Challenges associated with participation and compliance in auditory training

ROBERT SWEETOW*

University of California, San Francisco, California, USA

When individuals have hearing loss, physiological changes in their brain interact with relearning of sound patterns. Some individuals utilize compensatory strategies that may result in successful hearing aid use. Others, however, are not so fortunate. Aural rehabilitation has long been advocated to enhance communication but has not been considered time or cost-effective. Home-based, interactive adaptive computer therapy programs are available which are designed to engage the adult hearing impaired listener in the hearing aid fitting process, provide listening strategies, build confidence, and address cognitive changes. Despite the availability of these programs, many patients and professionals are reluctant to engage in and complete therapy. In this presentation reasons for the lack of compliance with therapeutic options will be identified and possible solutions to maximizing participation and adherence will be offered.

INTRODUCTION

The long held myth that the brain is a fixed, immutable system has been clearly dispelled and replaced by the notion that it is indeed plastic. It is now obvious that neural connections can be altered and that these modifications, whether considered refinements or weaknesses, can manifest themselves as behavioral changes. Research has demonstrated that peripheral dysfunction and attenuation, including hearing loss, leads to subsequent neuroplastic changes. Secondary plasticity may also occur following remedial efforts, such as provided by amplification, but problems persist due to limitations in hearing aids and cognitive deficits. Other attempts at remediation, including auditory training (AT), also results in plasticity, but there has been a reluctance by both patients and professionals to adopt this as a regular part of aural rehabilitation (AR). Few audiologists would argue with the notion that additional training beyond the use of wearable amplification could potentially benefit patients. Unfortunately, despite the logic and growing body of evidence supporting this position, most audiologists do not offer or prescribe additional therapies, and most patients do not ask for, or even wish to participate in additional rehabilitation. There are many possible reasons for this bilateral reluctance. In this paper, reasons for resistance, opportunities for change, and suggestions for greater compliance will be explored.

*Corresponding author: robert.sweetow@ucsf.edu

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WHY DO PATIENTS SEEK OUR HELP?

It would be too simplistic to assume that patients request advice from audiologists simply because they are having difficulty hearing. Indeed, few patients seek assistance because they are unable to detect birds chirping or other environmental sounds. Rather, patients seek intervention (although they don't state it as such) because of breakdowns in auditory communication. A number of elements comprise the hierarchy ranging from hearing to communication. The most basic step is hearing, which for the purpose of this discussion, can be defined as access to acoustic information. Ability to hear should (but does not always) lead to the ability to listen. This is because listening requires attention and intention. Listening is an active process requiring effort. Listening enables (but does not guarantee) comprehension, which presumes the accurate establishment of meaning. This results, in many cases, in communication, which entails the bidirectional transfer of information, meaning, and intent (Kiessling *et al.*, 2003; Sweetow and Sabes, 2004). Potential impediments to achieving mastery of these elements include peripheral hearing loss, progressive neurodegeneration (Kim *et al.*, 1997, Morest *et al.*, 1998), global cognitive decline, maladaptive compensatory behaviors, and loss of confidence (Sweetow and Sabes, 2010a). These elements are displayed in Fig. 1.

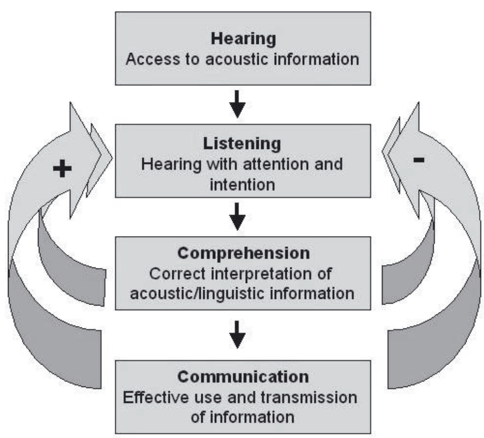

Fig. 1: Elements of communication. Adapted from Kiessling *et al.*, 2003; Sweetow and Sabes, 2004.

If adequate communication is not achieved, remedial efforts, including the purchase and use of hearing aids is impacted, both when owners refuse to wear their hearing aids, and when hearing aids are returned for credit. Returns and exchanges average in the double digits for hearing aids. Reasons include inaudibility, poor benefit/cost ratio, unrealistic expectations and inadequate counselling, neural plasticity, cognitive changes, and poor listening habits. Some of these factors can be eliminated or minimized. For example, the use of verification via probe microphone measures can mitigate inaudibility, and the use of realistic, time-based expectations can lower unrealistic patient expectations. The reality, however, is that there are numerous limitations to what modern hearing aids are capable of correcting. For example, hearing aids themselves cannot resolve impaired frequency resolution, rectify impaired temporal processing, undo maladaptive listening strategies, produce accurate proper localization cues which can be vital for navigating auditory space, 'properly' reverse neural plastic effects, or correct for changes in cognitive function that coincide with aging. This latter cause is particularly relevant because about two-thirds of people age 70 and older have hearing loss and older adults with hearing loss have a 24% higher risk of cognitive impairment. Lin *et al.* (2011) have speculated that this could be related to common cause hypothesis (shared neural pathways) leading to extra resource expenditure and isolation.

Imaging studies of word identification in unfavorable signal-to-noise ratios have revealed greater activation of memory and attention brain regions in older adults compared with younger adults (Wong *et al.*, 2009). To compensate for reduced audibility or deficits in temporal processing (Anderson *et al.*, 2013), older adults draw more on cognitive resources than younger adults (Wong *et al.*, 2010). Despite this, older adults often have a diminished cognitive reserve when trying to communicate in a complex listening environment. Pichora-Fuller and Singh (2006) evaluated the role of the auditory-cognitive system in speech-in-noise perception in older adults. They evaluated the strength of contributions from cognitive function (memory and attention), peripheral hearing status (audiometric thresholds and distortion product otoacoustic emissions), and neural processing (subcortical measures of pitch and response fidelity) to speech-in-noise perception. They also included a life experiences factor comprised of musical training because of its known long-term effects on speech-in-noise perception and memory (Parbery-Clark *et al.*, 2009). They found that cognitive function and neural processing were the biggest contributors to variance in speech-in-noise perception, but life experiences also had an effect. Interestingly, the contribution of hearing thresholds was not significant. This finding is consistent with previous work demonstrating that the audiogram is not a good predictor of speech-in-noise perception.

EFFECTS OF TRAINING

As stated earlier, plasticity occurs when there are peripheral deficits (Willott, 1993). But secondary plasticity can occur as a result of auditory training (Kraus *et al.*, 1995; Tremblay *et al.*, 1997; Menning *et al.*, 2000). Physiologic changes post training have been demonstrated in a number of studies and a variety of ways. For example, cortical thickening in older adults (Engvig, 2010); changes in mismatched negativity response (Recanzone *et al.*, 1993; Kraus *et al.*, 1995); changes in auditory evoked magnetic fields - (Vasama and Mäkelä, 1995); enhanced NI-P2 on novel speech sounds and demonstrated training effects (Tremblay *et al.*, 2001). Tremblay *et al.* (2009) attributed training related physiological changes to a greater number of neurons responding in the sensory field, and improved neural synchrony. They hypothesized that training decorrelates activity between neurons, making each neuron as different as possible in its functional specificity.

Training effects, in order to be truly beneficial, however, must extend beyond physiological changes and must be reflected in behavioral changes. Here too, there is ample evidence promoting the use of auditory training, both in individualized and group formats (Beynon *et al.*, 1997; Chisolm *et al.*, 2004; Hawkins, 2005). Sweetow and Palmer (2005), and more recently Henshaw and Ferguson (2013), conducted evidence-based reviews of the literature on individualized auditory rehabilitation and training in adults. Both reviews reached similar conclusions. They included: 1) less than 5% of studies published on auditory training meet rigorous evidenced based criteria; 2) auditory training resulted in improved performance for trained tasks in nearly all the articles that met evidenced-based criteria; 3) although significant generalization of learning was shown to untrained measures of speech intelligibility, cognition, and/or self-reported hearing abilities, the improvements were variable, relatively small and not robust, though retention of learning was shown at post-training. This individual variability in results is likely a product of protocol, but in addition, subtle reorganization could produce diverse presentations by scattering the deficit in neural space, and individuals' brain anatomy differ (i.e., variations in fissural patterns and propensities for adaptation and recovery).

Synthetic (top-down) training refers to training based on recognition of the overall meaning of discourse. Data indicate that it is capable of teaching hearing-impaired individuals to better use active listening strategies that can translate into improved psychosocial function. Some studies further support the finding that speech recognition skills, particularly in noise, can be improved by synthetic training. Uncertainty remains regarding the contribution of analytic training (bottom-up exercises using small segments of the speech signal such as phonemes or syllables). However, a number of issues may account for the lack of definitive results. Among these issues are the sensitivity of the outcome measures used in formulating conclusions and doubts regarding whether the optimal analytic training parameters have yet to be identified.

But while the improvements in speech recognition reflect a relatively modest statistic, the practical benefits may be larger than suspected. Consider, for example, that normal hearing people generally require a +2 dB signal to noise ratio for 50% recognition of words in sentences (while people with hearing loss require a +8 dB signal to noise ratio) (Killion, 2002) and that even a 1-dB reduction in SNR has been equated with a 6-8% improvement in sentence recognition (Crandell, 1991). Yet improvements, as reflected in off-task measures such as the QuickSIN for certain training protocols (as described below) may show group averages in excess of 3 dB and double-digit improvements in individual improvements. In addition, it has been shown that higher benefit from training is significantly correlated with reduced listening effort (Olson *et al.*, 2013); new hearing-aid-user groups experience the largest improvement (Olson *et al.*, 2013); patients with more severe handicap show greater benefit (Henderson-Sabes and Sweetow, 2007; Hickson *et al.*, 2007) and patients with more severe handicap are more likely to comply with therapeutic recommendations (Henderson-Sabes and Sweetow, 2007).

AUDITORY TRAINING PROGRAMS

As recently as ten years ago, the state of the art dictated therapy had to be performed in a face to face condition, thus rendering it less than cost effective. But now in the digital age, we have the means to provide therapy via computer-aided auditory rehabilitation so that it can be performed in a private, non-threatening environment, proceed at the individual's optimal pace, and progress assessment can be done automatically. A number of computerized auditory training programs are available. A partial list is shown in Table 1.

- CAST (Computer Assisted Speech Training)
- LACE (Listening and Communication Enhancement)
- Read My Quips
- Seeing and Hearing Speech
- Sound Auditory Training (Chermak, Musiek, and Weihing)
- Sound and Beyond
- SPATS (Speech Assessment and Training System)

Table 1: Partial list of available auditory training programs (in alphabetical order).

Of these programs, one in particular has been designed to engage the adult hearing-impaired listener in the hearing-aid fitting process, provide listening strategies, build confidence, and address cognitive changes characteristic of the aging process. LACE (Listening and Communication Enhancement) provides exercises in the types of situations most difficult for hearing-impaired listeners (Sweetow and Sabes, 2006). It utilizes an adaptive training algorithm so that the training difficulty level occurs near the individual's skill threshold and proceeds at the patient's optimal pace. The training combines listening training (analytic) with repair strategies (synthetic), and gives the patient feedback regarding performance. LACE provides a variety of tasks that are divided into three main categories (degraded speech, cognitive skills, and communication strategies). In a multi-site study of the effectiveness of a pilot version of LACE on 65 subjects, significant improvements were reported, not only on the training tasks, but also on a variety of 'off-task' standardized outcome measures including the QuickSIN (Etymotic Research, 2001; Killion *et al.*, 2004), Hearing Handicap Scale for the Elderly (HHIE) (Ventry and Weinstein, 1982), and Communication Scale for Older Adults (CSOA) (Kaplan *et al.*, 1997). Sixty percent of the subjects improved in all of the training tasks. Eighty-three percent of subjects improved in all but one of the training tasks. Subjects improved on the off-task outcome measures as well. Trained subjects improved an average of 2.2 dB SNR loss and 1.5 dB SNR loss on the QuickSIN test, presented at 45 dB and 70 dB, respectively. Eighty-five percent and seventy-four percent of the subjects showed improvement, with 46% and 42% of subjects showing clinically significant improvements on the QuickSIN (> 1.6 dB SNR loss improvement) for the 45 dB and 70 dB presentations, respectively.

Moreover, Song *et al.* (2012) evaluated the effects of LACE on 60 normal-hearing adults using both the QuickSIN) and HINT (Nilsson *et al.*, 1994), and concluded that "LACE training generalizes to standardized clinically-utilized measures of speech-in-noise perception – a critical factor if (auditory) training is to have an impact on real-world listening". They further stated that 'naturalistic training' that combines sensory and cognitive elements can enhance the central nervous system's ability to encode acoustic pitch-related fundamental frequency (FF) and second formant (F2) cues.

PROBLEMS

All of this is good news. Here's the bad news. Less than 20% of new users (and less than 10% of experienced users) receive any form of audiologic rehabilitation (beyond hearing aids) and only 2-5% are provided with formal retraining opportunities (Kochkin, 2009). Considering the fact that the profession of audiology was first formally conceived in 1946 for the purpose of providing rehabilitation for hearing-impaired veterans returning from World War II (Carhart, 1960), it is quite a disappointment that the use of formal rehabilitative services beyond hearing aids has reduced to such a level. What happened to aural rehabilitation? Ross (1997) has speculated that it declined beginning in the 1960s because outcome measures concentrated on analytic auditory training (difficult to achieve considering the limited bandwidth produced by hearing aids in those days) and speech-reading, and did not consider emotional and psychological by-products. In addition, many professionals consider it to be rather boring to administer, believe it is too time consuming, are reluctant to ask patients to spend more time or money, and are not convinced by the data supporting its efficacy. Each of these theories are quite tenuous. There is, however, validity to the belief that there is an undeniable, and unfortunate, lack of reimbursement.

Let us consider each of the arguments against providing auditory training.

Boring to administer: Many audiologists, including this author, initially attracted to the profession by the glamour and promise of technology, are underwhelmed by the tedium of plotting lesson plans and spending hours of individualized therapy. Yet indeed, auditory training in the 1950s though 2000 was comprised of exactly that. Now, however, the bulk of AT is conducted via computerized training that not only includes adaptive training to optimize individual learning rates, but automatic scoring.

Too time consuming: Since the bulk of training is done via computer, there is no need for the professional to spend significant time in the training phase (with the exception, of course, of initial instructions, occasional monitoring, and follow-up counseling). Establishing the protocol and collecting materials for both AT and group AR is also no longer an onerous task because there are numerous materials available via the web; e.g. Active Communication Education (Hickson *et al.*, 2007); Learning to Hear Again (Wayner and Abrahamson, 1996); Mayo Clinic Group AR (Hawkins, 2005).

Reluctance to ask patients to spend more time or money: Given the substantial cost of hearing aids, incorporating the relatively small additional monetary expenditure may seem insignificant to patients, or it can be included in the bundled pricing structure. Asking the patient to spend more time in the rehabilitation process is a somewhat trickier issue. If the audiologist is not convinced AT and AR will help, there may be a reluctance to ask the patient to participate in what could become a frustrating task. However, requesting patient participation in even more difficult, and sometimes uncomfortable, therapy such as physical therapy post-surgery is commonplace and a well-accepted component of such rehabilitation.

Not convinced by the data supporting its efficacy: As stated earlier, very few studies meeting evidence-based criteria have been published on AT efficacy. Those that have been published often have poor control or inadequate sample size. In addition, even some studies that support AR and AT can be misinterpreted. For example, Chisolm *et al.* (2004) indicated that hearing-aid users participating in an AR program performed better on a communication profile than those with no group AR experience at the conclusion of the program. However, there were no significant differences between the groups after one year. This finding may be interpreted as suggesting AR did not help. However, given the importance of hearing-aid uptake and usage to the overall AR process, the first month (the trial period) during which patients decide whether or not to keep and continue wearing hearing aids will be highly influenced by success that might be attributed to the AR classes. If patients do not recognize some early success, they may indeed cease amplification usage, thus increasing the likelihood of an unsuccessful rehabilitation. Uncertainties regarding the optimal training parameters required to drive secondary plasticity in the proper direction also account for the lack of belief in the value of therapy. Thus, in order for professionals to embrace the concept of the need for AR and AT, research data must be gathered and presented in a compelling scientific manner, and disseminated by established and respected investigators and clinicians.

But even if audiologists recognized the importance of providing AT, there is still the task of convincing patients to participate. Clinical data from over 3,000 individuals reported that adherence (defined as completion of at least half of the recommended number of AT sessions) was less than 30% (Sweetow and Sabes, 2010a). Similarly, in a study of home-based computerized AT for cochlear-implant users, Stacey and Summerfield (2005) reported that about 1/3 of their users completed less than 1/3 of the recommended training. It should be mentioned that the profession of audiology is not unique when it comes to non-compliance with recommendations. Non-compliance with prescribed medication regimens for hypotensive treatment ranges from 5% to 80% among glaucoma patients (Olthoff *et al.*, 2005). Vincent (1971) reported that 43% of glaucoma patients refused to take the physician-ordered measures necessary to prevent blindness, even when that refusal had already led to impairment in one eye.

It is also difficult to determine which patients will comply with recommendations. Intelligence, age, gender, and economic background are not correlated with compliance (Cameron, 1996). There are, however, some social and psychological factors believed to influence compliance. They include: knowledge and understanding including communication, quality of the patient-provider interaction, social and family support, and factors associated with the illness and the treatment including the duration and the complexity of the regimen (Cameron, 1996).

Six predictors of positive compliance cited by Laplante-Lévesque *et al.* (2012) are: higher socioeconomic status, greater initial self-reported hearing disability, lower pre-contemplation stage (denial), greater action stage of change, lower chance locus of control, and greater hearing disability perceived by others and self. In addition, motivation to improve, lifestyle, available free time, desire to please family members, and readiness for change are vital factors.

The following suggestions may improve compliance: 1) provide clear and understandable information about the condition and progress in a sincere and responsive way; 2) simplify instructions and therapy regimens as much as possible; 3) have systems in place to generate patient treatment or appointment reminders; and 4) for home based AT programs, conduct the first session with the patient in the clinic. This can be done by an assistant to maximize the professional's time. Data collected on compliance with the LACE program indicate that the number of participants completing the prescribed regimen increased by 20% when the first session was done in the clinic.

CHALLENGES AND CONCLUSIONS

The popularity of 'brain-training' programs continues to increase. Programs such as Lumosity, Fit Brains, and Brain HQ from Posit Science enjoy widespread usage. The challenge is to attain similar acceptance and popularity for AT. To do so, a number of improvements in current programs should be considered. Among them are: conduct large-scale, multi-site studies with adequate control groups and large sample sizes; develop mobile AT apps; incorporate videos, animations, and graphical interfaces into AT programs; and create more exciting and enjoyable training protocols. To this end, a number of studies suggest non-speech training materials can be of use. Music training can lead to better processing of speech in the auditory brainstem and cortex and to better understanding of speech in noise across age groups (Parbery-Clark *et al.*, 2009).

In fact, older musicians do not have the same brainstem timing delays in their speech-evoked responses as older nonmusicians do (Kraus and Anderson, 2013). The concept of using music as a stimulus for AT is supported by the Patel's acronym OPERA (Patel, 2012), which stands for:

- **O**verlap: in the anatomy and physiology for speech and music
- **P**recision: more precision is required for music processing than speech
- **E**motions: strong emotions evoked by music may induce plasticity via the brain's reward centers
- **R**epetition: extensive practice tunes the auditory system
- **A**ttention: focused attention to details of sound is required when playing an instrument

There is a great need to have better diagnostic and prognostic assessments. Computerized training may not be feasible for every patient. It would be useful to predict which subjects are more likely to commit to participating in, and then ultimately completing a training program. It is currently not possible to predict outcomes based on initial data. Therefore, clinical expertise and experience, as well as information obtained from counseling, is important when deciding who should participate in aural rehabilitation.

Many unresolved questions remain. What are the best training parameters and modes? What sequences of specific inputs will change the brain in desired ways? In training, should one use analytic microtraining (bottom-up) or synthetic macro-training (top-down) approaches, or a combination? Will training generalize to "real-life" experiences? Will training improve the acceptance of hearing aids? Will results be magnified when training is introduced in conjunction with introduction or changes to amplification? When should AT be offered (before hearing-aid fitting, during trial, after trial)? Will training last over extended time periods? Will audiologists be resolute in recommending training? And perhaps most important to convincing audiologists and patients about the efficacy of AT, what are appropriate outcome measures and how should success be measured? Certainly group mean data do not reflect individual variations in improvements from AT. Should success be defined by on-task improvement, generalized speech recognition performance, subjective communication confidence (Sweetow and Sabes, 2010b), or quality of life? The answers to these questions will solidify the place for computerized auditory training and aural rehabilitation in the clinical audiology practice. Research must lead the way to acceptance that hearing aids are one, but not the only, component of AR.

DISCLOSURE

The author has a financial interest in Neurotone, Inc., the company that produces LACE.

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