Electrophysiologic Assessment of Auditory Training Benefits in Older Adults

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ABSTRACT

Older adults often exhibit speech perception deficits in difficult listening environments. At present, hearing aids or cochlear implants are the main options for therapeutic remediation; however, they only address audibility and do not compensate for central processing changes that may accompany aging and hearing loss or declines in cognitive function. It is unknown whether long-term hearing aid or cochlear implant use can restore changes in central encoding of temporal and spectral components of speech or improve cognitive function. Therefore, consideration should be given to auditory/cognitive training that targets auditory processing and cognitive declines, taking advantage of the plastic nature of the central auditory system. The demonstration of treatment efficacy is an important component of any training strategy. Electrophysiologic measures can be used to assess training-related benefits. This article will review the evidence for neuroplasticity in the auditory system and the use of evoked potentials to document treatment efficacy.

KEYWORDS: Electrophysiology, frequency following response, auditory training, efficacy, plasticity

Learning Outcomes: As a result of this activity, the participant will be able to (1) describe ways that electrophysiology can be used to demonstrate auditory training principles and (2) describe effects of auditory training on the frequency following response in older adults.

Older adults are often seen for audiologic evaluation because of speech perception difficulties that impact their ability to communicate with others in a variety of listening environments. Amplification is the primary recommendation for people who experience speech

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perception difficulties. Tremendous advances have been made in hearing aid technology, including digital processing, noise reduction technology, directional microphones, and improved feedback management. However, despite these improvements in amplification technology, older adults with hearing loss continue to struggle in difficult listening situations such as in the presence of background noise and when listening to degraded signals.[1,2]

Although hearing aids provide audibility, speech perception ability is influenced by processes beyond the peripheral auditory system, especially in older adults. Perception of acoustic signals is influenced by the coding and integration of signals at central levels of the auditory system and by cognitive influences; therefore, the combined effects of signal processing at peripheral and central levels and cognitive functions (e.g., attention, auditory working memory, speed of processing) influence the resultant perception of the speech signal.[3–5] Age-related speech perception deficits in noise are still present when controlling for hearing loss and cognitive ability, suggesting that neural involvement is independent of hearing loss.[6] The temporal distortion of speech signals also decreases speech recognition in older listeners more than young listeners, even in listeners with normal hearing.[7] As hearing aids only address peripheral deficits and speech perception involves both peripheral and higher-order processes, additional treatment options should be considered for the management of older listeners with reported speech perception difficulties. The listening difficulties experienced by older listeners may be at least partially alleviated by therapeutic methods that address deficits beyond the peripheral auditory system. However, concerns exist regarding the efficacy of auditory training. This article will review the evidence that supports the use of auditory training as a management strategy for older adults with hearing difficulties. To address this topic, the following subject areas will be discussed with a focus on electrophysiologic studies: neural plasticity associated with enhanced sensory input or sensory deprivation, expected central auditory changes associated with aging and/or hearing loss, the use of computer-based auditory training strategies, learning principles revealed using evoked potential testing, efficacy of training in older adults, and considerations for maximizing training benefits.

CENTRAL AUDITORY SYSTEM PLASTICITY

Can the brain be trained to hear better? The brain is not a static organ; it develops and changes based on sensory input that occurs over time. Neural plasticity can be defined as the brain's ability to change and adapt based on individual experiences.[8] Within the central auditory system, these changes are both a result of varied auditory sensory input and a lack of auditory sensory input. Thus, neural plasticity may have both advantageous and detrimental effects on perception. Music training provides enhanced sensory input and may therefore have beneficial effects on perception and neural speech encoding. Parbery-Clark and colleagues investigated the influence of musicianship on peak timing of the auditory brainstem response to the speech syllable /da/ in younger and older normal-hearing listeners.[9] Aging and musicianship were both found to have distinct effects on the neural mechanisms responsible for stimulus encoding. Older listeners exhibited delayed encoding of the onset and transition of the speech stimulus when compared to younger listeners, with possible detrimental effects for stop consonant perception in older adults. However, older listeners who had a history of musical training did not have peak timing delays for the consonant–vowel transition. These results suggest that music training counteracts some of the deleterious effects of aging on response timing within the central auditory system.

The lack of sensory input associated with hearing loss can result in neural consequences at higher levels of the auditory system. Sensorineural hearing loss has deleterious effects on the representation of the temporal envelope and temporal fine structure components of speech in the auditory brainstem. Both the temporal envelope and temporal fine structure play a role in speech perception.[10] The envelope reflects slow amplitude fluctuations and conveys loudness,[11] vowel formant information,[12,13] and manner of articulation and voicing information.[14] The temporal fine structure reflects faster fluctuations of sound pressure that convey spectral information. The signal's fine structure contributes to the timbre of a signal and may play a role in listening in background noise.[15,16] Anderson and colleagues compared the neural responses to the speech syllable /da/ presented in noise in older listeners with hearing loss and in age-matched, normal-hearing controls. An imbalance in the temporal envelope and fine structure representation of the speech signal was seen in older listeners with hearing loss, with larger representation of the temporal envelope amplitude and reduced representation of the temporal fine structure compared to normal-hearing listeners.[17] These results are consistent with animal models of hearing loss, which have shown exaggerated encoding of the envelope and decreased encoding of the temporal fine structure in the auditory nerve and midbrain of chinchillas who have noise-induced hearing loss.[18–20] These studies provide a plausible explanation for why older adults often complain that speech is loud but unclear. In individuals with hearing loss, the exaggerated responses to amplitude fluctuations of the temporal envelope may reduce the saliency of the temporal fine structure. Because the envelope fluctuations are so large, they may serve as a distracter or they may mask the audibility of the fine structure.

Tonotopic reorganization is also a consequence of sensorineural hearing loss. Disrupted tonotopic organization results in an inability of the ventromedial region of the inferior colliculi (IC) to respond to high-frequency stimulation in C57 mice, which commonly experience sensorineural hearing loss in presenescence.[21] The loss of tonotopicity and decreased spectral tuning may affect the IC's ability to process the complex sounds of speech.[22] Hearing loss also can induce tonotopic changes in the auditory cortex. High-frequency hearing loss in humans leads to changes in cortical mapping, such that cortical neurons that are deprived of sensory input due to hearing loss begin to respond to frequencies adjacent to the region of the hearing loss.[23] These results demonstrate the plastic nature of the neural auditory system, which is susceptible to reorganization from reduced sensory input. Peripheral hearing loss impairs tonotopicity and frequency encoding, exacerbating the effects of reduced audibility on speech perception.

The reintroduction of sensory input, through the use of hearing aids or cochlear implantation, may reverse some of these neural consequences of hearing loss. Evidence of this reversal is seen in children after cochlear implantation. Rapid reductions in P1 latencies of cortical-evoked responses are seen in children who are implanted early, before the age of 3,[24] suggesting that the P1 latency may be a biomarker of central auditory maturation. However, there is limited evidence regarding plasticity of evoked potentials in adults who receive cochlear implants or hearing aids later in life. Given the considerable variability in speech perception performance in individuals who use cochlear implants or hearing aids, it is likely that (1) the neural consequences of deafness are only partially reversed with increased audibility or stimulation, and (2) other neural factors independent of hearing loss, such as age-related changes in temporal and spectral processing, limit the benefits of these devices. Evidence for temporal processing deficits associated with aging have been demonstrated in behavioral studies,[25–29] but the neural mechanisms underlying these deficits are not completely understood. A reduction in auditory nerve fibers,[30,31] changes in the balance of excitatory and inhibitory neurotransmitters,[32] and delayed neural refraction may be factors in decreased temporal processing.[33] These factors may lead to decreased intertrial response consistency and delayed latencies in evoked responses and subsequent declines in speech perception.[5,34,35]

NEED FOR AUDITORY TRAINING

Because the restoration of audibility only partially reverses the neural consequences of deafness, more active treatment approaches should be considered. The development of computer-based auditory training programs has led to renewed interest in these management options.[36,37] Many of these programs can be implemented on a personal computer in one's own home, increasing the feasibility of this recommendation. Several studies have demonstrated short-term improvement in speech recognition in noise with auditory training.[38–40] In one of these studies, older adults with hearing loss received training on open- and closed-set lists of words in noise for seven, 60-minute sessions over the course of 2 weeks.[38] This training resulted in improved recognition of trained words that maintained for 3 months, but generalization to untrained words was limited. Another study used training with the Listening and Communication Enhancement (LACE^{TM}, Neurotone, Inc., Redwood City, CA) program for 30 minutes, 5 days a week for 4 weeks in older adults with hearing loss.[41] Individuals who participated in the LACE training improved in sentence recognition in noise and in self-perception of hearing handicap, but the control group's performance did not change, and this improvement was maintained for 8 weeks.

Although the efficacy of auditory training has been demonstrated, many questions regarding optimal strategies remain unanswered. The following questions were posed by Boothroyd in his 2010 review[42]: What aspects of computer-based programs that include training on multiple features are responsible for the improvement? When speech recognition improves, what aspects of perception have changed? Can statistically significant differences on a single score translate to benefits noticed in everyday listening situations by the individual listener? In addition to these questions posed by Boothroyd, one also might ask: What is the time course of auditory training and does this differ in younger versus older adults? What is required for training to generalize? What can be done to improve compliance with training? How do we account for individual differences, especially in older adults and in individuals who wear cochlear implants? In summary, these questions point out the need to consider a variety of factors to maximize training efficiency. The following section reviews evoked potential studies that have demonstrated learning principles, such as generalization, time course of training, and stimulus-specific benefits.

WHAT CAN ELECTROPHYSIOLOGIC STUDIES TELL US ABOUT NEURAL PLASTICITY?

The use of electrophysiology to assess neural plasticity associated with speech perception gains may help to answer some of the previously mentioned questions. Tremblay and colleagues used the mismatch negativity response (MMN) to demonstrate auditory learning principles. The MMN is a derived response, obtained by subtracting a response to a rarely occurring stimulus from a frequently occurring stimulus. In one study, young, normal-hearing listeners learned to discriminate between labial native and nonnative syllable contrasts.[43] After a 5-day training period, the MMN showed an increase in the area of the response, an indication of enhanced neural perception of syllable differences, and this neural change was accompanied by better performance on the behavioral identification task (Fig. 1). Importantly, this training generalized to an untrained alveolar syllable contrast, also demonstrated by increased MMN area and enhanced behavioral performance. Therefore, the MMN can provide an objective measure of the extent to which training has generalized to untrained tasks.

The MMN also was used to evaluate the time course of plasticity in young adults with normal hearing.[44] Young adults were trained to discriminate between two syllables on the basis of voice-onset time (VOT). On days 1 and 2, testing was conducted to establish test–retest variability for neurophysiological and behavioral measures. Follow-up testing was performed on days 4, 6, 8, and 10, alternating with training on days 3, 5, 7, and 9. Training resulted in changes in the MMN response (duration, area, and latency) in all 10 subjects, but in 5 of those participants, behavioral changes were not seen until they had undergone at least 1 additional day of training. These results suggest that electrophysiologic measures may be used to predict behavioral gains. This information may be valuable when clinicians are making a decision about whether or not to continue auditory training. A change in neurophysiology may suggest that behavioral changes will follow with continued training; however, further studies of the time course of training are necessary to verify using evoked potentials in this manner.

Evoked potentials can be used to assess training effects on even shorter time scales. Perceptual training can be accomplished quickly, within a matter of minutes,[45] though longer training sessions may be necessary for

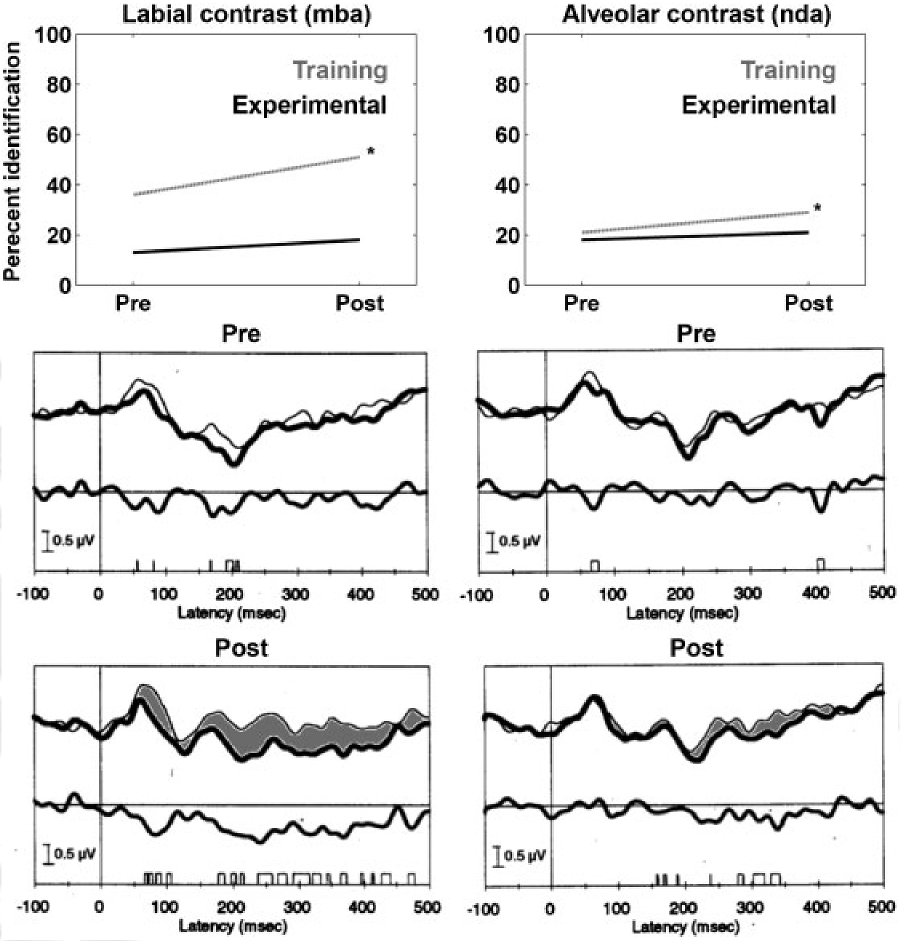

Figure 1 Training on a nonnative labial contrast generalizes to a nonnative alveolar contrast. (Top panels) Percent identification of the nonnative labial contrast (mba) improves significantly after training and generalizes to the nonnative alveolar contrast (mda) in the training group (gray line), whereas no changes are seen in the control group (black line). (Bottom panels) The mismatch negativity response (MMN; indicated by the shaded area) is not discernible prior to training, but after training the area and duration of the MMN increases significantly in both the trained and untrained syllable contrasts. (Adapted from Tremblay et al. *J Acoust Soc Am* 1997.[43])

maintenance or generalization. Alain and colleagues investigated the effects of training within just 1 hour and compared changes in behavioral performance with changes in the N1, P2, and N2b amplitudes of cortical evoked potentials.[46] Three stimuli were used in the perceptual training and cortical recording: “ba,” “mba,” and white noise. The “ba” and “mba” differed in VOT with the “ba” having a 20-millisecond VOT and the “mba” having a 30-millisecond VOT. These stimuli were chosen because of prior evidence that listeners can quickly learn to distinguish these syllables.[47] Training with syllables was compared to training with noise to determine whether changes in the cortical evoked potentials were specific to a particular speech cue. Results showed rapid improvement in behavioral performance in the first four blocks of trials that maintained for the remaining six blocks. Increases in the amplitudes of the N1, P2, and N2b components of the cortical responses coincided with the behavioral improvements. However, the N1 and P2 amplitudes also were increased for the noise stimulus—only the N2b component was specific to the speech stimulus.

This study demonstrates the usefulness of including a control condition to ensure that effects are due to training rather than to passive exposure.

A recent study also demonstrated effects of passive exposure on P2 amplitudes. Because of observed music training-related enhancements in the amplitude of the P2 component of the late latency response, it has been assumed that the P2 is a marker of auditory learning. To test this assumption, Tremblay et al assessed P2 amplitudes before and after 1 week of training on discrimination of nonnative VOT contrasts in three groups of participants: (1) training group that received feedback, (2) training group that received no feedback, and (3) control group that received no training.[48] They found that P2 amplitudes increased in all the groups, including the control group, and that these changes were maintained for 2 months after cessation of treatment. They concluded that the effects were due to passive exposure to the stimulus during testing and not the effects of training per se. Therefore, when using electrophysiology to measure treatment efficacy, it is important to determine the degree of change that is necessary to infer actual training-related changes.

The frequency following response (FFR), a midbrain response arising primarily from generators in the IC, is another electrophysiologic measure that can be used to document treatment efficacy.[49,50] The term *frequency following response* is used because the response reproduces the frequency of the stimulus,[51] and it also represents the timing and timbre components of the stimulus.[52] Similar to the auditory brainstem response, the FFR has good test–retest reliability,[53,54] a necessary feature for assessing clinical efficacy. Although FFR spectral amplitudes may increase with stimulus repetition during the course of a recording,[55] several studies have demonstrated changes specific to the trained and not the control group, and therefore the FFR may be less susceptible to effects of passive exposure than the cortical potentials.

Because the FFR reflects specific aspects of the stimulus, it may be used to evaluate the malleability of distinct aspects of speech representation. Two studies have examined training effects on subcortical pitch encoding. Song et al trained young native English speakers to recognize novel words based on lexical tones.[56] These tones are linguistically meaningful in Mandarin Chinese and included rising, falling, and dipping tones. Studies have shown that Mandarin Chinese speakers have better subcortical pitch tracking of tonal contours than non-Mandarin speakers.[57,58] Song et al predicted that the effects of training would be most evident for the dipping tonal contour, which was the least familiar to the listeners. They found that after just 8 days of training, behavioral improvement in recognition of the dipping tonal contour was accompanied by improvement in the accuracy of FFR pitch tracking.[56] Carcagno and Plack also evaluated training effects on the FFR using three pitch contours (rising, falling, and static).[59] In this experiment, however, each participant was trained on only one of the contrasts so that there were three trainings groups, one for each pitch contour and a control group, thus allowing them to determine the specificity of the training. After 10 training sessions over the course of 27 days, perceptual learning occurred only for the stimuli used to train each group. In addition, although the FFR changes were not specific to the direction of pitch trajectory (rising versus falling), they were specific to the modulation of the pitch contour (static versus dynamic). In other words, training on static or dynamic pitch contours enhanced phase locking of the FFR to the corresponding contour. The studies by Song et al and Carcagno and Plack demonstrate that subcortical plasticity can be achieved with relatively few training sessions (8 to 10) and that the FFR training effects are specific to the stimulus being tested.[56,59]

As mentioned above, the FFR is a reliable measure, and it might therefore be used to evaluate training-induced changes in clinical populations, such as children with language-based learning impairments or older adults who experience communication difficulties. Compared to the MMN and other cortical responses that have good reliability but relatively large interindividual variability,[60] the FFR's temporal precision is such that fractions of milliseconds can be clinically significant.[61,62] Nevertheless, more work is needed to establish that the FFR can be used in clinical diagnosis.

Earobics (Houghton Mifflin Harcourt Learning Technology, Boston, MA) is commonly recommended to treat auditory processing disorders in children with reading or language impairments. After 40 hours of Earobics training over an 8-week period, the FFRs of children with dyslexia are less degraded by the effects of noise. This is an especially important finding given the observation that children with dyslexia have more difficulty understanding speech in noise than children with normal learning abilities.[63,64]

TRAINING BENEFITS IN OLDER ADULTS

One might expect that the neural mechanisms responsible for auditory learning might be more malleable in children than in adults; so is it possible to observe these same training effects in older adults? A cross-species study was conducted in older rats and humans using adaptive cognitive training to reduce distractibility.[65] Cortical evoked responses to distracters were selectively reduced in both species, paralleling improvements in behavioral performance. Another study with older rats demonstrated that auditory training improved synchronization of auditory cortical responses to pulsed noise trains.[66] Therefore, one might expect that auditory training also would improve neural encoding of speech signals in older human adults. Anderson and colleagues used an auditory-based cognitive program to assess subcortical plasticity in older adults (ages 55 to 70).[67] FFRs were recorded to the speech syllable /da/ presented in quiet and in noise. The training group underwent an 8-week training program (Brain Fitness, Posit Science, Corp., San Francisco, CA) that was designed to improve speed and accuracy of auditory processing by adaptively expanding and contracting consonant–vowel transitions in different speech contexts. The FFR peak latencies were earlier and interpeak variability was reduced in the noise condition in the auditory training group, but no changes were noted in the active control group (Fig. 2). Similar to the Earobics study of training effects in children with dyslexia, measures of noise degradation also improved in the trained group, indicating that responses were more resistant to the deleterious effects of noise. Behavioral measures of speech-in-noise performance (Quick Speech-in-Noise test),[68] short-term memory (Memory for Words subtest of the Woodcock Johnson III Test of Cognitive Abilities),[69] and speed of processing (Visual Matching subtest of the Woodcock Johnson III Test of Cognitive Abilities) were administered to the participants and improvements on all three measures were noted in the training group but not the control group. This study demonstrates that age-related neural timing and speech perception deficits may be at least partially ameliorated with training and that training benefits can be documented with electrophysiology.

The study described above focused on older adults who had hearing levels ranging from normal to mild to moderate hearing loss. A follow-up study investigated training effects on the FFR in older listeners (ages 55 to 79) with and without hearing loss.[17] In particular, subcortical representation of two components of the speech signal, the temporal envelope and temporal fine structure, were evaluated before and after training. Prior to training, it was found that older listeners with hearing loss showed exaggerated representation of the temporal envelope and reduced representation of the temporal fine structure when compared to normal-hearing listeners for both conditions. Following training, there was a significant reduction in envelope encoding in the listeners with hearing loss to the extent that differences in envelope representation between individuals with and without hearing loss were eliminated. This reduction was not seen in normal-hearing listeners or in the active controls (Fig. 3). These studies suggest that home-based computerized auditory training can enhance central processing and partially restore age- and hearing-related changes in auditory function. Therefore, auditory training should be considered in the rehabilitative plan and the FFR can be used as a method to assess treatment efficacy.

MAXIMIZING TRAINING BENEFITS

It is important to consider the subject factors that maximize training improvements. For

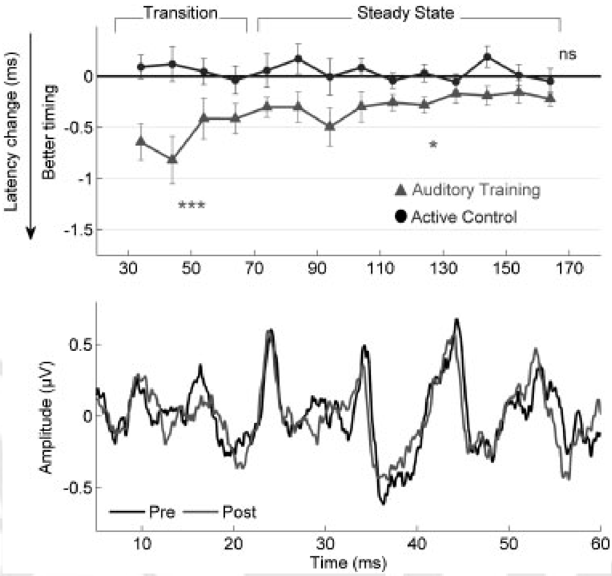

Figure 2 Frequency following response (FFR) training effects in older adults. (Top panel) Training decreased peak latencies of the FFR recorded to a speech syllable in noise, especially for the consonant–vowel transition region. These effects were not seen in the active control group. (Bottom panel) FFR waveforms demonstrating earlier peak latencies after training in an individual participant $^{*}p < 0.05$, $^{***}p < 0.001$. (Adapted from Anderson et al. *Proc Natl Acad Sci* 2013.[67])

example, sleep plays an important role in consolidation of sensory and motor learning, including training that involves learning new auditory skills.[70] The role of sleep in auditory learning was recently demonstrated in a concurrent vowel identification task using magnetoencephalography.[71] The authors evaluated training effects on the P2 component of the response waveform. The P2 component increases in amplitude with training and/or exposure to auditory stimuli and a night's sleep may further increase P2 amplitude.[72] They compared training that took place during sessions that were separated by 12 hours, but in one group the practice sessions were scheduled in the morning and evening of the same day, and in the other group the practice sessions were scheduled in the evening and the morning of the next day. In this way, they were able to compare training effects that were matched for passage of time between sessions. Although they found that participants' response times on the training task decreased after each session, the P2 amplitude increase was only observed after a night of sleep. They concluded that the P2 enhancement may reflect changes associated with repeated exposure and greater familiarity with the stimulus that requires a sleep-dependent consolidation stage. This study demonstrates that training should take into account the sleep schedule—this is an especially important issue in older adults who often find it difficult to get a full night's sleep.

Another consideration is the maintenance of training gains. It is probably not reasonable to assume that training effects last indefinitely, especially in an older population. As a follow-up of their original study, Anderson et al investigated maintenance of the auditory training effects on timing and behavioral measures.[73] Both groups of participants, those who underwent 8 weeks of Brain Fitness training and the active controls, returned for repeat testing after 6 months. In the training group, the improvement in peak latency was partially maintained—the reduction in peak latencies was still present in the FFR to a speech syllable presented in noise. In addition, there was no change in the interpeak variability from the post-8-week to post-6-month sessions in the training group. On the behavioral measures, the improvement in speed of processing was maintained, but the

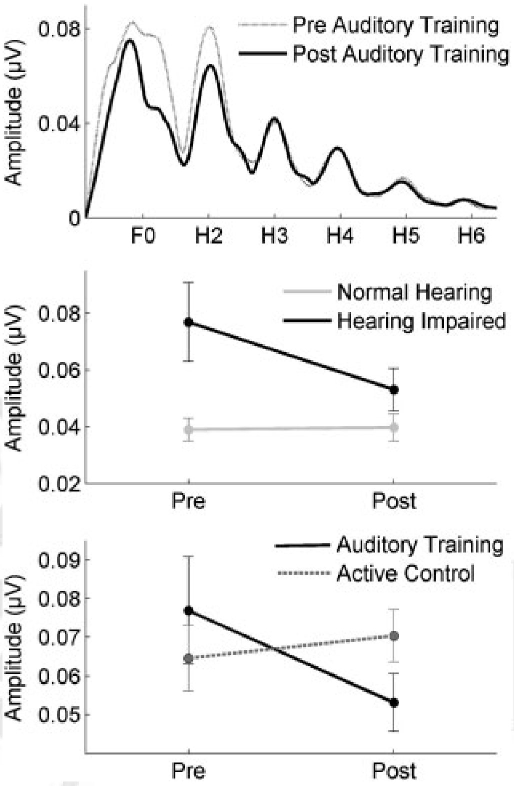

Figure 3 Training effects on older adults with hearing loss. (Top panel) Spectral amplitudes of the envelope (the fundamental frequency [F_0] and second harmonic) are reduced after 8 weeks of training. (Middle panel) Exaggerated envelope representation (amplitude of the F_0) in individuals with hearing loss reduces to levels equivalent to those of individuals with normal hearing. (Bottom panel) Training-induced changes in F_0 amplitude are seen in the auditory training group but not the active control group. (Adapted from Anderson et al. *Front Syst Neurosci* 2013.[17])

Quick Speech-in-Noise test and short-term memory scores were not significantly different from the scores obtained at the pretest session (Fig. 4). The fact that training benefits for speech perception in noise were not maintained for 6 months after cessation of training does not mean that training does not work. It does suggest, however, that a schedule of booster sessions is needed.

Compliance with continued participation is more likely if the training program is intrinsically reinforcing.[74] To address this issue, recent studies have incorporated video games into their training paradigms. A three-dimensional adaptive racing car program was used to assess and train multitasking performance in older adults.[75] After 1 month of training (1 hour, 3 times per week), multitasking performance improved and was maintained for 6 months. External measures of working memory and sustained attention also improved after training. These improvements were accompanied by an increase in visually evoked cortical activity in areas associated with working memory and attention, and these changes were not seen in the active or passive control groups. Video game training also may enhance speech-in-noise performance. A cross-species study compared training effects in young adult humans and mice on detection of tonal signals in noise.[76] The humans and mice were both trained on a foraging task involving the use of dynamic auditory cues to locate hidden targets; the humans used a game pad to control an avatar while the mice were trained in a physical behavior arena. Improvement on this task generalized to recognition of sentences in babble noise. Electrophysiology was not assessed in the

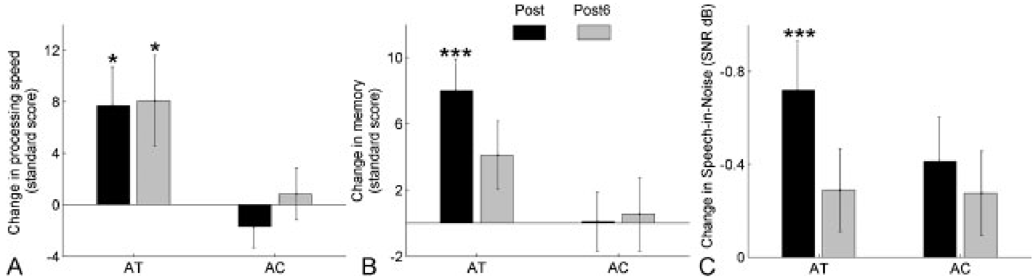

Figure 4 Training benefits persist for processing speed but not for short-term memory or speech-in-noise performance. (A) The change in processing speed noted after 8 weeks of training is still present after 6 months in the auditory training (AT), whereas no changes were noted at either time point in the active control (AC) group. (B, C) The robust improvements in memory (B) and speech-in-noise performance (C) noted at 8 weeks were no longer present after 6 months. (Adapted from Anderson et al. *Neuropsychologia* 2014.)

humans, but in mice, cortical encoding of the low-level tones was enhanced and responses were more resistant to noise degradation. A similar adaptive videogame may provide enhanced training benefits in older adults,[75] but other training types that may be appealing to older adults should be considered, such as music or word games.[36]

CONCLUSIONS

The speech perception difficulties experienced by older adults are not solely attributed to peripheral deficits, but rather a combination of audibility of acoustic stimuli, higher-order neural processing within the central auditory system, and cognitive function play a role in perceptual abilities. Hearing aids do not currently address age-related declines in temporal processing, tonotopic reorganization, or other central changes. Therefore, it is important to consider options that address communication deficits that may arise from impaired central auditory processing. The plasticity of the central auditory nervous system continues into older adulthood, suggesting that auditory training may play a role in the therapeutic remediation of older adults with speech perception deficits. Auditory training improves neural encoding of speech signals in noise, and these improvements are associated with enhanced abilities in behavioral speech performance measures. These benefits can be objectively measured using both subcortical and cortical electrophysiologic methods. The FFR may be a particularly effective clinical tool because of its reliability. Future research should investigate the specific aspects of training that are most effective for inducing long-lasting changes in speech-in-noise processing. In addition, electrophysiologic assessment may be used to document the additional benefits that can be realized by adding auditory training to the management protocol for new hearing aid users.

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