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Training the adult brain to listen

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I know that Page Ten is in *The Hearing Journal*. But you're talking about *listening*. What is the difference between hearing and listening?

Hearing is access to acoustic information. Listening, however, requires attention and intention. Hearing, listening, and the use of linguistic and contextual information lead to comprehension. All are needed to complete the journey to adequate communication.

Normal hearing alone does not assure that one is a good listener. We all know people who have normal hearing but are lousy listeners. Conversely, many of our patients have impaired hearing, yet are wonderful listeners. Listening is a skill that requires effort, and for a person with a hearing loss, that effort must be particularly concentrated.

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Okay, I can understand that if you have a hearing loss you might not have full access to all the acoustic information that a normal-hearing person has. But don't hearing aids give us the information we need to become good listeners?

I don't think you're *listening* very well. As advanced as hearing aid technology has become, hearing aids alone cannot produce the listening skills or comprehension needed for communication. Hearing aids are designed to provide access to as much acoustic information as possible, but they do not directly modify the user's brain or the user's behaviors.

However, proper use of the brain's resources, modified by behavioral compensatory strategies, can impact listening. Keep in mind that amplification cannot correct for changes in temporal or spectral resolution that are a consequence of cochlear damage. In addition, an increasing body of research is now proving that damage to the cochlea actually leads to changes in the brain.

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Whoa, wait a minute! Are you saying that people with hearing loss have brain damage?

No, not at all. What I am saying (now please listen carefully) is that significant attenuation or reduction of peripheral input likely induces a reorganization of the neural representation from the brainstem through the auditory cortex. This reorganization (also referred to as plasticity) takes place in all the sensory systems and occurs throughout our lifetime, albeit more so in childhood. For example, we know from animal studies that neural regions responsible for

processing high frequencies become more responsive to mid-frequencies if they are not receiving high-frequency stimulation.

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But once we put hearing aids on and the brain begins to receive stimulation once again in regions that have been deprived, won't the brain automatically readjust?

It is likely that there is some degree of "secondary plasticity," but we don't know to what extent this will occur, or how soon. We do know, however, that plasticity can be driven by associative learning. For example, in both animals and in humans training can induce cortical reorganization, just as deprivation can.[1]

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Is this plasticity responsible for all the listening problems that people experience?

No, it is only one component, and we don't yet have a way of determining just how much this will impact an individual or if it will even necessarily produce an undesirable effect.

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So, what other components contribute to listening problems?

There are several. A major contributor to such problems is the development of maladaptive compensatory strategies. We know that some people employ beneficial repair strategies, such as determining the general content of the conversation, setting up the acoustic environment as favorably as possible, asking the speaker to rephrase rather than repeat, or recognizing that speech tends to be redundant, so missing one word does not mean the message is lost.

However, there are also people with hearing impairment who develop maladaptive strategies, such as bluffing, dropping out, monopolizing the conversation, or becoming a passive (as opposed to assertive) listener. An assertive listener is one who, for example, is not shy about telling a speaker to slow down or face forward.

It seems logical that one way to improve listening is to try to drive brain plasticity while simultaneously providing behavioral training and teaching listening and communication strategies. In fact, the factors impacting listening and communication are interactive, so the development and implementation of behavioral compensation and communication strategies may alter cortical associations.

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All this talk about communication strategies sounds a lot like aural rehabilitation. Don't most audiologists already do that?

Actually, studies suggest that most audiologists provide hearing aid training and some education on communication strategies. However, more intensive listening

training usually is not offered, largely because of all the other demands placed on the audiologist's time.

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Why not just put our patients into group rehab? Won't they get information about communication strategies there?

There are studies indicating that group rehabilitation does indeed lower the return-for-credit rate and increase patient satisfaction with hearing aids. However, people with hearing loss are a very heterogeneous population. So, some patients may need a more individualized approach that allows for more intensive therapy and proceeds at the optimal pace for a particular individual.

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Do you think we can account for (and then correct) listening problems simply by driving brain plasticity and providing individualized behavioral strategies?

Well, no. You're getting closer, but there are two more important factors that we have to consider. Even though people of all ages wear hearing aids and experience listening problems, the reality is that most of our patients are elderly. And, as we get older, changes occur in our cognitive skills. Specifically, our processing speed slows down and our working memory is diminished.[2]

These two cognitive skills are very important for comprehending rapid speech (think about how many of our patients complain that people simply speak too fast) and for using our brain to help fill in the gaps that exist when speech is only partially audible (as is the case when we consider the complex interactions between distortions caused by sensorineural hearing loss, noisy environments, and the imperfect reproduction of sound created by hearing aids). We need to accurately process speech that normally occurs at 120-180 words per minute (speed of processing). Furthermore, we need to maintain what has just been said while logically predicting what is about to be said (working memory).

Last but not least, people who believe they are not communicating well often withdraw from social situations that place demands on their listening abilities. Therefore, it is important to boost our patients' confidence in their communication skills in order to prevent this unfortunate pattern from occurring.

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But can adults really be individually trained to improve their cognitive skills?

Absolutely. A recent study of over 2000 senior citizens proved that both speed of processing and auditory memory can be enhanced by training and that these improvements can endure over time.[3]

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Okay, I think I've got it. We need to train adults to maximize their cognitive skills and communication strategies to take full advantage of what they are hearing. That sounds logical, so why aren't we doing it?

We've suspected for years that providing therapy would be desirable for our patients, but it is not clear how this therapy can be delivered in a cost-effective manner. After all, few of us have the time or resources to provide multiple hours of individual training. Moreover, how exactly to provide this therapy has never been determined. For example, should it be conducted in a bottom-up or top-down model?

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"Bottom up or top-down"!?

Sorry, that just slipped out. By this I mean, should we be teaching our patients to distinguish among the fine elements of sound (such as differences in voice onset time or the differences between one phoneme and another) or should we be teaching communication strategies and addressing emotional by-products of hearing impairment? The first way would be considered bottom-up training, and the second would be considered top-down.

We do have some new knowledge obtained from neuroscience and learning theory, and we can use computer technology to create programs that might be effective. We know that learning is enhanced when certain criteria are met. For example, training should require active, rather than passive, participation by the learner. Practice material should be varied so learners can adapt to realistic variation and so that their motivation during exercises is maintained. Maintaining accurate performance records is necessary for evaluating progress and the effects of the training. Perhaps the single most useful contribution of learning theory is the provision for giving learners immediate knowledge (feedback) regarding their performance.

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This sounds complicated. What factors should I consider in creating a comprehensive program?

In addition to the concepts I just described, a program should:

- be cost-effective
- be accessible (able to be performed in the privacy of the patient's home)
- be easy, fun, and rewarding for the patient
- produce results that the clinician can verify via remote or "datalogging"
- integrate listening training along with communication repair strategies, and
- give the patient "responsibility" for participating in the rehabilitative process, whether or not that process includes hearing aids.

In addition, a comprehensive program must be adaptive so that the patient can be trained near his or her learning threshold. Doing this prevents the exercises from becoming either too easy (boring) or too difficult (frustrating).

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Is anybody doing this sort of thing?

Based on the number of papers being published in journals and presented at recent scientific meetings, there seems to be a remarkable resurgence in interest in auditory training. I think some of this relates to the fact that computerized training has been proven effective in sensory training for visual deficits,[4] as well as for cognitive disorders such as aging-associated memory deficits and early-stage Alzheimer's.[5] Programs such as an extensive computerized cognitive training program being developed for adults by some of the same scientists who developed FastForward are examples of the new surge in training to compensate for and prevent deficits.

This is all happening because well-established rules of perceptual learning, such as those discussed above, can be easily implemented in a computerized protocol. Other computerized training programs have been introduced to the hearing healthcare community for auditory training and speechreading, but have never become commonly used.[6-9]

Now is an optimal time to implement these training programs because our patients are becoming more and more comfortable with computers. I know of at least three groups that have begun work on new computerized training programs, but I will share with you some details of a therapy program that I believe incorporates all of the concepts discussed earlier. This is a program called LACE (Listening and Communication Enhancement) that Jennifer Henderson Sabes and I developed at the University of California, San Francisco (UCSF), and introduced at the 2005 American Academy of Audiology Convention. We had previously discussed the concepts behind this type of training in a 2004 *HJ* article,[10] but only in the past year has the program been tested on real patients.

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How does it work?

LACE is intended to be a cost-effective, home-based, interactive computer program that engages the hearing-impaired adult in the hearing aid fitting process, provides listening strategies, builds confidence, and addresses cognitive changes characteristic of the aging process. The current version requires the use of a PC, but to increase its accessibility to patients, the next version (available this fall) will have self-contained, portable dedicated hardware that can be loaned or rented to a patient who does not own a computer or is not computer-literate.

LACE provides interactive and adaptive tasks in three main categories (degraded speech, cognitive skills, and communication strategies). For degraded speech exercises, speech is either time-compressed (to simulate rapid speech) or presented with background babble noise or a single competing speaker. The patient listens to and identifies the signal, then sees the correct response on the screen. If it was correctly comprehended, the next task will be a little more difficult; if it was incorrect, the next task will be easier. In this way, both boredom and frustration are minimized and the principle of training near the skill threshold is maintained.

The program also includes adaptive training exercises to enhance auditory memory and speed of processing, two elements of listening that, as discussed

earlier, are particularly important in noisy environments. Additionally, the program presents interactive communication strategies.

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How does the patient know if he's making progress?

In addition to the immediate feedback for each task, LACE provides the patient with a graph depicting daily progress and improvement from the start of the training. Furthermore, the results of the training are tracked and electronically transmitted to a secure web site that the audiologist can access in order to monitor progress and implement any needed modifications in training.

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Are there are any data supporting the efficacy of this and other training programs?

Kelly Tremblay and her colleagues demonstrated electrophysiologic evidence in the form of N1-P2 changes following bottom up training detecting subtle differences in voice onset time.[11] Catherine Palmer and I recently completed an evidence-based review of individual auditory behavioral training that will appear later this year in a special issue of *JAAA* (*Journal of the American Academy of Audiology*).[12] Evidence supporting efficacy of individual training programs was found.

Although the literature did not produce unanimous or indisputable conclusions regarding the efficiency of individual auditory training, certain trends appeared. These trends suggest that top-down training may be capable of teaching hearing-impaired persons to make better use of active listening strategies that can translate into improved psychosocial function. Some studies suggest that speech recognition, particularly in noise, can be improved by synthetic (top-down) training.

There was less certainty regarding the contribution of analytic (bottom-up) training. However, certain 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 as to whether or not the optimal training parameters have yet been identified. Nearly all of the studies have indicated some degree of beneficial trends gleaned from individual auditory training.

Regarding our program, we have completed analysis of data collected at UCSF and several other research sites on more than 40 patients trying LACE and on 25 untreated patients (more data are being collected). Trial-by-trial data from the training tasks were assessed, as well as outcome measures including the QuickSin, HINT, CSOA (Communication Scale for Older Adults), and HHIE/A, to determine generalization to tasks other than those in the training.

As expected, there were statistically significant changes on all of the training tasks, with nearly 90% of subjects (37 of 42) showing significant gains on the training tasks. Statistically significant differences between baseline and post-training tests were shown on the Quick SIN, but not on the HINT. Fourteen of 42 subjects in the training group showed clinically significant (more than 1.6 dB) improvements on the QuickSin at 45 dB. Another 22 of these subjects showed

improvements between .5 and 1.5 dB. There were highly significant changes shown for the trained group on the HHIE/A social subscale (though not on the emotional subscale) and on the CSOA Strategies subscale. There were no significant changes for the control groups on any of these measures.

At least as important as changes in speech recognition was the finding that 36 of 42 subjects in the training group reported being more likely to enter a difficult listening situation and 37 of 42 reported greater confidence in conversations. No significant changes were found in the untrained group for any of the outcome measures.

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Is there any evidence of a long-term effect?

Unfortunately, no, because this is such a new procedure. But establishment of the long-term effects is critical. It is also important to determine if follow-up or "booster" training is useful.

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Do you think successful rehabilitation programs will translate into better market penetration or reduced return for credit rates?

We have no idea yet, but we are collecting data on these issues as well. I believe that any type of training adds value to hearing aids, and reinforces the notion that hearing aids alone cannot solve all of a patient's communication problems. As I mentioned earlier, hearing aids address hearing; rehabilitation should address listening.

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Is this type of training appropriate for all our patients?

Different types of individualized training are certain to become available in the near future, some with a top-down philosophy, some with a bottom-up philosophy. I think the key is to provide the means for training *all* of our patients, regardless of their degree of hearing loss or of whether or not they will be using amplification.

We should never allow patients to assume that hearing aids by themselves can solve their communication problems. Our patients need to accept responsibility for being a partner in the search for enhanced communication. They need to understand that hearing is addressed in a passive way by hearing aids, but that listening must be attacked in an assertive manner by mustering all the cognitive and strategic resources available.

When a person has shoulder surgery, the surgeon is adamant about prescribing physical therapy to strengthen the bond between the surgical intervention and the muscles adjacent to the surgical site and creating behavioral compensations that will enhance the results of the surgery. Audiologists need to be just as resolute in urging our patients to use rehabilitation. More important than which specific training program is chosen is the basic principle that every patient who reports difficulty listening should receive some therapeutic plan from

the professional. That plan may or may not include hearing aids, but it certainly should include some type of listening and communication strategies training.

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