respondents were unsure if they would use the approach, 10% indicated that a tele-audiology appointment would be reasonable to use some of the time, and 32% were definitely willing to have their appointments at a distance. The most commonly reported perceived advantages were reductions in travel time, cost, and appointment waiting times—with the last advantage considered the most important. Barriers to using telemedicine were the desire for face-to-face interaction and the sense that the quality of the telemedicine appointment would not be as good as that of a face-to-face appointment.

Patient acceptance of telehealth for other conditions has been more widely examined. For example, Edwards et al (2014) examined the acceptance of telehealth to support the remote delivery of health-care and promote self-management among 1,740 patients with depression or raised cardiovascular disease risk. They found that ~60% of participants were interested in using phone-based or e-mail/Internet-based telehealth. The primary predictor of acceptance was confidence in the ability to use the associated technology, with the perception of more benefits than barriers to its use also influencing acceptance. Health status, access to health care, age, and other sociodemographic factors did not influence opinions. Similar barriers to computer use have been noted elsewhere. Saunders et al (2015) found that some of their older participants felt they did not have the computer skills to take full advantage of a computer-based hearing-loss prevention program, and preferred face-to-face education, Kim et al (2012) and Griebel et al (2013) reported that computer self-efficacy influenced intention to use and acceptance of technology, and Melenhorst et al (2006) and Laver et al (2012) reported that some individuals prefer to interact with people rather than with a computer. It would seem probable that reluctance to use tele-audiology can be overcome with well-planned education to increase patients' confidence in their ability to use technologies associated with tele-audiology, to highlight the potential benefits of remote AR, and to address concerns such as the absence of face-to-face interaction—which can be overcome through the use of programs such as Skype.

Of course, clinicians must be willing to provide the AR services remotely. Thus it is important to understand their attitudes toward tele-audiology, as done in the work of Singh et al (2014). Singh et al surveyed the attitudes of 202 hearing health-care practitioners toward tele-audiology appointments in general, their willingness to conduct specific audiological tasks via tele-audiology, and the use of tele-audiology appointments with different patient populations. As a whole, there was general agreement by the hearing health-care professionals that tele-audiology would increase access to audiological services and decrease the need for patient travel. Some concerns, however, were expressed. About 20% of the respondents indicated that they believed that tele-audiology would have negative impacts on quality of care, patient–clinician interactions, and the quality of relationships with new patients. Interestingly, ~25% of respondents indicated that they believed tele-audiology would have positive impacts in these same domains. In terms of specific tasks, hearing health-care practitioners were most willing to answer questions about hearing and hearing aids via tele-audiology, but were very unwilling to use tele-audiology for hearing assessments, cochlear implant mapping, and first time fitting of hearing aids. Respondents were mixed with regard to their willingness to provide counseling and rehabilitative programs. In terms of patient populations, they considered tele-audiology an acceptable approach for "tech-savvy" patients, for those living in remote locations, and for those with mobility or transportation issues. Although there was a positive response to using tele-audiology in some circumstances, in general the clinicians were very unwilling to consider its use for first time patients, for children <17 yr, or for adults >65 yr. However, overall, most hearing health-care practitioners considered tele-audiology would have a positive impact on access to hearing health care. This would seem to indicate that tele-audiology will gain more and more support from practitioners over time and that with education, tele-audiology can be successfully and widely implemented.

CONCLUSION

The provision of AR via tele-audiology potentially provides a cost-effective mechanism for addressing barriers to the routine provision of AR beyond provisions of hearing technology. Not only does AR via tele-audiology have the potential to be cost effective, if designed appropriately, it has the capability of personalizing rehabilitation to the user in terms of content, depth of detail, and so on, thus permitting selection of the best content for a particular individual. Use of computer-based programs for AR have the advantage over face-to-face clinical interactions of being more quickly interactive, such that keyboard strokes or touch screen input can be used to tailor an intervention to the user's needs, and can provide immediate feedback to the user in the form of test results or advice. Furthermore, data regarding the user's actions, responses, and performance can be stored for later tailoring, and can be monitored off-line by a clinician. However, effective widespread implementation of tele-audiology will be dependent on good education of patients and clinician alike that must build confidence in their ability to use the technology and trust in the process, and must high-light the potential benefits, and address concerns of remote AR. Furthermore, researchers must continue to examine the effectiveness of these new approaches to AR to ensure clinicians provide effective evidence-based rehabilitation to their patients.

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Abbreviations

apps	applications
AR	audiological rehabilitation
GROUP	Group Rehabilitation Online Utility Pack
HON	Health On Net

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