Effects of Amplification on Brain Plasticity

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Eight Annual Conference
21 October 2016
A short history of the brain

http://www.pbs.org/wnet/brain/history/index.html
The first known writing on the brain is found in ancient Sumerian records from this period. Writer describes the euphoric mind-altering sensations caused by ingesting the common poppy plant.
2500 B.C.

- The ancient Egyptians believed that the heart is the most important organ in the body.
  - They discard the brain during embalming process even as they preserve other organs for mummification.
• Trapanation, a form of primitive brain surgery was widely practiced by primitive man
  – Involved boring a hole through the skull for spiritual, magical, and medical reasons (headaches, epilepsy, mental illness)
Aristotle states that the organ of thought and sensation is the heart and the brain is merely a radiator designed to cool it.

- The basis for thought, the “rational soul”, is immaterial and can not be found anywhere within the body.
Galen, a physician to the Roman gladiators, proposes that the brain is a glandular organ that contains four vital fluids or humors – blood, phlegm, choler and black bile.

- The important mental faculties (memory, emotion, the senses and cognition) are situated in the ventricles of the brain.
1100 - 1500

- Brain studies cease during the middle ages due to a church prohibition against human dissection and the study of anatomy
  - Primitive brain surgery is still performed by enterprising barbers who roam the countryside offering to remove the “stone of madness” from the skulls of the mentally ill
Anrdeas Vesalius, a Renaissance anatomist, publishes De humani corporis fabrica (On the Workings of the Human Body)

- Lavishly illustrated, it contains major sections on the workings of the nerves and the brain
Thomas Willis, a professor at Oxford, writes the first monograph on brain anatomy and physiology, *Cerebri Anatome*

- He states that the cerebral hemispheres, which constitute 70% of the human brain, determine thought and action and are completely separate from the part of the brain that controls basic motor functions like walking.
Hanz Joseph Gall, a German anatomist, founds the study of phrenology, which holds that a person’s character and personality can be discerned by reading the configuration of bumps on his head.

One of the basic premises of phrenology is that the larger a particular convolution in a person's brain the greater the role that particular personality attribute will play in his character.
Charles Bell, a Scottish surgeon, establishes that the nerves for each of the senses can be traced from specific areas of the brain to their end organ. He also demonstrates that motor and sensory functions are anatomically separated in the spinal roots.
Paul Brocca, a neurological clinician and researcher, determines the location of the speech center of the brain.

- He pinpoints the site of the speech center of the brain as being in the third gyrus of the prefrontal cortex. This section of the frontal lobe is now known as Broca's area.
1872

- Charles Darwin adds to the study of human psychology with the publication of, the Expression of the Emotions in Man and Animals
  - He carefully traces the origins of emotional responses and facial expressions in humans and animals, making note of the striking similarities between species
Emil Kraepelin, a practicing psychiatrist, is the first to describe manic depression as a separate illness from schizophrenia.

He also introduces the terms neurosis and psychosis into the modern vocabulary.
• Sigmund Freud publishes his groundbreaking work, The Interpretation of Dreams
  – Through psychoanalysis or "dreamwork," a patient is able to uncover the unconscious wishes or motives that lie behind a particular dream and so gain a greater understanding of himself
20th Century

• 1921: Herman Rorschach develops the ink blot test
• 1929: Hans Berger demonstrates the first EEG
• 1934: Egas Moniz pioneers prefrontal lobotomy
• 1938: Albert Hofmann synthesizes LSD
• 1953: N. Kleitman and E. Aserinsky describe REM
• 1961: G. Von Bekesy wins Nobel for work on the cochlea
1974: Development of PET scan
1987: Prozac is introduced
1990: President George H. Bush declares the 90s The Decade of the Brain
21st Century

- Brain-Computer Interfaces
- Deep brain stimulation
- Transcranial magnetic stimulation
- Advanced neuroimaging imaging techniques
  - Functional MRI (fMRI)
  - Diffusion Tensor Imaging (DTI)
  - MRI Spectroscopy (MRS)
  - Image Fusion
- The Plastic Brain
The auditory brain
The audio-visual brain
When things go wrong

6-Week Old Baby
"Normal" brain

6-Week Old Baby
"Fetal Alcohol Syndrome" brain

Alcoholic
Darker Colouring indicates depressed brain activity

Normal
Healthy levels of brain activity
Aging and Growing Older
Consequences of aging on speech perception

- Audibility
- Intelligibility
- Stream segregation (Attention)
- Speed of processing
- Temporal processing (e.g. gap detection, voice-onset time)
- Working memory
Consequences of compromised speech perception

- Withdrawal
- Reduced QoL
- Depression
- Isolation
- Cognitive decline
- Dementia(?)
Can we train the Brain?

• Evidence from musicians
  – Nina Kraus et al, Northwestern University
    • http://www.soc.northwestern.edu/brainvolts/slideshows/music/index.php
Musicians have better neural encoding of music...

...and also speech!

Musicians have more accurate neural tracking of linguistic pitch

Musicians have selective enhancements of complex aspects of vocal communication

implications for processing emotion in speech

Strait, Kraus, Skoe, Ashley (2009) Eur J Neurosci
Musicians’ stronger speech-sound processing builds up across the life span.

Neural responses to speech

Parbery-Clark et al. (2012) Front Aging Neurosci
Parbery-Clark et al. (2009) J Neurosci
Strait et al. (2009) Brain & Language
Strait et al. (2013) Dev Cog Neurosci; Cerebral Cortex

Musicians have stronger auditory cognitive skills across the life span. Strengthened auditory cognitive functions may contribute to stronger speech-sound processing.
Musicians across the life span are better at hearing speech in noise...

...and get better with increased music practice

Musicians’ neural responses across the life span are less degraded by noise

A single year of music training can reduce the effects of noise on the brain

Binaural hearing is enhanced in musicians and may account, in part, for musicians’ superior listening in noise abilities
Hearing in noise is difficult for everyone, and becomes particularly difficult as we age.

But... older adult **musicians** have superior hearing in noise & auditory cognitive skills – even **musicians with hearing loss**.
Musicians do not experience slowing of neural timing with aging.

Parbery-Clark, et al. (2012) Neurobiology of Aging;
Parbery-Clark et al. (2013) Frontiers in Aging Neuroscience
Neural responses to complex sounds demonstration

The Singing and Speaking Brain

SOUNDWAVES & BRAINWAVES

www.brainvolts.northwestern.edu
The more you play, the more you profit

- Attention
- Working memory
- Hearing speech in noise
- Neural speech-sound processing

...across the lifespan!

Reviewed in: Strait and Kraus (2013) Hear Res
How about non-musicians?

**QUESTION**
Can aging-related declines in the nervous system be reversed?

We randomly assigned older adults to a complete training or a control activity for 8 weeks and assessed changes in auditory processing.

**WE TEST:**
- Neural responses to speech
- Speech perception
- Cognitive skills

**8 weeks**

Audio training
Active control

Anderson, White-Schwoch, Parbery-Clark & Kraus (2013) PNAS

http://www.soc.northwestern.edu/brainvolts/slideshows/aging/index.php
Training improves hearing in noise and cognitive skills

- **Hearing in Noise**
  - Before training
  - After training
  - Better

- **Memory**
  - Before training
  - After training
  - Better

- **Processing Speed**
  - Before training
  - After training
  - Better

Training group
No training

Anderson, White-Schwoch, Parbery-Clark & Kraus (2013) PNAS
Figure 5. Pre- and post-training grand mean waveforms measured from electrode Cz. Pretraining waveforms are thin. Post-training waveforms are thick. As subjects learned to identify the difference between the -20 and -10 msec VOT stimuli, N1-P2 peak-to-peak amplitude increased.
OK...

• So, the auditory nervous system appears to be altered in response to environmental changes (i.e. “Auditory Plasticity”)
  – Musical training
  – Specific auditory feature-based training
• But what about hearing aids?
Hearing aids and plasticity

Reorganization of the Adult Auditory System: Perceptual and Physiological Evidence From Monaural Fitting of Hearing Aids

Kevin J. Munro, PhD

Changes in the sensory environment modify our sensory experience and may result in experience-related or learning-induced reorganization within the central nervous system. Hearing aids change the sensory environment by stimulating a deprived auditory system; therefore, they may be capable of inducing changes within the central auditory system. Examples of studies that have shown hearing aid induced perceptual and/or physiological changes in the adult human auditory system are discussed. Evidence in the perceptual domain is provided by studies that have investigated (a) speech perception, (b) intensity discrimination, and (c) loudness perception. Evidence in the physiological domain is provided by studies that have investigated acoustic reflex thresholds and event-related potentials. Despite the controversy in the literature concerning the rate, extent, and clinical significance of the acclimatization effect, there is irrefutable evidence that the deprived auditory system of some listeners can be modified with hearing aid experience.

Keywords: reorganization; plasticity; hearing aids; acclimatization; auditory deprivation

Hearing Aid–Induced Plasticity in the Auditory System of Older Adults: Evidence From Speech Perception

Limor Lavie, Karen Banai, Avi Karni, and Joseph Attias

Purpose: We tested whether using hearing aids can improve unaided performance in speech perception tasks in older adults with hearing impairment.

Method: Unaided performance was evaluated in dichotic listening and speech-in-noise tests in 47 older adults with hearing impairment; 36 participants in 3 study groups were tested before hearing aid fitting and after 4, 8, and 14 weeks of hearing-aid use. The remaining 11 participants served as a control group and were similarly evaluated but were not fitted with hearing aids. Three protocols were compared in the study groups: amplification for the nondominant ear, amplification for the dominant ear, and bilateral amplification. Subsequently, after 4 weeks, all participants were afforded bilateral amplification.

Results: In the study groups, unaided dichotic listening scores improved significantly in the nondominant ear by 8 weeks and onward. Significant improvements were also observed for unaided speech identification in noise, with some gains apparent after 4 weeks of hearing-aid use. No gains were observed in the control group.

Conclusions: Using hearing aids for a relatively short period can induce changes in the way older adults process auditory inputs in perceptual tasks such as speech identification in noise and dichotic listening. These changes suggest that the central auditory system of older adults retains the potential for behaviorally relevant plasticity.

Hearing aids and plasticity

• Hearing aids appear to alter the auditory nervous system, usually for the better
• So, are we done?
Not quite...

- Our patients still report difficulty understanding in less than optimum environments
### Top-3 Box Satisfaction

small samples in some cells – use caution

<table>
<thead>
<tr>
<th>Activity</th>
<th>Owners:</th>
<th>Non-Owners:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HA &lt;= 5 years</td>
<td>HA 6+ years</td>
</tr>
<tr>
<td></td>
<td>(n=769)</td>
<td>(n=112)</td>
</tr>
<tr>
<td>Overall, across all listening situations</td>
<td>80%</td>
<td>67%</td>
</tr>
<tr>
<td>In conversations with 1 person</td>
<td>88%</td>
<td>70%</td>
</tr>
<tr>
<td>In the workplace</td>
<td>83%</td>
<td>70%</td>
</tr>
<tr>
<td>At home with family members</td>
<td>82%</td>
<td>74%</td>
</tr>
<tr>
<td>In conversations with small groups</td>
<td>81%</td>
<td>67%</td>
</tr>
<tr>
<td>When listening to music</td>
<td>80%</td>
<td>69%</td>
</tr>
<tr>
<td>When watching TV with others</td>
<td>79%</td>
<td>68%</td>
</tr>
<tr>
<td>During leisure activities (e.g., exercising, taking a walk, etc.)</td>
<td>78%</td>
<td>66%</td>
</tr>
<tr>
<td>Outdoors</td>
<td>78%</td>
<td>65%</td>
</tr>
<tr>
<td>In a store, when shopping</td>
<td>76%</td>
<td>62%</td>
</tr>
<tr>
<td>At a movie theater</td>
<td>75%</td>
<td>70%</td>
</tr>
<tr>
<td>When riding in a car</td>
<td>75%</td>
<td>69%</td>
</tr>
<tr>
<td>In a larger lecture hall (e.g., theater, concert hall, place of worship, etc.)</td>
<td>73%</td>
<td>59%</td>
</tr>
<tr>
<td>When talking to children</td>
<td>72%</td>
<td>67%</td>
</tr>
<tr>
<td>In conversations with large groups</td>
<td>71%</td>
<td>57%</td>
</tr>
<tr>
<td>When talking on a cell phone</td>
<td>70%</td>
<td>59%</td>
</tr>
<tr>
<td>When talking on a traditional telephone</td>
<td>69%</td>
<td>50%</td>
</tr>
<tr>
<td>In a classroom (as observer or student)</td>
<td>68%</td>
<td>58%</td>
</tr>
<tr>
<td>When trying to follow conversations in the presence of noise (e.g., restaurant, etc.)</td>
<td>67% ✓</td>
<td>50% ✓</td>
</tr>
</tbody>
</table>
Training-induced plasticity

QUESTION
Can aging-related declines in the nervous system be reversed?

We randomly assigned older adults to a complete training or a control activity for 8 weeks and assessed changes in auditory processing.

WE TEST:
- Neural responses to speech
- Speech perception
- Cognitive skills

Auditory training

Active control

8 weeks

WE TEST:
- Neural responses to speech
- Speech perception
- Cognitive skills

Anderson, White-Schwart, Parbery-Clark & Kraus (2013) PNAS

http://www.soc.northwestern.edu/brainvolts/slideshows/aging/index.php
Training improves hearing in noise and cognitive skills

**HEARING IN NOISE**
- Before training: low performance
- After training: improved performance

**MEMORY**
- Before training: moderate performance
- After training: improved performance

**PROCESSING SPEED**
- Before training: low performance
- After training: improved performance

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Image: Elderly person using a laptop.

Anderson, White-Schwoch, Parbery-Clark & Kraus (2013) PNAS
What's available commercially?

- LACE
- Brain HQ
- Lumosity
- ReadMyQuips
Gamification

• The concept of applying game mechanics and game design techniques to engage and motivate people to achieve their goals
• Gamification taps into the basic desires and needs of the users impulses which revolve around the idea of Status and Achievement

https://badgeville.com/wiki/Gamification
My Brain Progress

Train your brain with the BrainHQ exercises and watch your brain bloom. How does my brain fitness compare to others?

Next Steps

To continue your brain training, click on Attention or Brain Speed at left, then choose one of the free exercises.
Challenge your brain with scientifically designed training

Build your Personalized Training Program
- Train memory and attention
- Web-based personalized training program
- Track your progress

Get Started Now ➔

Lumosity is a leader in the science of brain training

Prestigious research network
We collaborate with researchers from 36 top universities around the world in an effort known as the Human Cognition Project. Dozens of collaborations are underway.

7 published studies
Since 2007, 7 studies have been published on the effects of Lumosity in diverse populations including healthy adults, children, and cancer survivors.

Scientifically designed games
Lumosity scientists study many common neuropsychological tasks, design new ones, and transform these tasks into fun, challenging games.
Do Brain Games Work? Science Isn’t Sure

For a $14.95 monthly membership, the website Lumosity promises to “train” your brain with games designed to stave off mental decline. Users view a quick succession of bird images and numbers to test attention span, for instance, or match increasingly complex tile patterns to challenge memory.

While Lumosity is perhaps the best known of the brain-game websites, with 50 million subscribers in 180 countries, the cognitive training business is booming. Happy Neuron of Mountain View, Calif., promises “brain fitness for life.” CogniFit, owned by the British education company Pearson, says its training program will give students “improved attention and capacity for learning.” The Israeli firm NeuroVonix is developing a brain stimulation and cognitive training program that the company calls a “new hope for Alzheimer’s disease.”
Conceived by leading audiologists at the University of California at San Francisco and implemented by silicon valley software veterans, LACE® Auditory Training programs retrain the brain to comprehend speech up to 40% better in difficult listening situations such as:

🌟 Noisy Restaurants
🌟 Rapid speakers
🌟 Competing speakers

Just as physical therapy can help rebuild muscles and adjust movements to compensate for physical weakness or injury, LACE will help you develop skills and strategies to deal with situations when hearing is inadequate.
One of the most exciting innovations in speech comprehension

"Train Your Brain" and Understand Again!

A busy restaurant, a crowded family gathering, a noisy doctor's office—have you given up on hearing in places like these? Does it seem like there's no way to understand your friends when they speak in a noisy environment?

There is! When you train your eyes, ears and brain to work together, you'll be amazed at how much you can understand speech in the loudest of surroundings. ReadMyQuips™, the new audio-visual home training system, teaches you how!

ReadMyQuips™ can help you understand. And best of all, it's designed to be both entertaining and effective!

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For the Hearing Impaired
Find out more about the holistic approach of ReadMyQuips™. Have fun while you “train your brain” to understand speech in even the noisiest situations!

For Hearing Professionals
Home training is the perfect complement to traditional aural rehabilitation. Learn more about how adding ReadMyQuips™ to your practice can benefit you and your patients.
The evidence

- **LACE**

- **ReadMyQuips**
LACE (Sweetow & Henderson-Sabes, 2007)

Figure 2. Mean improvement on training task scores for each quarter of the training relative to the first quarter of training, for all subjects completing Listening and Communication Enhancement (LACE) training. (A) Group mean change on speech in babble performance. A decrease in decibels of signal-to-noise ratio (dB SNR) score indicates improvement. (B) Group mean improvement on speech with a competing speaker performance. A decrease in dB SNR score indicates improvement. (C) Group mean improvement on time-compressed speech performance. A decrease in score indicates improvement. (D) Group mean improvement on auditory memory performance. An increase in score indicates improvement. Error bars indicate 95% confidence interval of the mean.
The Effect of LACE DVD Training in New and Experienced Hearing Aid Users

DOI: 10.3760/joas.24.3.7

Anna D. Olson
Jill E. Preston
Jennifer B. Shain

Abstract

Background: Numerous studies have demonstrated that improving the ability to understand speech in noise can be a difficult task for adults with hearing loss (HL). The aim was to improve their speech understanding ability, specific training may be needed. Auditory training (AT) is one type of intervention that may enhance speech recognition abilities for adults with HL.

Purpose: The purpose of this study was to examine the behavioral effects of an AT program called Listening and Communication Enhancement (LACE) on the DVD format in new and experienced HA users. While some research has been conducted using the computer version of this program, no research to date has been conducted on the efficacy of the DVD version of the LACE training program in both new and experienced HA users.

Research Design: An experimental pretest posttest control group design with random assignment.

Study Sample: Twenty-nine adults with hearing loss were assigned to one of three groups: new HA users, experienced HA users plus training, or control (new HA users with no training during the study but provided with training afterward). New HA users were randomly assigned to either the training or control group.

Interventions: Participants in the training groups completed twenty 30-min training lessons from the LACE DVD program at home over a period of 8 wk.

Data Collection: Participants in both training groups were evaluated at baseline, after 8 wk of training, and again after 8 wk of no treatment. General cognitive training measures were administered including speech in noise, story recall, and sentence generation tasks. Subjective measures included evaluating the participant perception of the intervention and their perceptions of functional hearing abilities.

Results: Findings indicate that both new and experienced users improved their understanding of speech in noise, understanding of competing sentences, and communication function after training in comparison to a control group. Effect size calculations suggested that a larger training effect was observed for new HA users compared to experienced HA users. New HA users also reported greater benefit from training compared to experienced users. AT with the LACE DVD format should be encouraged, particularly among new HA users, to improve understanding in difficult listening conditions.

Key Words: Auditory training, hearing aid, hearing aid, ICA-N = International Outcome Inventory-Attackive Attitude Intervention; OA-HA = Outcome Inventory-Hearing Aid; LACE = Listening and Communication Enhancement; MCR = message comprehension scale; NAL-NL1 = National Acoustic Laboratories—Linear 1; QuickSPE = Quick Speech in Noise; SSQ = Synthetic Sentence Identification; SSQ = Speech, Spatial and Qualities of Hearing Scale

*Department of Rehabilitation Sciences, University of Kentucky, Department of Surgery, University of Louisville, Department of Otolaryngology Head and Neck Surgery, University of Kentucky

Anna D. Olson, 301 S. Limestone #121, Department of Rehabilitation Sciences, University of Kentucky, Lexington, KY 40536. 918-382-2286.

Further details of this article were presented at the Academy of Rehabilitation, Annual Meeting, September 2019, San Francisco, CA. (http://www.arcf.org). April 2019, Chicago, IL.
LACE (Olson, Preminger & Shinn, 2013)

**Figure 1.** Mean scores for QuickSIN (dB SNR) (error bars – 95% CI) at baseline, after 2 wk, and after 4 wk of training for training and control groups. Lower scores represent better ability to understand speech in noise.

**Figure 2.** Within group effect sizes (Cohen’s d) over time based on QuickSIN test. Larger training effects are seen for new HA users.
A Randomized Control Trial: Supplementing Hearing Aid Use with Listening and Communication Enhancement (LACE) Auditory Training

Gabrielle H. Saunders, Sherri L. Smith, Theresa H. Chisolm, Melissa T. Frederick, Rachel A. McArdle, and Richard H. Wilson

Objective: To examine the effectiveness of the Listening and Communication Enhancement (LACE) program as a supplement to standard-of-care hearing aid intervention in a Vietnam population.

Design: A multi-site randomized controlled trial was conducted to compare outcomes following standard-of-care hearing aid intervention supplemented with (1) LACE training using the 10-Session computer-based format, (2) placebo auditory training (PT) consisting of activities listening to 10hr of digitized books on a computer; and (3) educational counseling— the control group. The study involved 398 adult and elderly 227 veterans. Birth year and baseline hearing aid users participated to determine if outcomes differed as a function of hearing aid use status. Data for five behavioral and two self-report measures were collected during three sessions: baseline, immediately following the intervention period, and 6 months postintervention. The five behavioral measures selected to determine whether the perceptual and cognitive skills targeted in LACE training generalized to untimed tasks that required similar underlying skills.

Results: The authors report statistically significant main effects or interactions were found for the use of LACE on any outcome measure.

Conclusions: Findings from this randomized controlled trial show that LACE training does not result in improved outcomes over standard-of-care hearing aid intervention alone. Potential benefits of AT may be different from those associated with the performance of self-assessment and self-report measures utilized here. Individual differences not assessed in this study should be examined to evaluate whether AT with LACE has any benefits for particular individuals. Clinically, these findings suggest that audiologists may want to temper the expectations of their patients who embark on LACE training.

Key words: Auditory perception, Auditory training, Hearing, Hearing aids, Hearing rehabilitation, Neuropsychology

INTRODUCTION

Despite significant advances in hearing aid technology, only about 14% of individuals >50 years old who might benefit from hearing aids use them (Chen & Lin 2012). Furthermore, there is wide individual variation in treatment outcome among those using amplification (Humes 2013). One approach to improving hearing aid outcomes is the provision of auditory training (AT), or systematic listening practice, aimed at maximizing the use of an individual’s residual hearing. AT relies on the assumption that in the brain can reorganize and restructure following, for example, training or changes in sensory input (Krasr et al. 1995; Ramachandran 2005; Rentz-Lorenz & Lutg 2005). The possibility that an adult with hearing loss could be “trained” or “exercised” to use bottom-up and top-down auditory processing skills is noted in the recognition that (1) hearing aids cannot restore the auditory system to normal, (2) hearing and processed signals differ accessibility from unprocessed signals, and (3) the auditory system of a patient acquiring hearing aids likely has been deprived of normal auditory input for several years.

Although there are data demonstrating that AT can result in improvements in the understanding of speech-in-noise (see Swanson & Palmer 2005; Chabris & Arnold 2012 for reviews), AT is not commonly recommended to adults with hearing loss. This may in part be due to limited reimbursement for adult audiologic rehabilitation as well as the concurrent time, resource, and cost constraints associated with clinician-driven intervention models. One approach to addressing these limitations is the use of computer-based training (CBT). A number of computer-based training programs exist, such as CasperSoft (Boulby 2000), the Fragment and Word auditory training protocol (Humes et al. 2009), Listening and Communication Enhancement (LACE) (Sprowl & Saites 2006), and Speech Perception Assessment and Training System (Attiler et al. 2007). Although these programs differ in the specific skills trained, they are similar in terms of the underlying training principles, which include adaptive algorithms that maximize learning difficulty at a level near the upper limits of the user’s auditory ability, the provision of feedback to promote learning, “rewards” to increase motivation, and the expectation that the user will train without daily effort over several weeks. A fundamental assumption of any AT program is that the skills learned within the program will “generalize” or “transfer” to untrained stimuli and to everyday listening situations.
Fig. 2. Boxplot for WIN scores by visit for each intervention user group separately. The median value is shown by the solid horizontal line with the lower and upper ends of the box showing the 25th and 75th percentiles, respectively, and the upper and lower ends of the whisker indicating the range of values within 1.5 times the interquartile range. Circles depict outliers that are >2 whisker lengths above or below the 75th or 25th percentiles, respectively. WIN indicates Words-in-Noise test.
Learning to Listen Again: The Role of Compliance in Auditory Training for Adults With Hearing Loss

Theresa Hnath-Chisolm, a,b Gabrielle H. Saunders, a Melissa T. Frederick, c
Rachel A. McArdle, a,b Sherri L. Smith, a,b and Richard H. Wilson a,b

Purpose: To examine the role of compliance in the outcomes of computer-based auditory training with the Listening and Communication Enhancement (LACE) program in Veterans using hearing aids.

Method: The authors examined available LACE training data for 5 tasks (i.e., speech-in-noise, time compression, competing speaker, auditory memory, and word detection) for 50 hearing aids used by participants who worked in a randomized controlled trial designed to examine the efficacy of LACE training. The goals were to determine: (a) whether there were changes in performance over 20 training sessions on trained tasks (i.e., on-task outcome); and (b) whether compliance, defined as completing all 20 sessions vs. noncompliance, defined as completing less than 20 sessions, influenced performance on parallel unttrained tasks (i.e., off-task outcomes).

Results: The majority, 84% of participants, completed 20 sessions, with maximum outcome occurring with at least 10 sessions of training for some tasks and up to 20 sessions of training for others. Comparison of baseline to posttest performance revealed statistically significant improvements for 17 of 7 off-task outcome measures (p < 0.05) in the compliant group and no change for the noncompliant group.

Conclusion: The high level of compliance found in this study may be attributable to the use of systematical and written instructions with telephone follow-up. Compliance, as expected, appears important for optimizing the outcomes of auditory training.

Key Words: auditory training, adults, LACE, hearing loss, compliance

The goal of auditory training (AT) is to increase the listener’s ability to compensate for degradation in the auditory signal due to internal (e.g., hearing loss) or external (e.g., noise) factors (Sweetow & Palmer, 2005). The development of several computer-based AT programs for adults provides potential opportunities for adults with hearing loss to engage in perceptual learning, which in turn may lead to better speech understanding and improved communication ability (Boothroyd, 2007; Sweetow & Sibes, 2007). Systematic reviews of the literature provide evidence that AT can lead to improvements, albeit modest, in speech understanding (Chisolm & Arnold, 2012; Sweetow & Palmer, 2005).

An important question regarding AT outcomes relates to compliance, or adherence, to the treatment regimen. For example, the commercially available Listening and Communication Enhancement (LACE) program consists of 20 sessions that are completed over 4 weeks. A review of the clinical records of 3000 patients using LACE revealed that only 30% completed 16 or more of the 20 training sessions (Sweetow & Sibes, 2010). The question arises as to whether individuals who complete LACE’s 20-session training protocol (i.e., compliers) have better outcomes than those who do not (i.e., noncompliers). Lack of compliance with nonmedication interventions in other areas of healthcare is strongly related to outcomes (e.g., Diamant, Giordani, Lopyr, & Coughlin, 2003). It is logical, therefore, to assume that this positive relation exists for LACE use. The present study examines the potential influence of compliance on outcomes of LACE training for adult hearing aid users.

References: Thes authors have declared that no competing interests existed at the time of publication.

DOI: 10.1044/1090-4432(2013)5-0801
One of the most exciting innovations in speech comprehension

"Train Your Brain" and Understand Again!

A busy restaurant, a crowded family gathering, a noisy doctor's office—have you given up on hearing in places like these? Does it seem like there's no way to understand your friends when they speak in a noisy environment?

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Home training is the perfect complement to traditional aural rehabilitation. Learn more about how adding ReadMyQuips™ to your practice can benefit you and your patients.
• Focused, internet-based program proposed to improve auditory-visual speech perception
  – Designed to improve ability to communicate in difficult listening environments
• AV training through games, puzzles, and videos
• Adaptive in difficulty and background noise levels
Acting is all about honesty. (George Burns)
Acting is all about honesty. (George Burns)
If you can fake that, you've got it made.

whose office plants have died

never learn anything from experience.
Can a Remotely Delivered Auditory Training Program Improve Speech-in-Noise Understanding?

Harvey B. Abrams, Kirsten Bock, and Ryan L. Irey

Purpose: The aims of this study were to determine if a remotely delivered, Internet-based auditory training (AT) program improved speech-in-noise understanding and if the number of hours spent engaging in the program influenced postintervention speech-in-noise understanding.

Method: Twenty-nine first-time hearing aid users were randomized into an AT group (hearing aids = 3 weeks remotely delivered, Internet-based auditory training program or a control group [hearing aids alone], the Hearing in Noise Test (Nilsson, Sad, & Sullivan, 1994) and the Words-in-Noise Test (Wilson, 2003) were administered to both groups at baseline = 1 week and immediately at the completion of the 3 weeks of auditory training.

Results: Speech-in-noise understanding improved for both groups at the completion of the study; however, there was not a statistically significant difference in postintervention improvement between the AT and control groups. Although the number of hours the participants engaged in the AT program was far fewer than prescribed, time on task influenced the postintervention Words-in-Noise but not Hearing in Noise Test scores.

Conclusions: Although remotely delivered, Internet-based AT programs represent an attractive alternative to resource-intensive, clinic-based interventions, their demonstrated efficacy continues to remain a challenge due in part to losses associated with compliance.

Abstract:

Unintended hearing loss has been found to have negative overall functioning and quality of life effects, such as cognitive and functional decline, social isolation, higher risk of falls, decreased social and emotional function, and communication decline (Kramer, Kapleyen, Kula, & Dreg, 2002; Lin et al., 2011; Tim, McCoy, & Wingfield, 2009; Ulman, Larson, Reis, Koppell, & Ducleur, 1980). Hearing aids are the primary intervention strategy for hearing loss, and despite impressive technological advancements and evidence of their effectiveness, only 54% of hearing aid users report being satisfied, with the remaining 46% reporting either dissatisfaction or having neutral feelings toward their hearing aids. One of the top reasons for dissatisfaction is a perceived lack of benefit, particularly in background noise (Kochkin, 2007). In order to overcome this dissatisfaction, patients may require additional postfitting audiological rehabilitation (AR) services, including auditory training (AT) designed to improve speech understanding in challenging listening situations (Swierotow & Henderson-Sobe, 2006). Research has supported the benefits of AT on speech perception (Cholesta & Arnold, 2012; Henslew & Ferguson, 2013; Kiers & Holmes, 1996; Olson, Preminger, & Shinn, 2013; Walden, Eridman, Montgomery, Schwartz, & Prosek, 1981).

Despite the potential benefit of AR, only 16% of audiologists report providing such services to their patients (Schow, Balsera, Smiley, & Whitcomb, 1993). Reasons for the small percentage of professionals offering these services include a perceived lack of adequate time or financial resources (Norman & Beyrer, 1999). Another barrier to the implementation of AR is a lack of patient acceptance and compliance (Swietow & Sobe, 2010); this could be addressed by providing AR remotely. The goal of remotely delivered computerized AT is to provide postfitting care that is effective, convenient, and accessible. One currently available program that appears to meet these criteria is ReadMyQuips (RMQ; http://www.strongeear.com/readmyquips). RMQ is an audiovisual (AV) adaptive training program delivered through the use of games, puzzles, and videos. There is no published research, however, that has examined the efficacy of RMQ for improving...
### Participants

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>PTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>65.6</td>
<td>M= 11</td>
<td>R: 32.33</td>
</tr>
<tr>
<td></td>
<td>F=4</td>
<td>L= 35.16</td>
</tr>
</tbody>
</table>

### Mean Audiogram (RMQ)

- Right ear
- Left ear

### Mean Audiogram (Ctrl)

- Right ear
- Left Ear

<table>
<thead>
<tr>
<th>Age</th>
<th>Gender</th>
<th>PTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>61.8</td>
<td>M= 6</td>
<td>36.16</td>
</tr>
<tr>
<td></td>
<td>F=8</td>
<td>36.87</td>
</tr>
</tbody>
</table>
Test Measures

- **Abbreviated Profile of Hearing Aid Benefit (APHAB)**
  - Questionnaire design to measure amount of trouble the patient is having with communication or noises in various everyday situations

- **Device-Oriented Subjective Outcome (DOSO)**
  - Questionnaire designed to measure hearing aid outcomes in a way that is relatively independent of wearer personality

- **Hearing-in-Noise Test (HINT)**
  - 25 ten sentence lists presented in speech-shaped noise presented in an eight speaker array

- **Words-in-Noise Test (WIN)**
  - 35 monosyllabic word lists presented at 0, 2, 4, 8, 12, 16, 20 and 24 dB SNR based on PTA

- **The System Usability Scale (SUS)**
  - Ten-item Likert scale of subjective assessments of program usability

- **Overall satisfaction/Likelihood to Recommend Questionnaire**
<table>
<thead>
<tr>
<th></th>
<th>Daily Use</th>
<th>% Directional</th>
<th>% Noise</th>
<th>%Speech in Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMQ</td>
<td>9.6 hours</td>
<td>19.16%</td>
<td>1.4 %</td>
<td>41.3%</td>
</tr>
<tr>
<td>CTRL</td>
<td>8.4 hours</td>
<td>17.6 %</td>
<td>1.2 %</td>
<td>41.2%</td>
</tr>
</tbody>
</table>
Observations

• Though remotely delivered AR is convenient, compliance to a program schedule may be problematic
  – “Internet user” has a wide range of meaning
  – Patients may need technological support

• Large variability in performance within groups
  – Suggests some individuals benefit much more than others
Neural Correlates of Selective Attention With Hearing Aid Use Followed by ReadMyQuips Auditory Training Program

Aparna Rao,1 Dania Rishiq,2 Luodi Yu,3 Yang Zhang,3,4 and Harvey Abrams3

Objectives: The objectives of this study were to investigate the effects of hearing aid use and the effectiveness of ReadMyQuips (RMQ), an auditory training program, on speech perception performance and auditory selective attention using electrophysiological measures. RMQ is an auditory training program designed to improve speech perception in everyday noisy listening environments.

Design: Participants were adults with mild to moderate hearing loss who were hearing aid users. After 4 weeks of hearing aid use, the experimental group completed RMQ training for 4 weeks, and the control group received training on noise reduction during the same period. Electrophysiological measures (ERP) were collected at baseline, post-training, and post-training to assess effects of hearing aid use and RMQ training. An oddball paradigm allowed testing of changes in P1 and P3 ERP in detection and target, respectively. Behavioral measures were also obtained while ERP were recorded from participants.

Results: After 4 weeks of hearing aid use, some but not all of the auditory selective attention task showed significant improvement compared to baseline. ERP measures in the auditory selective attention task showed significant changes related to training.

Conclusions: Auditory training was associated with a decrease in auditory attention in the auditory selective attention task. RMQ training led to improvements in speech perception in noise and improved listener confidence in the auditory selective attention task.

Keywords: Amplification, Auditory selective attention, Auditory training, RMQ, P1, P3, ReadMyQuips, Speech perception training

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INTRODUCTION

A fundamental issue in cognitive neuroscience research is to understand neural plasticity associated with age, experience, and pathologic conditions. Individuals with hearing loss reported interesting population to study because they commonly suffer compromised speech perception, particularly in noisy environments (Hickams & Tacker, 2007), leading to significant problems in verbal communication. Interventions designed to enhance speech perception in adults have included the design of hearing aids with advanced digital signal processing algorithms and the development of novel auditory training programs (Pichora-Fuller & Singh, 2006; Sweld & Sales, 2006, 2007; see reviews in Pichora-Fuller & Levin, 2012). Hearing aids primarily amplify sounds to compensate for loss of intelligibility, although new signal-processing algorithms also aim at extracting speech cues from background noise. Auditory training programs for adults enhance the plasticity of the neural system to enhance function in response to training (Humes & Moir, 1995; Anderson et al., 2013).

Traditional hearing aids compensate for loss of intelligibility by amplifying signals, causing new hearing aid users to report immediate improvement in communication function and reduced perception of handicap (Chowdhury et al., 2007). Continued use over a period of over two months leads to gradual improvements in signal detection because users use new sensory cues over time, a process called “accommodation” (Guthrie, 1992; Aulin et al., 1996). Despite gains through advances in signal-processing technology, hearing aid users report persistent problems in speech perception in the presence of noise relative to pretraining experience (Kochkin, 2007, 2010). Because amplification alone cannot compensate for listening difficulties, training has been proposed to enhance this skill in adults with hearing aids and cochlear implants (Booker, 2007, Moore & Am tyr, 2007). This is possible because the adult brain retains the positive features of plasticity, which refers to the ability to change in response to experience. Structural changes in the brain can be induced as a consequence of stimulation, training, and learning (Cookin & Weinberger, 1991; Recanzone et al., 1993). In addition to behavior- oriented approaches, imaging and electrophysiological techniques have been used to document these changes (Jinkins et al., 2001; see reviews in Tierney & Kranz, 2002).

Mechanisms of speech perception recruit both peripheral and central auditory functions (Pichora-Fuller & Singh, 2006; Boord, 2010). Perceptual factors include audibility and processing of the acoustic elements of speech, such as temporal cues, gap detection, and frequency discrimination. Cognitive abilities of attention, memory, and comprehension also play a crucial role in difficult listening situations. Thus, successful perception of speech signals involves a combination of bottom-up (sensoric) and top-down (cognitive) processes (Sweld & Sales, 2006; Fu & Galvin, 2007; Woods & Yund, 2007). Analytic or “bottom-up” processing emphasizes extracting stimulus-based cues, while synthetic or “top-down” training involves improving cognitive skills. The analytic approach targets the building blocks of speech and may involve discrimination or identification of phonemes or words. In contrast, the synthetic approach...
Selective Attention

• The ability to suppress irrelevant information and focus on relevant signals in the environment

• A cognitive skill of tremendous importance for everyday living and learning

• We hypothesized that participants trained with RMQ will show enhanced auditory selective attention measured using ERP components (P3b and P3a) and behavioral measures
Auditory ERP in Selective Attention

**ODDBALL**

- Easy Stimulus Discrimination

**THREE-STIMULUS**

- Difficult Stimulus Discrimination
- Distracter Stimulus

- **P3b**
  - Voluntary
  - Task relevant
  - Increases with cognitive effort & performance

- **P3a**
  - Involuntary
  - Task irrelevant
  - Increases with distractor salience

Polich, J. (2007)
Methodology

• Before HA fitting

Session 1: Pretest

• Four weeks after HA fitting

Session 2: HA posttest

Training (4 weeks)

Session 3: Training posttest

Dual Channel Task

ATTEND
TARGET
STANDARD

IGNORE
DISTRACTORS

Control group: Audiobooks

Experimental group: RMQ

Training + amplification

• Reduced P3a from pretest to training posttest found in both groups, indicating reduced distractor salience after hearing aid use (and training)

• Link between changes in d' and in P3b were found only in the experimental group, indicating relationship between listening performance and task-relevant attentional allocation strengthened by RMQ training
Behavioral-ERP Correlation

Fig 6. Correlations between change in $d'$ and mean amplitude of P3b at Pz for the experimental (A) and control groups (B) are shown here. Change was measured from before training to after training. Asterisks denote statistically significant values (*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$).
Can a Commercially Available Auditory Training Program Improve Audiovisual Speech Performance?

Dania Rishiqa, Aparna Raoa, Tess Koernerb, and Harvey Abramsde

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Design

• Randomized between-group, within-subjects design
• Experimental and control groups
• 12 participants in each group:
  • Experimental group (HA +RMQ)
    - 8 males.
    - Average age = 68 years (range 51 years to 84 years).
  • Control group (HA only)
    - 10 males.
    - Average age = 69 years (range 62 to 81 years).
Training protocol

• Read My Quips
  – 30 minutes per day
  – 5 days per week
  – 4 consecutive weeks

• All participants completed a written log
  – Tracked start time and end time
  – Difficulty level

• Control group participants did not receive any structured treatment
Outcomes measured using Multimodal Lexical Sentence Test for Adults (MLST-A)

- Developed by Dr. Karen Kirk and colleagues
- 12 equivalent lists
  - 24 sentences per list
- Seven to nine words per sentence
- Three key words per sentence
  - Scores could range from 0 to 3 per sentence
MLST-A

• Words controlled for lexical characteristics of frequency (how often words occur in a language) and density (number of phonemically similar words or lexical neighbors to target)
• Five male and five female talkers
• For this study, administered in AO and AV modes
• Presentation Level
  – 60 dB SPL
• Three signal-to-noise ratios (SNRs)
  – +5 dB
  – 0 dB
  – -5 dB
• Mode of presentation (AO vs AV) and SNR randomized for testing
Participants were tested at the time of hearing aid fitting, after four weeks of hearing aid use, and after four weeks of RMQ training.
Results
Randomized between-group, within-subjects repeated measures ANOVA - Main effects

<table>
<thead>
<tr>
<th>Main Effects</th>
<th>F-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test: 3 levels</td>
<td></td>
</tr>
<tr>
<td>Pretest vs. posttest 1 vs. posttest 2</td>
<td>F (2, 44) = 2.3, p = .12</td>
</tr>
<tr>
<td>Mode: 2 levels</td>
<td></td>
</tr>
<tr>
<td>AO vs. AV</td>
<td>F (1, 22) = 205, p &lt; .01</td>
</tr>
<tr>
<td>SNR: 3 levels</td>
<td></td>
</tr>
<tr>
<td>+5 dB, 0 dB, -5 dB</td>
<td>F (2, 44) = 520, p &lt; .01</td>
</tr>
<tr>
<td>Interactions</td>
<td>F values</td>
</tr>
<tr>
<td>--------------</td>
<td>----------</td>
</tr>
<tr>
<td>Test × SNR</td>
<td>F (4, 88) = 3.9, p &lt; .01</td>
</tr>
<tr>
<td>Mode × SNR</td>
<td>F (2, 44) = 8.2, p &lt; .01</td>
</tr>
</tbody>
</table>

**None of the interactions involving Group significant**
• **Interactions**
• **Mode × SNR**
  – AV scores always greater than AO scores
  – Scores at +5 dB SNR > scores at 0 dB SNR > scores at -5 dB SNR
Average Improvement with Visual Cues (Audiovisual - Auditory Only)
Some interesting findings, however...

Functionally-defined regions of interest (ROIs) identified through the functional localizer. The audiovisual ROI (red) contains voxels responsive to both auditory and visual words in the posterior STS. The auditory ROI (green) contains voxels responsive to auditory words within Heschl's gyrus. The visual ROI (yellow) contains voxels responsive to visual words within extrastriate lateral occipitotemporal cortex.
Summary

• The availability of visual speech cues improved speech perception (consistent with the literature)
• RMQ training did not improve audiovisual speech perception as measured using the MLST-A
  – Regardless of SNR and mode, changes were not seen
• Enhancement from visual cues varied significantly across subjects
  – One individual showed a difference of 45% with addition of visual cues at 0 dB SNR at posttest 1
**Discussion**

- Possible explanations for lack of AV benefit:
  - Training exposure was insufficient
  - Training not designed to achieve criterion level at various difficulty levels
  - Participants were advised to challenge themselves, but varied in their ability to do so
  - Participants were individuals with acquired hearing loss in the mild to severe range
    - They did not have to rely on visual cues and speechreading as much as individuals with congenital severe profound hearing loss
Overall Summary

- Compliance matters
  - Even in closely controlled research protocols, compliance was a challenge
  - Clinicians must carefully monitor patient compliance
  - AT must be engaging for the patients
    - Create meaningful reward incentives
Lessons Learned

Like most veterinary students, Doreen breezes through chapter 9.
“The brain is wider than the sky”
-Emily Dickinson
Thank You

harvey_abrams@starkey.com


References & Additional Reading


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