The Effects of the Listening and Communication Enhancement™ Program on Communicative Function in Adult Cochlear Implant Recipients: A Pilot Study

THESIS

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Abstract

Communicative function is typically impaired among adult cochlear implant (CI) users. Aural rehabilitation, or treatment for hearing loss and/or deafness, is a crucial part of the successful use of an amplification device, such as a CI. Auditory training is one component of an aural rehabilitation plan. Specifically, auditory training is a perceptual learning technique that focuses on improving speech understanding and communicative function among hearing impaired listeners. The present pilot study sought to explore the subjective and objective effects of a computerized auditory training program (Listening and Communication Enhancement, LACE™; Sweetow & Sabes, 2006) in adult CI-users. Results indicated individual benefit on subjective measures as evidenced by improvement on the Personal Adjustment subscale of the Communication Profile for the Hearing Impaired (CPHI) and on speech recognition in quiet. CI-users can complete auditory training tasks and show benefit on speech recognition measures and personal perception of hearing abilities.
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Chapter 1: Introduction

Cochlear Implants

Cochlear implants (CIs) provide a sensation of hearing for individuals with severe to profound hearing loss who do not receive benefit from traditional amplification (i.e., hearing aids). Individuals with CIs receive auditory information through pulsed electrical stimulation of the VIII nerve via an electrode array implanted in the cochlea, compared to those with normal hearing who receive auditory information from a series of acoustic to mechanical to neural stimulation traveling from the outer to middle to inner ear and eventually reaching the auditory cortex. Currently, CI speech processing strategies compress the frequency information of the speech signal into bands and distribute the compressed information to corresponding electrodes. The processing strategy and number of active electrodes varies by the manufacturer of implant technology and typically utilizes between 8 and 12 electrodes at any given time (Loizou, 1998), although the implanted array includes between 6 and 22. With only up to 12 electrodes providing the speech signal to the auditory nerve, the CI delivers limited information to the auditory cortex compared to normal hearing individuals. The signal is spectrally degraded because of the number of electrodes and their placement along the cochlea, which can result in poor speech recognition (Fu et al., 1998). CI’s do not extend into the cochlea far enough to stimulate all frequencies resulting in poor spectral resolution which also
ultimately effects speech recognition abilities. Although CIs are a viable treatment option to provide a sensation of hearing and in many cases improved speech recognition, a CI does not restore normal hearing (Loizou, 1998).

Cochlear implants have been effective at improving speech recognition in quiet and providing a sensation of sound (improve thresholds of hearing) for many recipients. Speech recognition is foundational for auditory-oral communication because in order to create messages that are understandable to the majority of listeners, one must first be able to understand auditory messages. It has been reported that children implanted at a young age can achieve academic performance similar to their peers (Svirsky, 2000). Speech recognition in adults can also improve after implantation and activation of a CI, regardless of age of implantation (Labadie et al., 2000; Budenz et al., 2011; Friedland et al., 2010). As demonstrated by Labadie et al. (2000), word recognition significantly improved pre- and post-implantation for both elderly patients (mean age of 71 years) and young adults (mean age of 45 years). Furthermore, Friedland and colleagues (2010), reported that speech recognition was significantly improved for both younger and older adults (i.e., speech recognition of words and sentences in quiet and in noise) when comparing sentence recognition in noise pre-implantation and at one year post-implantation. Additionally, adults with CIs have reported an increase in their quality of life (Djalilian, et al., 2002; Vermeire et al., 2005). For example, significant improvement was observed post-implantation on both the Hearing Handicap Inventory for Adults (Newman et al., 1990) and the Glasgow Benefit Inventory (Robinson et al., 1996) for both young and older adults when compared to their pre-implantation scores (Vermeire et
al., 2005). Improvements in technology and less strict implantation candidacy have also
led to overall improvements in speech understanding among individuals using CIs (i.e.,
better pre-implantation scores result in better post-implantation scores; Fu & Galvin,
2011). Overall, the benefit of CIs in adults is evidenced by significant improvements
between pre- and post-implantation in the areas of speech recognition and quality of life.

**Perceptual Learning Relative to Auditory Training**

Perceptual learning is a change in behavior due to experience, such as active training. Perceptual learning occurs when the brain learns a skill for the first time or
relearns a skill after infarct, injury, or lack of input, in the case of senses such as vision or hearing (Calford, 2002). Research regarding perceptual learning via the senses includes
what factors contribute to the change (e.g., type or duration of training) and what was
specifically changing (e.g., performance or neural activity). Auditory training is a
perceptual learning technique that provides structured listening tasks to re-establish
cognitive networks.

Children often learn more easily than adults; however the recent upsurge of
research in the area of adult neuroplasticity indicates that adult brains are receptive to
similar learning patterns (Moore et al., 2003; Karmarkar & Buonomano, 2003). In the
case of auditory training, the ability of adults to show improvements in perceptual skills
after practice is due to top-down influences (i.e. years of listening to speech). By
providing bottom-up practice (auditory input), adults merge top-down ability and
experience with bottom-up training to improve their perceptual auditory abilities (Polley
et al., 2006). Normal hearing adults began experiencing perceptual learning at birth.
Bottom-up information, such as speech, music and environmental sounds, was sent to the auditory cortex where the brain then made a reference for what that particular sound sounds like and what it means. Throughout life, as new input arrives at the cortex, the brain uses previous knowledge regarding what other things sound like and creates a new reference point for the new stimulation, therefore merging new bottom-up information with top-down experience. Individuals with hearing loss experienced a similar perceptual learning pattern prior to their onset of hearing loss. After individuals have experienced hearing loss for a period of time, merging of the new bottom-up auditory input with top-down processes (previous experience with listening prior to hearing loss) may be difficult. The new bottom-up auditory input may sound different from the references points that have been established in the brain for what various sound stimuli should sound like. Therefore, structured perceptual learning and auditory training tasks are beneficial to provide bottom-up auditory input that may sound different than the reference points currently available as well as to provide a meaning. The result is a new reference point (top-down experience) for auditory input via a hearing device that can be used in the future.

Several factors that should be incorporated into effective auditory training: repetition, rehearsal, illustrative examples, animation and/or videos, active participation and immediate feedback regarding accurate performance (Sweetow & Palmer, 2005; Wolfle, 1951). For example, Sweetow and Sabes (2006) incorporated all described components in the development of the Listening and Communication Enhancement (LACE™) program. LACE™ is an at-home auditory training program that provides
interactive and adaptive training for speech recognition in a variety of environments, such as noise or multiple talkers in the background of a message. Active participation in practice results in improved perceptual performance, as compared to passive learning through daily listening and communicating (Wolfle, 1951). Feedback regarding accurate performance is needed to cognitively encode a reference point for what the individual has just heard so they can use the information later. Additionally, the adaptive component of perceptual learning adjusts the difficulty level for each individual so the tasks are not too easy or too difficult in order to maximize perceptual training effects, such as improved speech recognition.

Changes in neural activity of the auditory cortex and increased performance have also been demonstrated after auditory training for normal hearing adults (Tremblay et al., 1998). Results of Tremblay et al. (1998) indicated auditory cortical changes that occurred before an improvement in behavioral response. Reorganization of auditory cortical representations of sounds occurs before speech recognition improvements are observed. Because both cortical changes and speech recognition improvement have been observed, it can be concluded that structured perceptual auditory learning contributes to cortical reorganization of speech sound representations and will result in behavioral changes such as improved speech recognition.

**Aural Rehabilitation and Auditory Training**

Aural rehabilitation (AR) is a clinical service traditionally provided by a Speech Language Pathologist or an Audiologist after implementation of an amplification device [i.e., hearing aid(s), or CI(s)]. The ultimate goal of AR, and more specifically auditory
training, is to improve functional communication. AR can be provided in a group or individual setting. A variety of forms of AR are often recommended for those with hearing impairment in order to maximize the benefit of the amplification device (Sweetow & Palmer, 2005). For example, AR can include training on strategies to assist with adjusting to listening through the device and/or communication strategies, auditory training and addition of further assistive listening devices (e.g., an FM system).

Auditory training involves training or retraining of the auditory system and cortex to hear, listen, process and understand sounds such as speech or music. Candidates for auditory training include individuals with hearing loss using hearing aids or CIs. Individuals with varying degrees of hearing loss, for example pre-, peri-, or post-lingually deafened, may benefit from auditory training. Pre-lingually deafened individuals are those who lost their hearing before learning language or were born congenitally deaf. Peri-lingually deafened individuals lost their hearing during language development or approximately between the years of two and seven. Post-lingually deafened individuals lost their hearing after learning language. Post-lingually deafened individuals have the most experience with listening, speech and sounds, followed by peri-lingually deafened and lastly, pre-lingually deafened individuals. The amount of auditory training or bottom-up practice is dependent on the amount of top-down influences the individual has prior to hearing loss onset. For example, many post-lingually deafened adults have extensive top-down experience and therefore the benefit from auditory training is greater than that of individuals with less top-down listening experience (i.e. pre-lingually deafened CI-users).
There are several factors that may contribute to the need for auditory training for hearing aid or CI-users. First, decreased input to the auditory system due to hearing loss can result in decreased speech understanding, even after the fitting of an amplification device. A process known as auditory deprivation occurs when individuals receive minimal input to the auditory nerve for a period of time and the auditory nerve atrophies. The result of atrophy of the auditory nerve is difficulty understanding speech (Gatehouse, 1989). Adjusting to listening and understanding speech again can take up to a month for individuals using hearing aids (Francis et al., 2003). Secondly, for those individuals who use CI(s), the spectral and temporal resolution provided to the auditory cortex via a CI is degraded. Those listening through a CI hear a substantially altered and degraded signal. In either case, auditory training can be beneficial to aid in the adjustment to listening again. Although some individuals are more suitable for auditory training, if any individual using a hearing aid(s) or CI(s) feel they would like to improve their listening abilities, auditory training may be appropriate.

There are different types of auditory training tasks, often divided into analytic training, synthetic training or a combination of the two (Sweetow & Sabes, 2009). Analytic training consists mainly of auditory discrimination and identification of consonants and vowels. The progression of auditory training moves from the easiest tasks to more difficult tasks ranging from sound awareness to comprehension. Synthetic training is based on the listener focusing on the meaning behind an auditory message. Synthetic training material may contain word recognition and sentence or paragraph understanding. The difference between analytic and synthetic training can further be
distinguished based on differentiating top-down processes (synthetic) and bottom-up processes (analytic). Top-down processes require use of sensory perception and understanding at the level of the cortex, therefore, utilizing context, inherent knowledge about language and attention (Sweetow & Sabes, 2009). Bottom-up processes (analytic) mostly require use of a sensory input, in this case, an auditory signal, such as a phoneme in isolation.

There are several different tasks that can be included in auditory training. Examples include practice identifying consonants and vowels or speech recognition at the sentence or paragraph level in noise, reverberation or quiet. Tasks move in a progression from easy to more difficult as the patient improves. Training can be provided to the patient on an individual basis, in a group setting or at-home via a computerized program. Recently, with the widespread use of computers, auditory training has been completed using computerized auditory training programs in the patient’s own home. Examples of computerized auditory training programs that are commercially available include: *Listening and Communication Enhancement* (LACE™, Neurotone; Sweetow & Henderson Sabes, 2006), and *Seeing and Hearing Speech* (Sensimetrics; Boothroyd, 2003), among others.

There are a wide variety of uses of auditory training, across many different populations. It has been linked to improved speech understanding among those with hearing loss (Bode & Oyer, 1970; Walden et al., 1981; Montgomery et al., 1984; Rubinstein & Boothroyd, 1987; Kricos & Holmes, 1996; Burk et al., 2006), decreased auditory sensitivity to particular sounds in children with autism (Bettison, 1996),
objective and subjective improvements in functional communication in patients with auditory processing disorder (Musiek et al., 2002; Chermak & Musiek, 2002), increased verbal memory in patients with schizophrenia (Adcock et al., 2009), and most recently, improvements in speech recognition and personal perception of hearing abilities in CI-users (Fu & Galvin, 2007; Miller et al., 2008; Stacey et al., 2010). Early research in auditory training assessed the effects of auditory training on speech recognition and speech and language development in profoundly deaf children in a school setting (Hudgins, 1953). The subject sample consisted of classroom children with hearing loss ranging from severe to profound who traditionally were taught in a classroom via visual communication/stimuli only. Hudgins implemented a hearing system (either individual hearing aids or a group hearing aid, similar to a sound field system, today) in a classroom that was traditionally taught in a visual only modality. Therefore, auditory training was defined as listening practice with the individual hearing aids or group hearing aid. Experimental testing of speech recognition via auditory only or auditory-visual stimuli was completed pre- and post-implantation of the hearing device. Results showed minimal improvement on speech perception (auditory only) from auditory training; however, Hudgins reported that the effects of auditory training could not be fully revealed by completing an auditory only test. When children were provided with both auditory and visual information (i.e. addition of lip reading), enhanced speech and language development of profoundly deaf children was observed. Although Hudgins expected to observe gains on auditory only tasks, the effect seen in improvement in
communicative function is still valuable. The results indicate that auditory training can improve communicative function in severe to profoundly deaf children.

**Auditory Training for the Hearing Impaired**

Auditory training has been studied extensively within the hearing impaired population. Improvement in speech understanding has been shown for both analytic and synthetic auditory training (Bode & Oyer, 1970; Walden et al., 1981; Montgomery et al., 1984; Rubinstein & Boothroyd, 1987; Kricos & Holmes, 1996; Sweetow & Henderson Sabes, 2006). Rubinstein and Boothroyd (1987) investigated the effects of synthetic training only, analytic training only and a combined auditory training that incorporated both synthetic and analytic for hearing impaired listeners. After training in one of the three training paradigms, the authors assessed then participants speech recognition of nonsense syllables, sentences of high and low context in noise and self-perception of hearing abilities via a structured discussion. Auditory training, whether synthetic or analytic often shows improvements in trained areas variable generalization to new environments across subjects and improvements in self-perception of hearing abilities when provided with both analytic and synthetic training rather than analytic training alone (Rubinstein & Boothroyd, 1987). The use of analytic training alone provides minimal efficacy results, as noted by Rubinstein and Boothroyd (1987) who suggest a combined analytic-synthetic or synthetic alone model. Similar results were reported by Walden et al. (1981). Walden et al. (1981) examined the effects of auditory only or visual only training on the speech recognition of hearing impaired adults. Only analytic training (consonant training in either auditory only or visual only modality) was provided
to young and older adults. A comparison between speech recognition scores of both phonemes and sentences showed improvements for both groups, however more for younger adults as compared to older adults. In contrast, Bode and Oyer (1970) reported improvements in performance of trained items with analytic training only. It should be noted that participants in the Bode and Oyer (1970) study completed training and testing on the same day, therefore not reporting lasting effects or the effect of multiple training sessions and therefore are only reporting immediate effects. Improved performance due to auditory training demonstrated by the above studies indicates that the adult hearing impaired listener is receptive to perceptual training, specifically auditory training.

Benefits in speech recognition and self-perception of hearing abilities are variable across subjects and over time (Sweetow & Palmer, 2005). Only one study provided evidence for positive outcomes that remain over time (Rubinstein & Boothroyd, 1987). Furthermore, research supporting generalization to new environments, such as a novel speaker (Montgomery et al., 1984) is minimal. The generalization observed by Montgomery et al. (1984) was a result of synthetic auditory-visual training. The addition of visual support during training may have impacted the results and therefore is not a true auditory-only training study. Without assessing the long term effects or the impact of auditory training of any kind on other tasks or on self-perception of hearing abilities, the research findings cannot be indicative of an increase in functional communication, which is the ultimate goal of any form of AR.

Across studies, it is difficult to determine whether analytic or synthetic auditory training is the cause of improvement in speech perception or self-perception. Therefore,
based on available evidence, Sweetow and Palmer (2005) suggest using a combination of both analytic and synthetic training techniques. Both hearing impaired individuals and those with hearing within normal limits showed benefit from auditory training (combined analytic and synthetic via LACE™; Sweetow & Sabes, 2006), further indicating the receptiveness of the central auditory system to changes as a result of auditory or perceptual training.

**Auditory Training for Cochlear Implant Users**

Aural rehabilitation is included in the treatment plan for the majority of children receiving CIs. In this case, it is often termed aural habilitation because the children are learning speech and language via CI stimulation. Children receiving CIs and adults fitted with traditional amplification (i.e. hearing aids) often receive AR in some form. Often times, however, AR is not part of the treatment plan for adults receiving CIs (Tucci et al., 1990; Rossi-Katz & Arehart, 2011). It is thought that most adults receiving CIs have established speech and language skills, and will adjust adequately on their own without formal AR. Rossi-Katz and Arehart (2011) conducted a survey study to evaluate services provided by audiologists to individuals receiving CIs of young and older age. Although this study could not identify the amount of AR provided to patients, the authors reported that audiologists utilized material provided from the CI manufacturer, audio books or websites for AR purposes (Rossi-Katz & Arehart, 2011). Duration and methodology of the use of these other materials was not discussed. Audiologists also indicated that reimbursement issues interfered with AR in the majority of recipients whom did not receive formal AR post-cochlear implantation. The Rossi-Katz and Arehart study,
however, reported a low response rate of 15% and thus results are neither definitive nor conclusive. Regardless, the information can provide some insight into the widespread use of auditory training or AR, in general, which appears to be quite small based on the results. Tucci et al. (1990) studied practice patterns for CI teams for adults receiving CIs via a questionnaire to Otolaryngologists. Only 35% of adult recipients were provided auditory training through their CI program, as compared to 77% of children. Furthermore, results revealed that the CI program, in many cases, only provides the implant procedure with the remaining audiological and aural rehabilitation services completed at a different facility, with the assumption that they are indeed receiving these services elsewhere. Therefore, the CI teams often do not know who received or did not receive AR post-implantation. However, Tucci et al. (1990) recognized that all CI recipients are candidates for AR services. This review of information suggests that Audiologists (among other professionals), as a whole, are likely not providing training for communicative function for the majority of adults receiving CIs. In cases where AR is provided, a clear methodology or program is not widely used nor accepted.

The value of AR after cochlear implantation is evidenced by research over the last 20 years. Although CIs were created to provide a sensation of hearing, post-implantation research has indicated that the CI can provide far more than just a sensation of hearing for many individuals. Over the last 20 years, research has addressed how to improve performance with the CI (i.e. AR) rather than just to improve the device or processing strategies alone. Although current practice does not appear to include formal AR with an auditory training component as part of the CI protocol, a limited number of CI speech
recognition studies have reported the potential benefits of AR post-implantation (Busby et al., 1991; Dawson & Clark, 1997; Fu & Galvin, 2007; Miller et al., 2008; Stacey et al., 2010; Fu et al., 2005a, 2005b). Additionally, experimental studies of normal hearing individuals listening to spectrally degraded simulations of speech stimuli have been conducted to mimic listening and performance through a CI. Improvements in speech recognition post-training have been observed (Nogaki et al., 2007; Stacey & Summerfield, 2008). CI simulation is when normal hearing listeners are tested with a spectrally degraded signal. When normal hearing listeners complete auditory training with CI simulated material, the results may be generalized to CI-users.

Auditory training research for CI-users began in the early 1990’s (Busby et al., 1991; Dawson & Clark, 1997), with small and diverse participant groups. Regardless of participant demographics, improvement in speech recognition was observed in both studies after analytic training of phonemes. Improvement in the perception of speech was observed in poor performing CI-users, as studied by Busby et al. (1991) with post-lingually deafened adult CI-users showing greater improvements than pre-lingually deafened adult CI-users. Age contributed to the observed improvement, as the participant in adolescence showed increased improvement compared to two adult participants. The study consisted of only three pre-lingually deafened adult CI-users and thus may not fully represent this population. As further studied by Dawson and Clark (1997), pediatric participants showed improved vowel recognition after specific vowel recognition training. The change was small, albeit statistically significant. These early research studies focused on training in specific areas, such as vowels (Busby et al., 1991) or
phonemes (Dawson & Clark, 1997), and contained an auditory-visual or visual-only group. Because the training and testing material were similar, it is difficult to distinguish whether the participants in these studies showed improvement because they learned the task or because their perceptual abilities had improved. Although the results of these studies were not generalizable to other populations, individuals within that population, or tasks, the research provided a rationale for more research in the area and the clinical application of auditory training and AR.

Fu and Galvin (2007) suggested that auditory training has the potential to be beneficial to all CI-users, regardless of how well they perform on speech understanding measures. CI-users demonstrated improvement post-training on trained items and generalized learning to non-trained items, indicating that the plasticity of the nervous system of this population is receptive to perceptual learning and auditory training (Fu & Galvin, 2007). Similarly, Miller et al. (2008) examined the effects of auditory training in CI-users. Subjects completed 12 to 24 hours of training over the course of six weeks. CI-users completed speech recognition measures of phonemes and sentences in quiet and in noise. Participant’s speech perception in quiet showed the greatest improvement. Auditory training in both quiet and noise conditions among adult CI-users was also examined by Stacy et al. (2010). Participants completed training at home for one hour per day, five of seven days of the week, for three weeks. Participants were tested pre- and post-training on consonant recognition, vowel recognition and speech recognition of words in sentences. Results indicated speech recognition improvement of consonants and no improvement on the recognition of words in sentences or vowel recognition. Only
eight of eleven participants completed the training at this frequency indicating that daily training may be too demanding, or participants did not want to participate for a variety of reasons. Fu and colleagues (2005a, b) conducted a series of studies to explore the effects of auditory training in adult CI-users at a frequency of 1 hour per day, 5 hours per day for a month or greater. Results indicated up to a 15% improvement in performance on the perception of consonants and vowels and up to 30% improvement in performance on a sentence recognition task in quiet. Training material consisted of monosyllabic words and was not used for experimental comparison measures. An improvement in performance to non-trained items can show generalization and the generalization to non-trained items observed in this study was significant. Additionally, improvement was observed in all subjects, therefore supporting perceptual learning and efficacy of auditory training in adult CI-users.

Normal hearing listener’s ability to understand spectrally degraded speech is often compared to what CI-users experience daily. By simulating the spectral information provided through a CI, researchers are presenting an acoustic signal to normal hearing individuals that is thought to be comparable to the degraded signal provided via a CI. Research in this area includes the effects of training material (words, words in sentences, phonemes in nonsense syllables) on the performance of normal hearing listeners provided with a spectrally degraded signal (Stacey & Summerfield, 2008). Eighteen normal hearing individuals were randomly divided into three groups with each group receiving a different type of training material. Training was completed for 20 minutes for nine sessions, over a maximum of three weeks. Pre- and post-training measures included
consonant and vowel identification and speech recognition of words in sentences in quiet. Results indicated that the training of words and words in sentences led to significant improvement in post-training measures and minimal improvement from training of phonemes in nonsense syllables. Normal hearing listeners provided with a spectrally degraded signal perform better after training on synthetic (i.e., words or words in sentences) than from training on analytic material (i.e., phonemes in nonsense syllables). Improvements on consonant and vowel identification tasks were non-significant regardless of training material, indicating that consonant and vowel identification measures may not be an appropriate measure for functional outcomes. Nogaki and colleagues (2008) studied the effects of training rate on the speech recognition abilities of normal hearing individuals listening to spectrally shifted speech (a form of CI simulation, spectrally degraded signal). Eighteen normal hearing listeners were trained for five one-hour sessions at the rate of five, three or one session per week. Training consisted of vowel perception training only. Participants were randomly assigned to one of the training rate groups. Pre- and post-training measures consisted of consonant and vowel recognition tasks and a sentence recognition task. Regardless of training rate, improvement of approximately 15% was observed across participants for vowel recognition post-training. Improvement on consonant recognition and sentence perception were also observed (approximately 20%), even though training was not provided for these tasks. Normal hearing listeners provided with spectrally shifted speech can improve on trained and non-trained items after as little as five hours of auditory vowel recognition training. The normal hearing listener provided with a
spectrally degraded signal is most similar to a post-lingually deafened adult CI-user. Therefore, studies of CI simulation are relevant to rationalize the use of auditory training for adult CI-users, especially for the post-lingually deafened adult CI-user population.

Based on a review of current literature available regarding auditory training for CI-users, it can be concluded that CI-users can be receptive to perceptual learning (i.e., auditory training), some CI-users are motivated to complete training at home, and moderate benefit in speech recognition can be achieved. However, these studies also indicate some limitations including a potentially lengthy auditory training time of one hour per day (Stacey et al., 2010) and that the training task may not correlate to functional gains. For example, minimal information is available regarding self-perception of hearing abilities pre- and post-training.

Due to limited and inconclusive information available, more research is warranted to determine adult CI-user’s receptiveness to auditory training. Like adult hearing impaired listeners, who have showed benefit in speech recognition from auditory training, adult CI-users are appropriate candidates for auditory training. The application of a developed auditory training program for CI-users is beneficial as it could immediately affect current clinical practice for adults receiving CIs.

**Listening and Communication Enhancement (LACE™)**

The LACE™ program, originally developed in 2006 (Sweetow & Sabetes, 2006), is an auditory training program designed for new hearing aid users to use at home in order to maximize the benefits provided from hearing aid(s). Previous research has shown both subjective and objective positive effects of the program for aided hearing impaired
listeners (hearing aid users) and individuals with normal hearing (Sweetow & Sabes, 2006).

As part of the development of LACE™, researchers investigated areas that most simulated the real listening environment that listeners experience daily (Sweetow & Sabes, 2006). Based on the development study, the LACE™ program contains five training areas (Sweetow & Sabes, 2007): speech in noise, missing word, competing voice, rapid speech and word memory. The tasks included in the program are interactive and adaptive. Tasks are interactive in that participants receive feedback regarding performance after each trial as well as after completion of each section. Tasks are adaptive because the difficulty of the next trial is based on previous trials (i.e., if the participant is consistently responding correctly, the task will become more difficult).

Positive gains on the training tasks in the program as well as post-training measures (subject and objective) were observed in those with hearing status ranging from normal to profound hearing loss. Objective measures were: Quick Sentence in Noise (QSIN; Killian et al., 2004), Hearing in Noise Test (HINT; Nilsson et al., 1994), the Listening Span test (auditory memory; Pichora-Fuller et al., 1995), and Stroop Color Word test (speed of processing; Utl & Graf, 1997). Subjective measures of perceived benefit were the Hearing Handicap Inventory for the Elderly (HHIE; Ventry & Weinstein, 1988) and the Communication Scale for Older Adults (CSOA; Kaplan et al., 1997). All measures were completed before and after training. Results indicated improved performance on objective measures and training items across participants, except for HINT, indicating generalization from training items to non-training items. No
improvement on the HINT was reported as a lack of sensitivity to changes post-training because participants improved on a different measure of speech recognition in noise, the QSIN Test. Improvements on the subjective measures of the HHIE and the CSOA were also significant, indicating the training improved subjective perspective on hearing abilities. Although long term effects were not assessed, the program appears to be cost and time effective and beneficial to the client. Based on high participant compliance (Sweetow & Sabes, 2006), it can be concluded that the LACE™ program utilizes an appropriate training duration. As compared to other studies (Burk et al., 2003; Stacey et al., 2010), the LACE™ program utilizes a training time that does not indicate fatigue from the program (30 minutes per day). The training allows for days off and is completed in four weeks (instead of two or three as prescribed by the above mentioned studies, respectively).

The LACE™ program provides a cost, time and patient effective means to improving communication for those with hearing impairment using traditional amplification (i.e., hearing aids). Although previous research has indicated the benefits of auditory training in hearing impaired listeners including those using CIs, there is currently little evidence to support the widespread use of an auditory training or an aural rehabilitation program among CI-users. Therefore, the current pilot study was designed to explore the effects of an established auditory training program on CI-users’ speech understanding and self-perception of listening abilities. It was hypothesized that adults with CIs will show improvement on objective speech understanding measures and
positive gains on a subjective measure of their listening abilities, as compared to their pre-training assessment.

**Purpose**

The ability of adults to improve speech recognition abilities with practice is due to perceptual learning, or improvement in performance as a result of experience or practice. Current clinical practice does not regularly include auditory training or extensive aural rehabilitation because the adult CI-patient population has language knowledge and experience. It is therefore assumed that adults with CIs will adjust independent of formal training or rehabilitation. By applying an auditory training program that has shown benefit for hearing impaired listeners utilizing traditional amplification [i.e., hearing aid(s)] to those with CIs, the current pilot study seeks to investigate subjective and objective benefit of auditory training in adult CI-users.

Therefore, the **purpose** of this study was to assess the subjective and objective benefits of LACE™, a computerized auditory training program, in adults with CIs. The current pilot study sought to investigate the effects on speech understanding and self-perception of communication abilities in CI-users, after they have completed a four week course of at-home auditory training. The present pilot study sought to answer the following research question: Do adult CI-users demonstrate perceptual benefit from an at-home auditory training program (i.e., LACE™)? Specifically, it was hypothesized that adult CI-users would demonstrate improved speech recognition in quiet and in noise and would show improvements in at least two of the four subscale scores on the Communication Profile for the Hearing Impaired (CPHI).
Chapter 2: Methods

Participants

Three adult CI-users (2 male, 1 female) were recruited for the current pilot study. The subjects ranged in age from 37 to 65 years with a mean age of 52 years. Two of three participants reported completing informal AR via the computer software provided from the manufacturer of their device. At the time of pre-training measures, all participants had not completed any formal or informal AR within the previous six months. Two of three participants had used their CI’s for greater than one year at the time of pre-training measures. One of three participants was activated six months prior to pre-training measures in one ear, with duration of use in the contralateral ear greater than one year. Participants were recruited via advertisements in the community or medical offices in the Columbus, OH area and were paid for their participation. Table 1 includes participant demographics, including age (in years), duration of implant use (in years), onset of deafness, previous AR and score on the Self Administered Gerocognitive Examination [SAGE] Scharre et al., 2010]. Participants were screened for cognitive impairment via the SAGE. There are four versions of the SAGE, which were randomized across subjects. Appendix A includes Form 1 of the SAGE screening measure. All participants scored above the criterion cutoff of 17 (22 total points possible) on the screen indicating “very likely to be normal”. After the pre-training assessment CI3 voluntarily
withdrew from the study for personal reasons. The present pilot study was approved by the Behavioral and Social Sciences Institutional Review Board at The Ohio State University.

**Table 1**

*Participant Demographics*

Table 1 includes subject identification number (ID), age (in years), duration of implant use (in years), onset of deafness, previous experience with auditory training or AR and score on the SAGE (cognitive screen, criterion = 17) are reported. R = right, L = left.

<table>
<thead>
<tr>
<th>Participant Demographics</th>
<th>Subject ID</th>
<th>Age</th>
<th>Duration of implant use</th>
<th>Onset of deafness</th>
<th>Previous AR</th>
<th>SAGE Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CI1</td>
<td>54</td>
<td>R: 8:7 L: 3:5</td>
<td>Peri-lingual</td>
<td>At-home AR program from manufacturer of CI; completed after implantation</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>CI2</td>
<td>65</td>
<td>R: 2:8 L: .6</td>
<td>Post-lingual</td>
<td>At-home AR program from manufacturer of CI; completed after implantation</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>CI3</td>
<td>37</td>
<td>L: 2:0</td>
<td>Pre-lingual</td>
<td>None</td>
<td>22</td>
</tr>
</tbody>
</table>

**Design**

A within subjects pre-post case study design was utilized to assess the effects of the LACE™ program on communicative function in adults with CIs. All participants
received the same treatment, therefore acting as their own controls. Assessment of change was obtained via comparison of pre- and post-training performance.

**Materials**

Sentence recognition in quiet was measured using the IEEE sentence material (Institute of Electrical and Electronics Engineers, 1969). The IEEE sentence material consists of 72 lists of ten sentences. Each sentence has five key words. Sentence recognition in noise was measured using the Quick Sentence in Noise test (QSIN; Killion et al., 2004). There are 12 QSIN lists and each list contains six sentences. Each sentence has five key words.

The CPHI was administered pre- and post-training to assess personal perception of communication abilities. The CPHI is a 145-item written self-assessment. Four core areas are assessed resulting in four subscale scores: Communication Performance, Communication Environment, Communication Strategies, and Personal Adjustment. The CPHI assesses both perception of communication performance as well as behavioral and emotional aspects of communication that may be impacted by their hearing loss and subsequent use of their CI.

**Procedure**

Experimental testing for speech recognition in quiet and in noise, assessment of personal perceptions of communicative function via the CPHI, as well as the cognitive screen (SAGE) were completed at The Ohio State University in the Department of Speech and Hearing Science.
After recruitment, verification of inclusion criteria, consent and pre-training assessment measures were completed, participants were provided with LACE™ material and instructions regarding installation and use. Participants were instructed to complete the LACE™ training program for 30 minutes per day, 5 days/week, for 4 weeks as recommended by the program instructions (Sweetow & Henderson Sabes, 2007). LACE™ is a computerized, at-home, auditory training program that focuses on the following domains to improve speech understanding for those with a hearing impairment: speech in noise, missing word, competing voice, rapid speech and word memory. Each domain is addressed via auditory training through a series of tasks that are interactive and adaptive.

Additionally, at this time, participants were scheduled for an appointment with the experimenter in approximately four to five weeks. At the follow-up appointment, post-training assessment measures were repeated and conducted in the same manner as pre-training.

**Experimental Testing**

Experimental testing consisted of speech perception in quiet and in noise before training with the LACE™ program. Participants were tested in a sound-attenuating booth. All stimuli were presented from a compact disc player (model) through a two-channel audiometer (Grason Stadler, Model 61) at 50 dB HL via sound field speakers. The audiometer was calibrated according to the appropriate American National Standards Institute standard (ANSI, 2004). Participants utilized their own CI processor and current clinical settings during these measures. The clinical settings used for pre- and post-
training measures were also used by the participants in their homes while completing the LACE™ program. After completion of the speech recognition measures (pre- and post-training), participants completed the CPHI.

Speech recognition in quiet was assessed via thirty IEEE (Institute of Electrical and Electronics Engineers, 1969) sentences, or three lists. Each key word correctly identified was recorded for each participant and reported as percent correct across the thirty sentences. Participants were instructed to repeat back the sentence they heard as best they could. Prior to any listening tasks during the pre- and post-training testing sessions, participants were provided with ten IEEE sentences in quiet as practice in order to familiarize the participants with the task.

Speech recognition in noise was assessed via six QSIN lists or 36 sentences. Performance for each participant was recorded as SNR loss (Killion et al., 2004). The intended use of QSIN material is to establish a SNR loss. SNR is defined as the noise level at which participants can understand 50% of the key words. Key words correctly identified were recorded for each participant and reported as SNR-loss according to the QSIN Test instructions.

Each subject completed the CPHI at pre- and post-training testing sessions. Participants were given as much time as needed to complete the questionnaire. Participants rated each statement between one and five, from ‘Strongly Agree’ to ‘Strongly Disagree’. Specific instructions for each section were provided (for a detailed description of the CPHI, see Demorest & Erdman, 1987). Scores were reported as the average rating within the subscale. Average scores were reported for four subscales:
Communication Performance, Communication Environment, Communication Strategies and Personal Adjustment.
Chapter 3: Results

Pre- and post-training measures were compared on an individual participant basis via a paired t-test and observation of trends between measures. A paired t-test for means (alpha level of 0.05) was used for all statistical tests. A summary of mean scores for each subject’s pre- and post-training on IEEE sentences in quiet (in percent) and the QSIN Test (in SNR-loss) are provided in Table 2.

Table 2.

Scores for Speech Recognition Measures

Table 2 provides participant’s mean score and standard deviation (SD) pre- and post-training on IEEE sentence recognition in quiet (% correct), and the QSIN Test (SNR-loss in dB). * = significant at p < 0.05.

<table>
<thead>
<tr>
<th></th>
<th>IEEE</th>
<th>QSIN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td><strong>CI1</strong></td>
<td>Mean</td>
<td>44.0</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.16</td>
</tr>
<tr>
<td><strong>CI2</strong></td>
<td>Mean</td>
<td>75.3</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>.05</td>
</tr>
</tbody>
</table>

CI1 was a peri-lingually deafened 54 year old adult male who had been using a CI for over eight years in the right ear and over three years in the left ear at the time of the experiment. There was a non-significant change in performance between pre- (44%) and
post-training (47.3%) scores on speech recognition in quiet \([t(2) = -0.320, p = 0.389]\).

There was a significant decrease in performance on the QSIN between pre-training (15.83 dB) and post-training (20.16 dB); \(t(5) = -3.606, p = 0.008\). Lastly, a paired t-test was used to analyze differences between pre- and post-training on the four subscales of the CPHI (see figure 1). Mean rating (between 1 and 5) for each subscale were reported. A lower mean indicates an area of weakness (Demorest & Erdman, 1987) A non-significant improvement was observed on the Communication Performance subscale between pre-training (mean = 3.846, \(SD = 1.286\)) and post-training (mean = 3.346, \(SD = 1.056\)); \(t(25) = 1.639, p = 0.060\). A non-significant decline in performance was observed on the Communication Environment subscale between pre-training (mean = 2.065, \(SD = 1.063\)) and post-training (mean = 2.290, \(SD = 0.973\)); \(t(30) = -1.270, p = 0.107\). A non-significant improvement was observed on the Communication Strategies subscale between pre-training (mean = 4.560, \(SD = 4.440\)) and post-training (mean = 4.44, \(SD = 1.083\)); \(t(24) = 0.569, p = 0.287\). A significant improvement in performance was observed on the Personal Adjustment subscale between pre-training (mean = 3.623, \(SD = 1.635\)) and post-training (mean = 3.918, \(SD = 1.382\)); \(t(60) = -1.670, p = 0.050\).
CI1 - CPHI

![Graph showing CI1 - CPHI ratings]

**Figure 1.** CI1 - Communication Profile for the Hearing Impaired (CPHI). Results of data obtained on the CPHI pre- and post-training with the LACE™ program for CI1. * = significant at p < 0.05.

CI2 was a post-lingually deafened 65 year old adult male who had been using a CI for two years, eight months for his right ear and approximately six months for his left ear at the time of the experiment. Results of a paired t-test comparing pre- and post-training scores on speech recognition in quiet indicated a significant increase in performance from 75.3% to 84.6%, \( t(2) = -2.745, p = 0.023 \). There was a non-significant decline in performance on the QSIN Test between pre-training (13.3 dB) and post-training (14.3 dB); \( t(5) = -3.606, p = 0.008 \). Lastly, a paired t-test was used to analyze differences between pre- and post-training on the four subscales of the CPHI (see figure 2). Mean rating (between 1 and 5) for each subscale were reported. A lower mean indicates an
area of weakness (Demorest & Erdman, 1987) A non-significant decline in performance was observed on the Communication Performance subscale between pre-training (mean = 3.320, $SD = 1.145$) and post-training (mean = 3.577, $SD = 0.946$); $t(25) = -1.022$, $p = 0.158$. A non-significant improvement in performance was observed on the Communication Environment subscale between pre-training (mean = 3.968, $SD = 1.048$) and post-training (mean = 3.806, $SD = 1.222$); $t(24) = -1.155$, $p = 0.130$. A non-significant decline in performance was observed on the Communication Strategies subscale between pre-training (mean = 3.640, $SD = 1.036$) and post-training (mean = 3.840, $SD = 1.179$); $t(30) = 0.867$, $p = 0.196$. A significant improvement in performance was observed on the Personal Adjustment scale between pre-training (mean = 3.820, $SD = 0.885$) and post-training (mean = 4.426, $SD = 1.117$); $t(60) = -5.625$, $p = <0.001$. 
Figure 2. CI2 - Communication Profile for the Hearing Impaired (CPHI). Results of data obtained on the CPHI pre- and post-training with the LACE™ program for CI2. * = significant at p < 0.05.
Chapter 4: Discussion

Interpretation of Results

The purpose of the current pilot study was to assess the potential of an auditory training program to improve speech recognition performance and self-perceived communication abilities among CI-users. Previous research has indicated that CI-users may benefit from AR and/or auditory training (Fu et al., 2005a; Miller et al., 2008; Stacey et al., 2010). Many CI-users, however, do not receive these AR services. The current pilot study utilized an auditory training program (LACE™; Sweetow & Sabes, 2006) that included crucial aspects of successful perceptual learning, such as immediate feedback regarding performance and active participation. Participants completed objective and subjective communicative function measures (speech recognition in quiet, the QSIN, and the CPHI) pre- and post-training. Results demonstrated significant subjective improvement for both participants on the Personal Adjustment subscale of the CPHI. A significant improvement on speech recognition in quiet was also observed for CI2 and a non-significant improvement for CI1. However, neither participant showed improvement on the QSIN. The current results are similar to previous studies indicating subjective and objective benefit after auditory training for hearing impaired individuals (Sweetow & Sabes, 2006) and CI-users (Miller et al., 2008; Fu et al. 2005a).
Sweetow and Sabes (2006) observed subjective and objective benefit post-training with the LACE™ program in individuals with hearing impairment. Subjective and objective improvements were also observed in the present pilot study for individuals with CIs who participated in auditory training. Sweetow and Sabes (2006) was the founding study for the LACE™ program, which was the auditory training program used in the current pilot study. The results are comparable between the current pilot study and Sweetow and Sabes (2006) because the same training program was utilized. The participant population was different, thus indicating that the LACE™ program can be beneficial for individuals other than those with hearing loss, the population for which the program was intended. Although the results are similar in terms of subjective and objective improvement, the pre- and post-training assessment measures were different between the two studies.

The current pilot study selected two objective speech recognition measures [compared to four in Sweetow and Sabes, (2006)] that were general measures to assess overall benefit. Comparatively, Sweetow and Sabes (2006) administered four objective measures that incorporated tasks that were used in training. For example, one training area was speech recognition in noise, so the author used the QSIN to assess the effects of training. Both studies utilized the QSIN, however the current pilot study did not result in an improvement in performance for either participant, compared to the Sweetow and Sabes study that observed a significant improvement for over 40% of subjects. Sweetow and Sabes (2006) may have observed benefit on the QSIN because the participants started at a better SNR-loss level than in the current pilot study (mean SNR loss 9.3 dB and
14.56 dB, respectively). Listening in quiet is an easier task than listening in noise. In the current pilot study, the two participants performed below ceiling when listening in quiet, 44% (CI1) and 75% (CI2). This result indicates that speech recognition in quiet has yet to reach mastery for both individuals. Without mastering speech recognition in quiet, it would be difficult to show improved performance with background noise. Similar to the current pilot study, Miller et al. (2008) also observed significant improvement on speech recognition in quiet for CI-users after auditory training. This further indicates that those with CIs may show different benefit post-training than hearing impaired individuals.

Additional auditory training may be beneficial for those with CIs, especially in noise because it is a well known area of weakness for many CI-users (Hochberg et al., 1992; Fetterman & Domico, 2002). In order to improve speech recognition abilities in noise, participants must first improve speech recognition abilities in quiet, as it is the easier of the two tasks.

Additionally, different subjective measures were utilized between the current pilot study and the Sweetow and Sabes study (2006). The CPHI (Demorest & Erdman, 1987) was selected in the current pilot study because a wide range of areas are assessed via the 145 item questionnaire, including communication performance, communication environment, communication strategies and personal adjustment. Sweetow and Sabes (2006) utilized the HHIE (Ventry & Weinstein, 1988) and the CSOA (Kaplan et al., 1997). Subjective benefit was observed by Sweetow and Sabes (2006) via the HHIE and the CSOA, therefore the current pilot study elected to administer one questionnaire to assess many areas of personal perception of communicative function versus two
questionnaires. The results of the current pilot study also showed significant improvement for both participants on the CPHI, although only for one subscale (Personal Adjustment), while the Sweetow and Sabes study (2006) showed subjective improvement on both subscales of the CSOA (strategies and attitudes subscales) and on the HHIE.

The studies by Fu and colleagues (2005a, 2005b) regarding auditory training for CI-users were fundamentally different from the current pilot study. Fu et al. (2005a; 2005b) utilized analytic training of words with phonemic differences and the identification of individual consonants and vowels. Comparatively, the current pilot study utilized a program (LACE™) with synthetic training only and focused on areas for functional communication in different listening environments (Sweetow & Sabes, 2006). Additionally, Fu and colleagues modified starting points for participants based on their current speech recognition abilities, which is not possible with the LACE™ training program. However, the training program utilized by Fu and colleagues is not commercially available and therefore is not a viable option for individuals with CIs to use to improve their communicative function. The current pilot study assessed subjective and objective benefit after auditory training while Fu et al. (2005a) observed objective changes only. Fu et al. (2005a) observed objective benefit for all participants. The current pilot study observed objective improvement for the two pilot participants on speech recognition in quiet; however, the improvement was only significant for one participant (CI2).

The two pilot study participants lost their hearing at different stages in life or different onsets of deafness. CI1 was peri-lingually deafened and showed no significant
improvement on either speech recognition task, while CI2 was post-lingually deafened and showed significant improvement on speech recognition in quiet. Because CI2 was a post-lingually deafened adult CI-user, he experienced more sound, speech and auditory cortex stimulation than CI1 who was peri-lingually deafened. The onset of deafness could have played a role in the observed objective benefit from auditory training observed in this study because CI2 had more top-down information accumulated throughout life than CI1. Consistent with Polley et al. (2006) in regards to perceptual learning, CI2 maximized the benefits of auditory training, combining his top-down experience of listening to sounds and speech with bottom-up auditory training. The result of merging of top-down experience with bottom-up auditory training was improved performance on speech recognition in quiet. Therefore, CI2 was able to show more benefit from auditory training (bottom-up) because he had more top-down experience than CI1. Changes in objective performance could have been influenced by differences in available top-down experience (more for CI2 than for CI1). Despite differences between the participants in regards to onset of deafness, both participants showed subjective improvement post-training on the CPHI Personal Adjustment subscale. The results indicate that auditory training provided subjective benefit for the two pilot participants.

**Interpretation of CI1’s Results**

For CI1, speech recognition in quiet showed an improvement in performance after auditory training; however this change was not significant. Auditory training did not result in an improvement on the QSIN, instead, a significant decrease in performance was
observed. The decrease in performance could have been a result of many factors, such as fatigue or day to day variable performance.

The information provided via a comparison between pre- and post-training indicated a significant improvement on the Personal Adjustment subscale of the CPHI. Although there was minimal improvement in speech recognition in quiet and no improvement on speech recognition in noise for CI1, improvement on the CPHI Personal Adjustment subscale indicates that auditory training provided subjective benefit, specifically in the area of adjustment to hearing loss and current hearing abilities.

CI1 completed 15 of 20 LACE™ training sessions (75% completion). After completing 15 of 20 sessions of the LACE™ training, CI1 independently began using a different auditory training program. It was not intended for participants to complete any other auditory training during the training with the LACE™ program. However, because it was similar in nature, the data obtained are still relevant. CI1 reported completing an additional ten hours of auditory training via this alternative program. Therefore, the observed benefit post-training (minimal improvement on speech recognition in quiet and significant improvement on the Personal Adjustment subscale of the CPHI), can only be attributed to auditory training in general and not specifically as a result of the LACE™ program.

**Interpretation of CI2’s Results**

After training with the LACE™ program, CI2 showed significant improvement on speech recognition in quiet and on the Personal Adjustment scale of the CPHI. The significant improvements in these areas indicate that auditory training via the LACE™
program provided both subjective and objective benefit for this participant. Improvements, although non-significant, that were observed on two additional subscales of the CPHI (Communication Performance and Communication Strategies) are also relevant when discussing the observed improvement in communicative function for CI2 as the trend indicates an overall improvement in subjective benefit after auditory training. Although the training did not result in a significant improvement on the QSIN, a less variable mean SNR-loss was observed as evidenced by a decrease in the standard deviation (SD) across data points on the QSIN. The decrease in SD indicates that there was less variable performance on speech recognition in noise post-training.

With an overall completion rate of 50% (10 of 20 LACETM training sessions completed), CI2 may have experienced increased improvement had the entire program been completed. Therefore, the results indicate that the training may have led to a significant improvement in performance when listening in quiet, more consistent speech recognition abilities in the presence of noise (QSIN Test), and subjective improvement, as assessed by the CPHI, Personal Adjustment subscale.

**Barriers to Training Completion**

Complications related to study completion included computer/software difficulties and time constraints. Due to the limited time available to complete the training (approximately 4 weeks), both participants in the study found it difficult to complete all training sessions. In addition, both experienced technical difficulties with the program, which delayed them further in completing more sessions of the training. Alternatively, lack of completion of the training program by either individual could have
been due personal reasons that withheld participants from completing the entire training program. When given the opportunity to complete training at home, participants may not be as compliant when compared to completing training at the study site, as evidenced by decreased compliance in the current study as compared to Sweetow and Sabes (2006) with a compliance rate 75% of participants enrolled completed the training program at the study site. Therefore, even when training is controlled by the study site, it is difficult to maintain participants in a study, even when subjective and objective benefits are expected.
Chapter 5: Conclusions

Auditory training via the LACE™ program has the potential to provide benefit to individuals using CIs as evidenced by improvement on both objective speech recognition measures and on subjective communicative function measures. Although the observed objective improvements were minimal and/or non-significant, the results from the two pilot subjects on the subjective measures demonstrate that further research in this area is warranted. The results of the current pilot study demonstrate that CI-users can complete auditory training tasks and show individualized benefit (i.e., benefit in different areas of communicative function such as personal perspective of hearing abilities or speech recognition measures). Despite minimal improvement on objective measures, the two pilot participants showed significant improvement on the Personal Adjustment subscale of the CPHI indicating that auditory training resulted in subjective benefit. Based on the current pilot study and relevant research regarding the use of auditory training in those with CIs, it may be useful to provide auditory training to those with CIs and reported any observed benefit(s) in order to guide future research and clinical practice.

Limitations and Future Research

Although the goal of the current pilot study was to assess any potential benefits of the LACE™ program in adult CI-users, due to the small subject population and the diversity of their duration of hearing loss, the current pilot study is limited. The results
cannot easily be generalized to a greater population of CI-users. The current pilot study consisted of only two participants because of time commitment issues for other potential participants. The author was in contact with five other individuals who expressed interest in participating, however declined participation due to the time commitment. However, because benefit was observed, the results provide rationale for a larger scale study with more participants with varying durations of hearing loss, compared to two individuals in the current pilot study. The effects of auditory training on subjective and objective communicative function are especially relevant for this population as the current results indicated there was potential for improvement in both areas.

Neither of the two pilot participants completed the entire auditory training regimen with the LACE™ program. Even after committing to completion and being paid for their time, neither participant completed the study. This observation is crucially important when discussing the efficacy of an at-home auditory training program. Increased improvement, both objectively and subjectively, may have been observed if the participants had completed the entire training regimen. The freedom to complete the training at home and on their own time could have led to the lack of training completion. Results may have been different had participants been required to attend the study site for training sessions. However, if participants were required to attend the study site for 20 training sessions (as recommended by Sweetow and Sabes, 2006), the cost of the study would have increased and potentially could have prevented people from participating because they did not want to attend the study site that often. It was difficult to recruit participants to attend the study site for two sessions and would have been more difficult.
to have participants complete training at the study site as well. Although the current geographical area has a population of CI-users, it is difficult to recruit and maintain participants in a study, especially with a daily training to complete.
References


Appendix A: Self Administered Gerocognitive Examination
How Well Are You Thinking?

Please complete this form in ink without the assistance of others.

Name ____________________________ Date of Birth __________ / __________ / __________

How far did you get in school? ____________________________ I am a Man ______ Woman ______

I am Asian ________ Black ________ Hispanic ________ White ________ Other ________

Have you had any problems with memory or thinking? Yes ______ Only Occasionally ______ No ______

Have you had any blood relatives that have had problems with memory or thinking? Yes ______ No ______

Do you have balance problems? Yes ________ No ________

If yes, do you know the cause? Yes (specify reason) ____________________________ No ________

Have you ever had a major stroke? Yes ________ No ________ A minor or mini-stroke? Yes ________ No ________

Do you currently feel sad or depressed? Yes ________ Only Occasionally ________ No ________

Have you had any change in your personality? Yes (specify changes) ____________________________ No ________

Do you have more difficulties doing everyday activities due to thinking problems? Yes ________ No ________

1. What is today’s date? (from memory – no cheating!) Month ________ Date ________ Year ________

2. Name the following pictures (don’t worry about spelling):

   ![Wreath](image1)
   ![Volcano](image2)
Answer these questions:

3. How are a watch and a ruler similar? Write down how they are alike. They both are... what?

________________________________________

4. How many nickels are in 60 cents? __________________________________________

5. You are buying $13.45 of groceries. How much change would you receive back from a $20 bill?

________________________________________

6. Memory Test (memorize these instructions). Do later only after completing this entire test:
   At the bottom of the very last page: Write “I am done” on the blank line provided.

7. Copy this picture:

![Cube Image]

8. Drawing test
   - Draw a large face of a clock and place in the numbers
   - Position the hands for 5 minutes after 11 o’clock
   - On your clock, label “L” for the long hand and “S” for the short hand
9. Write down the names of 12 different animals (don’t worry about spelling):

______________________________

______________________________

______________________________

______________________________

Review this example (this first one is done for you) then go to question 10 below:
Draw a line from one circle to another starting at 1 and alternating numbers and letters (1 to A to 2 to B to 3 to C).

1. Start

2. B

3. C

4. A

5. End

6. C

10. Do the following: Draw a line from one circle to another starting at 1 and alternating numbers and letters in order before ending at F (1 to A to 2 to B and so on).

1. Start

2. B

3. C

4. A

5. F

6. End
Review this example (this first one is done for you) then answer question 11 below:

- Beginning with 1 triangle and 1 square
- Move 2 lines (marked with an X)
- To make 2 squares and no triangle
- Each line must be part of a complete square (no extra lines)

1 triangle, 1 square  Move these 2 lines  Makes 2 squares (answer)
(Example)        (Example)        (Example)

11. Solve the following problem:

- Beginning with 2 squares and 2 triangles
- Move 4 lines (mark with an X)
- To make 4 squares and no triangles
- Each line must be part of a complete square (no extra lines)

2 squares, 2 triangles  Move 4 lines  Draw answer here
Mark with an X  4 squares

12. Have you finished? ___________________________________
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Douglas W. Scharre, Scharre.1@osu.edu, (614) 293-4969

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