Options for Auditory Training for Adults with Hearing Loss

Anne D. Olson, Ph.D.[1]

ABSTRACT

Hearing aid devices alone do not adequately compensate for sensory losses despite significant technological advances in digital technology. Overall use rates of amplification among adults with hearing loss remain low, and overall satisfaction and performance in noise can be improved. Although improved technology may partially address some listening problems, auditory training may be another alternative to improve speech recognition in noise and satisfaction with devices. The literature underlying auditory plasticity following placement of sensory devices suggests that additional auditory training may be needed for reorganization of the brain to occur. Furthermore, training may be required to acquire optimal performance from devices. Several auditory training programs that are readily accessible for adults with hearing loss, hearing aids, or cochlear implants are described. Programs that can be accessed via Web-based formats and smartphone technology are reviewed. A summary table is provided for easy access to programs with descriptions of features that allow hearing health care providers to assist clients in selecting the most appropriate auditory training program to fit their needs.

KEYWORDS: Auditory training, hearing loss, adult, hearing aids, cochlear implant, computer training, mobile training

Learning Outcomes: As a result of this activity, the participant will be able to (1) identify the range of features in auditory training programs for computers and for smartphone technology and (2) describe methods of using auditory training throughout the rehabilitation process.

[1]Department of Rehabilitation Sciences, University of Kentucky, Lexington, Kentucky.

Address for correspondence: Anne D. Olson, Ph.D., Department of Rehabilitation Sciences, University of Kentucky, Room 124J Wethington Building, 900 South Limestone Street, Lexington, Kentucky 40536-0200 (e-mail: aolso2@uky.edu).

Audiologists and other hearing care professionals continue to dispense hearing aids as the primary intervention for age-related hearing loss. In 2013, hearing aid sales worldwide increased an estimated 5%,[1] with the most total units dispensed in the United States followed by Germany, Japan, China, and Great Britain. Given that an estimated 40% of dispensed devices may not be used effectively or not used at all,[2,3] clinicians likely wonder what else could be done to improve actual uptake and effective use of devices. The focus of this article will be on auditory training options that may enhance the uptake, utilization, and satisfaction of hearing aids among clients.

Auditory training can be defined as a purposeful and systematic presentation of sounds such that listeners are taught to make perceptual distinctions about those sounds.[4] Although some studies have shown that auditory training results in improvements in speech understanding,[5–7] only an estimated 10% of audiologists recommend auditory training for their clients.[8] Although the lack of time and reimbursement are primary factors underlying this practice pattern, another factor is the lack of compelling research reflected by two systematic reviews.[9,10] Both of the in-depth reviews concluded that individuals improve on the tasks on which they are trained. Although outcomes for untrained measures following training are significant, reported improvements are small. However, individual differences have been reported such that some persons obtain greater benefit from training than others. Compliance with training protocols has been identified as a major contributor that explains some of this variability.[11,12] Additionally, some variables such as a greater perception of hearing handicap and a greater degree of hearing loss,[13] as well as shorter duration of hearing aid use,[6,14] have been predictive of improved overall outcome.

Auditory training has historically been provided in a face-to-face setting that centers on a range of auditory skills including detection, discrimination, identification, and comprehension.[15] These auditory skills can be trained using various stimuli such as syllables, words, phrases, sentences, and connected discourse. Presentation of paired sound contrasts using drill-like activities are described as analytic therapy activities, whereas sentence identification or paragraph comprehension activities are synthetic in nature.[4] Training often incorporates both types of synthetic and analytic training activities. Although access to auditory training has been limited in previous decades, innovations in technology have advanced intervention options in our digital world. Many auditory training programs are available not only through downloadable computer-based programs, but also through Web-based formats and even through mobile smartphone applications.

There is an increased recognition that patients need to be more involved in their aural rehabilitative process and provided with options for improving their overall auditory skills.[16] As the range of intervention formats increases, health care providers encounter ongoing challenges to keep pace with options. Clients are known to seek the Internet for additional methods of managing and coping with their hearing loss beyond amplification alone.[17] In fact, many older adults may be doing so before they even contact an audiologist.[18] Therefore, the purpose of this article is to review currently available auditory training options for individual use by adults. To date, no such summary has been provided in a single publication. By summarizing program options, including the evidence underlying effectiveness, clinicians can direct clients to self-management resources targeted for improving speech understanding that may best suit an individual's needs.

METHODS

Two searches were conducted to identify current auditory training programs in January 2015 and again in February 2015 by reviewers (the author and a graduate research assistant). One search was completed to identify the current computer-based auditory training programs through search engines such as PubMed, EBSCOHost, Web of Science, and Google Scholar. Search terms included auditory training, computer auditory-based training, and hearing training for hearing loss. Known training programs and their associated Web sites were also reviewed. A second search was completed to identify mobile auditory training smartphone applications (apps) through the Google Play

store and the Apple App Store. Search terms used for the app search included; auditory training, speech perception training, hearing training, sentence training, and consonant and or vowel training.

Programs that met the following inclusion criteria; (1) were readily available and operable after downloading, (2) were appropriate for adult populations, (3) incorporated speech (sentence, word, or phoneme) stimuli, and (4) provided empirical evidence or some indication of evidence-based strategies related to auditory teaching and learning, were fully reviewed. These inclusion criteria were deemed important for several reasons. First, whereas many programs were initially identified, several were not actually usable when reviewers tried to open and operate them. Furthermore, several apps identified had limited or no reviews, or had not been updated in several years. Second, programs that were targeted for children were excluded as they could be viewed as juvenile and therefore demotivating for adult use. Third, programs that used speech stimuli were judged to have more ecological validity in relation to understanding of speech. Furthermore, training with speech stimuli has been shown to promote improved speech perception particularly for cochlear implant users.[19] Therefore, programs that focused on frequency discrimination or pitch matching were eliminated from this review. Although specific evidence was located for many computer-based training programs, there was no evidence to support mobile app programs. Therefore, the apps were reviewed for their inclusion of at least some attribute related to effective auditory training as discussed by Watson and colleagues.[20] This group of experts in auditory perceptual learning outlined five critical attributes that are essential to effective training of speech recognition and include the use of timely feedback after each response, the availability of a large set of training stimuli by multiple speakers, options for training on specific phonemes that are difficult for an individual, inclusion of both analytic and synthetic activities, and a curriculum that tracks performance so that listeners continue to complete the training program. Given that apps will be limited in relation to storage capacity, apps were only expected to include one of the attributes related to effective auditory learning as described previously.

Programs meeting the inclusion criteria were further evaluated by reviewers for their usability for adults over 50 years of age. Usability was believed to be important to determine how likely an individual may be able to interact with various programs. For example, some research suggests that programs should use clear visual designs with adequate font and color contrast.[21] In addition, simple instructions should be provided in a logical, organized format to promote independent navigation especially for adults. To evaluate usability of mobile apps and computer-based training programs, selected questions from the System Usability Scale (SUS)[22] were included in the present review. The SUS is a widely used scale to quickly assess the usability of various devices. A summary of the selected questions considered from the SUS is provided (Table 1).

RESULTS

Mobile Smartphone Auditory Training Apps

The total number of different apps found was 127 for iPhone, iPad, Macintosh, and Android systems. All apps were reviewed for applicability based on inclusion criteria. Four apps met the in-depth inclusion criteria and are shown in Table 2. All apps were either available free or at a low cost. A Quick Response (QR) code was generated for the Web site associated with the mobile app access citation. Language options and unique attributes also are described. Although all apps incorporated evidence-based features related to auditory learning (i.e., use of feedback, opportunity to repeat a stimulus, or client selection of difficult training stimuli), no app included evidence-based research to support its actual use. The exception to this was the Angel Sound app that was derived from the more extensive computer training Angel Sound program. This program evolved from the computer-assisted speech training program developed at the House Ear Institute, which has been the source of several auditory training studies with adults.[23,24]

Table 1   **System Usability Scale (SUS) Applied to Auditory Training Programs**

Attribute	Description Characteristic	1	2	3	4	5	Comments
Clarity of visual layout	Provides adequate font and color contrast						
Instructions	Directions are simple to follow and promote independent navigation						
Need for general training	Need general instruction in use of the system prior to independent use						
Need for specialized training	Need specialized instruction in use of the system prior to independent use						

Note: The scale was used as a worksheet by reviewers for all computer- and Web-based programs and all smartphone mobile apps that met inclusion criteria for use by adults over the age of 50. Scores range from 1 = strongly disagree to 5 = strongly agree.

Thus, although the Angel Sound app itself does not have any specific empirical findings, its origins do.

Computer Auditory Training Programs

Nineteen different auditory training programs were identified. From this set, all programs were reviewed for applicability based on inclusion criteria. Some programs were eliminated because they did not relate directly to auditory training (i.e., lipreading training) or the program was still being used for research purposes and thus not available for consumer use. Of these, nine programs were found for in-depth review and are shown in Table 3. Seven of the nine computer-based training programs had at least one research study that contributed to its evidence base. Two programs eARena and AB CLIX, developed by a hearing aid and cochlear implant company respectively, cite only internal studies. Many programs such as Listening and Communication Enhancement (LACE),[12,] Angel Sound,[23,25] and ReadMyQuips[12] allow clients to train at home at their leisure and are self-directed. Others require more clinician-directed training such as Seeing and Hearing Speech,[26–28] Speech Perception Assessment and Training System for the Hearing Im-

paired,[29,30] or Kungliga Tekniska Högskolan (KTH) Speech Tracking.[31] The Computer-Assisted Speech Perception Testing and Training at the Sentence Level (CasperSent) can be configured for self-directed or clinician-directed use.[32,33] Some programs provide training only by means of auditory stimuli (LACE, Angel Sound, eARena, KTH Speech Tracking), whereas others use both auditory plus visual training (Seeing and Hearing Speech, ReadMyQuips, CasperSent and AB CLIX) options. Programs varied in availability of language, cost, targeted auditory skill(s), type of stimuli, and the number of speakers used during training. Comments also are provided related to usability as previously described (see Table 3). QR codes were also generated for the Web site associated with the particular program.

DISCUSSION

Overall, computer training or Web-based programs had a larger range of stimuli available than the stimuli available in mobile apps. For example, the Angel Sound computer program has over 10,000 stimuli and the app version has ~2,000. Although memory for storage is clearly an issue in mobile app technology, a take-home message here is that the apps will have a

Table 2 Summary of Smartphone Mobile Apps Currently Available That Met Inclusion Criteria

Name	Author or Developer	Description	QR Code	Incorporation of EB auditory learning principles	Language	App Compatibility	Stimuli	Usability: Visual Layout	Usability: Clarity of instructions	Usability: Need for instruction
Hear Coach	Starkey Laboratories	Targeted for persons with HL, new and experienced HA users. Uses listening games for cognitive and auditory training with varying types of background noise. Updated periodically.		Tracks progress, more difficult levels and background noise adjustment available	American English, French, German, Italian	iOS 5.1 or later, iPhone, iPad, iPod Touch (optimized for iPhone 5)	Word level, quiet or noise with varying types	Simple layout, easily visible with large font	No instructions with App once downlaoded, but easily navigable	Adults will need minimal instruction after account set up and demonstration
i-Angel Sound	University of California; TigerSpeech Technology Inc., Emily Fu Foundation	Interactive auditory training program, self-paced with at least 2000 stimuli. Can be used with children and adults.		Feedback is audiovisual, increasing difficulty, tracks progress	American English	iOS 5.0 or later, iPhone, iPad, iPod Touch, optimized for iPhone 5	Environmental sounds, music, phonemes, monosyllabic words	Inadequate color contrast for older adults	No instructions with App once downloaded, the many options for training may be confusing	Adults will need instruction and demonstration before using this app independently
AB Clix	Advanced Bionics	Word differences in quiet and noise uses over 2300 recorded words presented alone or in sentences		Placement test, provides feedback, tracks progress, more difficult levels available, background noise adjustable	American English	iOS 3.2 or later for iPhone or Ipad	Words and words in sentences	Good color contrast and font	Requires login before accessing the App, no instructions once App downloaded, but options are simple	Adults will need minimal instruction after login and demonstration
British English Vowel Training	Paul Iverson University of College London (UCL)	Designed to improve vowel perception of British English. Listener chooses speaker from one of 4 speaker options. Training uses single words in quiet. Listener selects answer from a closed set of 4 answers.		Provides feedback and repetition opportunity if wrong, final score provided at end of session.	British English	Requires iOS 3.0 or later. Compatible with iPhone, iPad, and iPod touch.	Words that emphasize different vowels	Good color contrast and font	No instructions with App once downloaded, but few options provided, so easy to navigate	Adults will need minimal instruction and demonstration

Table 3 Summary of Computer or Web-based Training Options Currently Available That Met Inclusion Criteria

Program	Developer or Company	Description	Evidence Base citation	QR code	Cost	Language	Mode	Auditory Skill(s) targeted	Stimuli	Number of Speakers	Usability: Visual Layout	Usability: Clarity of instructions	Usability: Need for instruction
Read my Quips	Harry Levitt/Sense Synergy	User completes a cross-sentence puzzle rather than a cross word puzzle. Individual words fit into blanks that make up a phrase. Written feedback provided with repetition option, records time on task. Developer wanted to create a humorous and entertaining training experience	Levitt, Oden, Simon, Noack, & Lotze (2011)[12]		Complementary trial provided with option to upgrade for full program ($100.00). Provided with any dispensed Starkey instrument.	American English	Auditory-Visual	Comprehension	Sentences/quips from witting sayings in quiet or noise	4 (2 male, 2 female)	Good color contrast, visually clear cross designs	Instructions are simple to follow however there are many steps involved	Some older adults may need multiple training and and demonstration opportunities before independent use
Listening and Communication Enhancement (LACE)	Robert Sweetow/Neurotone	Topic related sentence based training in noise. Adaptive so noise level will adjust based on user perfromance so that training is neither too easy or too hard. Provides repetition and feedback about responses. Options for training on computer, or with DVD	Henderson-Sabes & Sweetow (2007)[13] Chisolm, Saunders, Frederick, McArdle, Smith & Wilson (2013)[11] Olson, Preminger & Shinn (2013)[14]		Varies by product type (DVD, computer program) with range from $75.00-100.00.	American English	Auditory	Comprehension	Speech in babble, time compressed speech, competing speaker, target word	3 (male, female, child)	Layout is visually clear and provides adequate font and color contrast	Instructions are fairly simple to follow and promotes independent navigation	Only brief demonstration and general instruction needed before independent use for most older adults
Angel Sound	Emily Shannon Fu Foundation (originally from Computer Assisted Speech Training (CAST), Tiger Speech Technology by House Research Institute)	Self-paced interactive listening exercises using over 10,000 sounds, words and sentences. Special modules available for training in noise, on the telephone, or with music. Level of difficulty adjusts automatically as skills improve. As listener completes sections, tests that show progress are also completed. Programs also	Fu, Galvin, Wang & Nogaki(2004)[24] Fu & Galvin (2007)[25] Oba, Fu & Galvin (2011)[26]		Free digital access through website	American English, Chinese, Spanish, Japanese	Auditory	Discrimination, identification, comprehension	Phonemic based minimal acoustic and perceptual contrast	Multiple	Layout is clear, but color contrast may be difficult for some older adults	Simple instructions to follow, but many options could be overwhelming to some older adults	Adult users will need training and demonstration to determine best way to train because of the many options available before independent use

(Continued)

Table 3 (*Continued*)

Program	Developer or Company	Description	Evidence Base citation	QR code	Cost	Language	Mode	Auditory Skill(s) targeted	Stimuli	Number of Speakers	Usability: Visual Layout	Usability: Clarity of instructions	Usability: Need for instruction
Seeing and Hearing Speech	Sensimetrics	known by other names such as CAST and Sound and Way Beyond Multi media technology that provides lessons in lip reading and listening through interactive training exercises, carefully planned lessons with multiple options from 1200 speech utterances. Users can adjust difficulty by adding background noise with training. Option to present stimulus in regular or slow speed. Practice or test mode available for all lessons; available in CD or ROM format.	Richie, Kewley-Port & Coughlin (2005)[28] Richie& Kewley-Port (2008)[27] lingvalson, Lee, Fiebig & Wong (2013)[29]		$85.00	English	Auditory, Visual, or Auditory-Visual	Discrimination, identification, comprehension	Vowels, consonants, stress, intonation, word length and everyday communication	Multiple (11)	Layout is easy to read with adequate font and color contrast	Instructions are clear, simple and easy to navigate after instruction	Adult users will need initial overview about how program works and strategies to use for training before independent use
Speech Perception Assessment and Training System for the Hearing Impaired (SPATS-HI)	Charles Watson and James Miller	Sentence and phoneme cluster training based on 109 essential sound clusters in English that are arranged from the most important to the least important. Adaptive training strategies include balanced presentation of 'easy' and 'hard' words tailored for each user.	Miller, Watson, Kewley-Port, Sillings, Mills and Burleson (2007)[30] Miller, Watson, Kistler, Wightman, Preminger and Wark (2008)[31]		$150.00 for 1 year license	English, Spanish	Auditory	Discrimination, identification, comprehension	Auditory only presentation of mostly phonemes and some sentences, in quiet and noise	8 talkers for phonemes, 15 talkers for sentences	N/A as tasks are intended for clinician directed training	N/A as tasks are intended for clinician directed training	N/A as tasks are intended for clinician directed training
Computer Assisted Speech Perception Sentences (CasperSent)	Arthur Boothroyd /Gallaudet University Rehabilitation Engineering and Research Center	Sentence training program interfaces with a computer and clinical audiometer. Training can be self administerded or clinician controlled. Stimuli	Mackersie, Boothroyd and Minniear (2001)[34] Boothroyd, Hnath-Chisolm, Hanin, & Kishon-Rabin (1988)[33]		Full set stimulus available by contacting Director of Research at Gallaudet University	American English	Auditory, Visual, or Auditory-Visual	Comprehension	Variable sentence length with familiar topics, word scoring results	3 talkers (1 male, 2 female)	N/A as layout is intended for clinician directed training	N/A as tasks are intended for clinician directed training	N/A as tasks are intended for clinician directed training

Table 3 (Continued)

Program	Developer or Company	Description	Evidence Base citation	QR code	Cost	Language	Mode	Auditory Skill(s) targeted	Stimuli	Number of Speakers	Usability: Visual Layout	Usability: Clarity of instructions	Usability: Need for instruction
		include 60 sets of 12 sentences each. Sentence vary in length from 3-12, viewing angles variable.											
eARena	Siemens	DVD or computer program versions provide adaptive training through 20 interactive lessons of 30 minutes each; includes movies explaining hearing loss and expectations	Internal studies only		Varies by dispenser	American English	Auditory	Awareness, discrimination, identification, comprehension	Everyday sounds, word and phoneme, speech in noise	Multiple	Layout is clear, simple and direct	Instructions are adequate for adults to follow	Adults will need only minimal training and demonstration prior to use
AB CIx	Advanced Bionics (available through the Listening Room)	Interactive exercises include listening at word and sentence level. Part of a series of rehabilitation applications available at Advanced Bionics website. Lesson plans can be developed, progress charted and shared with others	Internal studies only		Free digital access through website	AmericanEnglish	Auditory-Visual	Discrimiation, identification, comprehension	Phoneme, word, and sentence tasks with options for music and telephone training	Multiple	N/A as layout is intended for clinician directed training	N/A as tasks are intended for clinician directed training	Adults will need only minimal training and demonstration prior to use
KTH Speech Tracking	Harry Levitt and Chris Oden/ Advanced Hearing Concepts and Geoff Plant/MedEL	Stories presented using speech tracking method which requires word by word repetition of sentence. Performance is recorded in a number of words correctly identified per minute.	Bernstein, Baake, Mazevski, Blake-Rahter, Presley, Hume, Plant, & Levitt, (2012)[32]		Free digital download and instructional video	American English	Auditory	Comprehension	Sentence training with short stories about a main character (John)	1 talker - clinician directed live voice	N/A as layout is intended for clinician directed training	N/A as tasks are intended for clinician directed training	N/A as tasks are intended for clinician directed training

different application than the computer programs. For example, a provider could introduce clients to the concept of auditory training through the apps given their modest cost. Based on interest and need, further training options through computer training programs could be described.

The research base of computerized programs is also more extensive in comparison to mobile app programs. Many computer programs were developed in laboratories whose purpose was to create and evaluate training paradigms related to scope, duration, and materials for training.[29,34] For example, a series of studies conducted at Indiana University identified that complex speech stimuli and training with multiple speakers yielded greater improvements in speech understanding in noise than training with simple stimuli or with a single speaker. Additionally, they concluded that training should be at least 15 hours in duration before generalization is observed.[5,35–37] The development of commercial programs expanded auditory training options and additional research about these products. Therefore, it is not surprising that the research underlying computer-based programs is fairly extensive at this time. However, clinicians should be mindful that the outcomes related to this research base will likely vary for individual clients.

In contrast, very little is known about mobile apps at this time, suggesting that clinicians should proceed with caution in recommending these as interventions. For example, it is unclear if the delivery of sound through mobile phones is adequate for hearing aid and cochlear implant users. Additionally, there may be unwanted noise within smartphone technology that creates additional distortion. The visual layout on a smartphone is small, and even with large font, may not be adequate for adults over 50-years-old.

Despite these possible limitations, mobile apps may offer unique opportunities for patients. Considering that the investment for the apps described here is extremely low or free and that access to either smartphones or iPads is fairly common, this type of training is a low-cost option for patients. Several possible clinical applications are envisioned. One would be to encourage adults to explore apps when hearing loss first presents. A recent study by Ferguson and colleagues showed that phoneme discrimination training improves speech perception for persons with hearing loss who are not yet using amplification.[38] Therefore, audiologists could recommend auditory training for clients with hearing loss *before* they acquire amplification. Another option is for audiologists to have the apps available on a smartphone for demonstration of auditory training during an initial hearing aid fitting or implant mapping. This way, patients become informed about the potential need for more training beyond amplification. Educating clients that additional effort may be required to maximize hearing aid or cochlear implant performance would facilitate setting appropriate expectations for clients. Holding a more in-depth discussion about training could be completed at follow-up appointments. Thus, providing a gradual increase in information about auditory training early in the rehabilitation process, even before hearing aid acquisition, might be valuable in setting expectations for devices. If clients understand that additional training may be necessary to obtain optimum performance from amplification, they may be more satisfied with their devices or become more motivated to complete training to improve their own performance. In addition, including education about auditory training throughout the rehabilitative process would be consistent with client needs as theorized by the Stages of Change model related to health behavior change.[39] In this model, information and education is important in actually shaping behavior. Therefore, informing and educating clients about options beyond device function and operation could be an important contribution toward improving the uptake of rehabilitative steps such as auditory training. The training programs summarized here provide clinicians with a tool for informing clients about the various characteristics of rehabilitative training options. As such, this table may help the clinician facilitate a conversation with clients about the most appropriate training program to complement a client's interests and needs.

There is an increased recognition of the role of patient-centered care in aural rehabilitation.[40] An important theme emerging from

this body of knowledge is that audiologists need to consider clients as individuals and adjust rehabilitation and service to their particular needs. Although many of us will do this related to device selection, we also should do this in relation to auditory training options. Many other health-related areas have already begun to study the use of apps in areas such as mental health,[41] treatment for posttraumatic stress disorder,[42] smoking cessation,[43,44] and self-reporting for diabetes and weight management.[45,46] Therefore, the provision of information related to self-management of hearing loss through use of apps also would provide more patient-centered care as described previously and potentially improve retention and satisfaction with devices.

Limitations

Any review of mobile apps could be outdated by the time of written publication. The reviews focused on iOS and Android, and currently available apps for other operating systems were not considered. The usability scale was generated for the purposes of this review and has not been peer reviewed or assessed for psychometric qualities. However, the scale was derived from a widely published usability scale.[47] The comments provided in the table are impressions formed by the author in collaboration with a graduate student. Although limited in application, the concept of usability is critical for older adults and should be integrated in future descriptions of programs and research studies evaluating auditory training for adults.

REFERENCES

1. Strom K. Worldwide hearing aid sales. Hear Rev 2014;21(2):xx–xx
2. Lupsakko TA, Kautiainen HJ, Sulkava R. The non-use of hearing aids in people aged 75 years and over in the city of Kuopio in Finland. Eur Arch Otorhinolaryngol 2005;262(3):165–169
3. Smeeth L, Fletcher AE, Ng ES, et al. Reduced hearing, ownership, and use of hearing aids in elderly people in the UK—the MRC trial of the assessment and management of older people in the community: a cross-sectional survey. Lancet 2002; 359(9316):1466–1470
4. Schow R, Nerbonne M. Introduction to Audiologic Rehabilitation. Vol. 5;Boston, MA: Pearson Education, Inc.; 2007
5. Burk MH, Humes LE. Effects of long-term training on aided speech-recognition performance in noise in older adults. J Speech Lang Hear Res 2008; 51(3):759–771
6. Stecker GC, Bowman GA, Yund EW, Herron TJ, Roup CM, Woods DL. Perceptual training improves syllable identification in new and experienced hearing aid users. J Rehabil Res Dev 2006; 43(4):537–552
7. Sweetow R, Sabes J. Listening and communication enhancement (LACE). Semin Hear 2007;28(2): 133–141
8. Sweetow RW, Sabes JH. Auditory training and challenges associated with participation and compliance. J Am Acad Audiol 2010;21(9):586–593
9. Henshaw H, Ferguson MA. Efficacy of individual computer-based auditory training for people with hearing loss: a systematic review of the evidence. PLoS ONE 2013;8(5):e62836
10. Sweetow R, Palmer CV. Efficacy of individual auditory training in adults: a systematic review of the evidence. J Am Acad Audiol 2005;16(7):494–504
11. Chisolm TH, Saunders GH, Frederick MT, McArdle RA, Smith SL, Wilson RH. Learning to listen again: the role of compliance in auditory training for adults with hearing loss. Am J Audiol 2013;22(2):339–342
12. Levitt H, Oden C, Simon HJ, Noack C, Lotze A. Entertainment overcomes barriers of auditory training. Hear J 2011;64(8):40–42
13. Henderson Sabes J, Sweetow RW. Variables predicting outcomes on listening and communication enhancement (LACE) training. Int J Audiol 2007; 46(7):374–383
14. Olson AD, Preminger JE, Shinn JB. The effect of LACE DVD training in new and experienced hearing aid users. J Am Acad Audiol 2013;24(3):214–230
15. Erber N, Hirsh I. Auditory training. In: Davis H, Silverman S, eds. Hearing and Deafness, 4th ed. New York, NY: Holt, Rinehart and Winston; 1978:358–374
16. Laplante-Lévesque A, Hickson L, Worrall L. Rehabilitation of older adults with hearing impairment: a critical review. J Aging Health 2010; 22(2):143–153
17. Knudsen LV, Nielsen C, Kramer SE, Jones L, Laplante-Lévesque A. Client labor: adults with hearing impairment describing their participation in their hearing help-seeking and rehabilitation. J Am Acad Audiol 2013;24(3):192–204
18. Henshaw H, Clark DP, Kang S, Ferguson MA. Computer skills and internet use in adults aged 50-

74 years: influence of hearing difficulties. J Med Internet Res 2012;14(4):e113

19. Stacey PC, Summerfield AQ. Effectiveness of computer-based auditory training in improving the perception of noise-vocoded speech. J Acoust Soc Am 2007;121(5 Pt1):2923–2935

20. Watson CS, Miller JD, Kewley-Port D, Humes LE, Wightman FL. Training listeners to identify the sounds of speech: I. A review of past studies. Hear J 2008;61(9):26

21. Nahm ES, Preece J, Resnick B, Mills ME. Usability of health Web sites for older adults: a preliminary study. Comput Inform Nurs 2004;22(6):326–334, quiz 335–336

22. Brooke J. SUS: A quick and dirty usability scale. In: Jordan P, Thomas B, Weerdmeester B, McClelland A, eds. Usability Evaluation in Industry. London, UK: Taylor and Francis; 1996

23. Fu QJ, Galvin J, Wang X, Nogaki G. Effects of auditory training on adult cochlear implant patients: a preliminary report. Cochlear Implants Int 2004;5(Suppl 1):84–90

24. Fu QJ, Galvin JJ III. Perceptual learning and auditory training in cochlear implant recipients. Trends Amplif 2007;11(3):193–205

25. Oba SI, Fu QJ, Galvin JJ III. Digit training in noise can improve cochlear implant users' speech understanding in noise. Ear Hear 2011;32(5): 573–581

26. Richie C, Kewley-Port D. The effects of auditory-visual vowel identification training on speech recognition under difficult listening conditions. J Speech Lang Hear Res 2008;51(6):1607–1619

27. Richie C, Kewley-Port D, Coughlin M. Vowel perception by noise masked normal-hearing young adults. J Acoust Soc Am 2005;118(2): 1101–1110

28. Ingvalson EM, Lee B, Fiebig P, Wong PC. The effects of short-term computerized speech-in-noise training on postlingually deafened adult cochlear implant recipients. J Speech Lang Hear Res 2013; 56(1):81–88

29. Miller JD, Watson CS, Kewley-Port D, Sillings R, Mills WB, Burleson DF. SPATS: Speech Perception Assessment and Training System. J Acoust Soc Am 2007;122(5):3063

30. Miller JD, Watson CS, Kistler DJ, Preminger JE, Wark DJ. Training listeners to identify the sounds of speech: II. Using SPATS software. Hear J 2008; 61(10):29–33

31. Bernstein C, Baake M, Mazevski A, et al. Benefits of speech tracking training on sentence recognition, tracking rate and self-assessed communication function in adult cochlear implant users. J Acad Rehabil Audiol 2012;45:11–39

32. Boothroyd A, Hnath-Chisolm T, Hanin L, Kishon-Rabin L. Voice fundamental frequency as an auditory supplement to the speechreading of sentences. Ear Hear 1988;9(6):306–312

33. Mackersie CL, Boothroyd A, Minniear D. Evaluation of the Computer-Assisted Speech Perception Assessment Test (CASPA). J Am Acad Audiol 2001;12(8):390–396

34. Fu QJ, Galvin JJ III. Computer-assisted speech training for cochlear implant patients: feasibility, outcomes and future directions. Semin Hear 2007; 28(2):142–150

35. Burk MH, Humes LE. Effects of training on speech recognition performance in noise using lexically hard words. J Speech Lang Hear Res 2007;50(1):25–40

36. Burk MH, Humes LE, Amos NE, Strauser LE. Effect of training on word-recognition performance in noise for young normal-hearing and older hearing-impaired listeners. Ear Hear 2006;27(3): 263–278

37. Humes LE, Burk MH, Strauser LE, Kinney DL. Development and efficacy of a frequent-word auditory training protocol for older adults with impaired hearing. Ear Hear 2009;30(5): 613–627

38. Ferguson MA, Henshaw H, Clark DP, Moore DR. Benefits of phoneme discrimination training in a randomized controlled trial of 50- to 74-year-olds with mild hearing loss. Ear Hear 2014;35(4): e110–e121

39. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. Am J Health Promot 1997;12(1):38–48

40. Grenness C, Hickson L, Laplante-Lévesque A, Davidson B. Patient-centred care: a review for rehabilitative audiologists. Int J Audiol 2014;53 (Suppl 1):S60–S67

41. Bush NE, Skopp N, Smolenski D, Crumpton R, Fairall J. Behavioral screening measures delivered with a smartphone app: psychometric properties and user preference. J Nerv Ment Dis 2013; 201(11):991–995

42. Kuhn E, Greene C, Hoffman J, et al. Preliminary evaluation of PTSD Coach, a smartphone app for post-traumatic stress symptoms. Mil Med 2014; 179(1):12–18

43. Bricker JB, Mull KE, Kientz JA, et al. Randomized, controlled pilot trial of a smartphone app for smoking cessation using acceptance and commitment therapy. Drug Alcohol Depend 2014;143:87–94

44. BinDhim NF, McGeechan K, Trevena L. Assessing the effect of an interactive decision-aid smartphone smoking cessation application (app) on quit rates: a double-blind automated randomised control trial protocol. BMJ Open 2014;4(7): e005371

45. Wharton CM, Johnston CS, Cunningham BK, Sterner D. Dietary self-monitoring, but not dietary

quality, improves with use of smartphone app technology in an 8-week weight loss trial. J Nutr Educ Behav 2014;46(5):440–444

46. Min YH, Lee JW, Shin YW, et al. Daily collection of self-reporting sleep disturbance data via a smartphone app in breast cancer patients receiving chemotherapy: a feasibility study. J Med Internet Res 2014;16(5):e135

47. Grindrod KA, Li M, Gates A. Evaluating user perceptions of mobile medication management applications with older adults: a usability study. JMIR Mhealth Uhealth 2014;2(1):e11