Optimizing Performance in Adult Cochlear Implant Users through Clinician Directed Auditory Training

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ABSTRACT

Clinician-directed auditory training using the KTH Speech Tracking Procedure can be a powerful approach for maximizing outcomes with adult cochlear implant (CI) users. This article first reviews prior research findings from an 8-week clinician-directed auditory training (AT) program using speech tracking that yielded significant gains in speech tracking rate and sentence recognition scores following training. The second focus of the article is to illustrate the value of intensive face-to-face long-term AT using speech tracking with adult CI users. A detailed case study report is presented that demonstrates major ongoing and progressive gains in tracking rate, sentence recognition, and improvements in self-perceived competence and confidence over the course of intensive long-term training. Given the potential of both short- and long-term clinician-directed auditory training via KTH speech tracking to help CI users reach their optimal performance level, consideration for more widespread clinical use is proposed in the overall rehabilitation of adult CI users.

KEYWORDS: Auditory training, cochlear implants, aural rehabilitation, speech tracking

Learning Outcomes: As a result of this activity, the participant will be able to identify three benefits of clinician-directed auditory training using the KTH Speech Tracking approach and two outcome measures.

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The approach to auditory training (AT) offered to most adults with hearing loss appears to be either an app for a tablet or phone, or a computerized self-training program.[1,2] Although self-directed training approaches are both time- and cost-effective, the reliance on this model of rehabilitation does not take advantage of the unique training and professional rehabilitation skills of audiologists and other communication specialists and may not always be the best method to improve communication abilities for individuals with hearing loss. The value of clinician-directed aural rehabilitation (AR) to help individuals with hearing loss improve their auditory perceptual skills through focused AT may be key to optimizing performance of adults with hearing loss, and cochlear implant (CI) users in particular.[3–7]

It is instructive to note that one of the most recent AT apps for CI users was intended by its developer, Dr. Ratnanather at Johns Hopkins University, to "supplement in-person auditory training."[8] Thus, a comprehensive AR model of intervention is proposed, which relies on in-person AT with a clinician whenever possible, using self-directed training to support rather than supplant this training, except when it is the preferred mode for the client.

There is a powerful approach to clinician-directed AT, building on the speech tracking technique introduced by DeFilippo and Scott,[9] combined with computer-assisted methodology, that can serve to significantly improve the auditory perceptual skills of adult CI users—the KTH speech tracking technique of AT. The KTH computer-assisted method is based on an MS-DOS program created at the KTH in Stockholm, Sweden by Gnosspelius and Spens,[10] which was adapted as a Windows-compatible program by the Rehabilitation Engineering Research Center on Hearing Enhancement at Gallaudet University in 2007. Both speech tracking techniques require a talker (usually the clinician) and a receiver (usually the person with hearing loss). In the original form of this approach, the talker reads from a text, segment by segment, and the receiver has to repeat each segment without error. If an error occurs, the talker re-presents the segment until it is repeated verbatim. To reduce the level of difficulty, the talker could give clues, reword, rephrase, and so forth, to help the receiver correctly identify the original segment. At the end of a specified time period (usually 5 or 10 minutes) the total number of words presented and correctly identified is divided by the time elapsed to yield the receiver's tracking rate (TR), which is expressed in words per minute (wpm).

In the KTH speech tracking method, the clinician uses live voice presentation, but with predetermined segment length, and the use of only one repair strategy—repetition. The client is allowed a maximum of three repetitions after which the word that they have blocked on is presented visually, and the story continues from that point. Because the KTH method uses a computer for all of the variables of interest, TR and other performance measures are monitored unobtrusively and stored for subsequent analysis. The computer also provides the clinician with instructions on how to implement the strict set of rules that distinguishes the KTH method from the traditional method of speech tracking.

This article will review the findings for this approach, for both short- and long-term training paradigms. This article has the following two aims. The first aim and focus of this article is to demonstrate the importance of clinician-directed AT as a means of maximizing speech recognition outcomes for adult CI users. This will be shown through the review of prior research using KTH speech tracking for AT and through a case study report. The second aim of this article is to illustrate the value of intensive face-to-face long-term AT with adult CI users. A review of prior research shows that improvement can be seen within a short time frame of 8 weeks. The value of long-term training is demonstrated in great detail through a case study report that shows ongoing improvements over the course of intensive long-term training.

PREVIOUSLY PUBLISHED RESEARCH

With respect to the first aim of this article concerning clinician-directed AT, we report on a prior study by Bernstein et al that examined whether clinician-directed AT by means of speech tracking training can yield improved communication skills in postlingually deafened adult CI users.[3] Two methods of speech tracking training, DeFilippo and Scott's traditional (TRAD) method and the KTH computer-assisted method, were compared to determine their effectiveness for enhancing communication skills and maximizing benefits for adult CI users.[9]

Ten postlingually deafened adult CI users participated in this study and engaged in an 8-week auditory-only training program. A balanced design was used in which half of the participants began with four training sessions using the KTH method, followed by four training sessions using the TRAD method for a total of 8 sessions. The other group began with the TRAD method followed by the KTH method. Participants were randomly assigned to the two groups. Although both methods rely on verbatim responses to connected discourse, the KTH methodology uses computer-controlled, predetermined segment length and strict repair strategies. Each training session consisted of four speech tracking trials of 5-minute duration. Preassessment testing (PRE1, PRE2) was conducted using Boothroyd's CasperSent multimedia program that evaluates sentence-level speech perception.[11] A total of four sets of recorded sentence lists were presented via audition only, and the 60 sentence lists were randomized to ensure that participants did not receive the same list twice. Testing using CasperSent was performed after 4 weeks of training (MID1, MID2) and following 8 weeks of training (POST1).

Subjects showed significant gains in both TR ($p < 0.001$) and sentence recognition ($p < 0.001$) following training with both speech tracking methods. Improved sentence recognition was maintained 3 months after the completion of training. Fig. 1 shows mean TR as a function of training session. Three regression lines are shown: (1) mean TR averaged over all subjects, (2) TR of the subjects showing the smallest improvement, and (3) TR of the subjects showing the largest improvement. The fitted linear regression line for the mean TR averaged over all subjects showed an increase of 16 wpm from first to last training session (standard deviation = 10.4 wpm). It should be noted that the majority of subjects continued to improve across the training period and did not reach a plateau in performance.

A comparison of the order of tracking method revealed that learning was greatest in the first 4 weeks of training for both tracking methods. However, three subjects demonstrated greatest

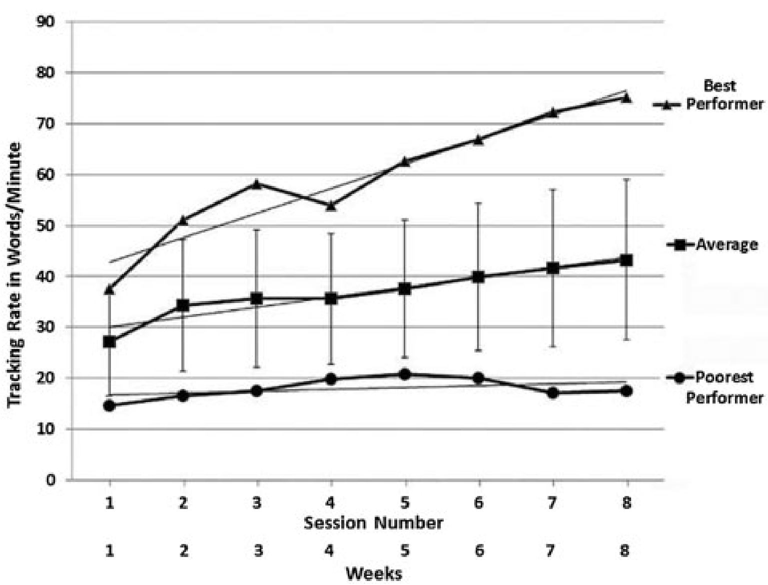

Figure 1 Improvement in tracking rate across all trials for Kungliga Tekniska Högskola and traditional approaches combined: average, poorest, and best performance.

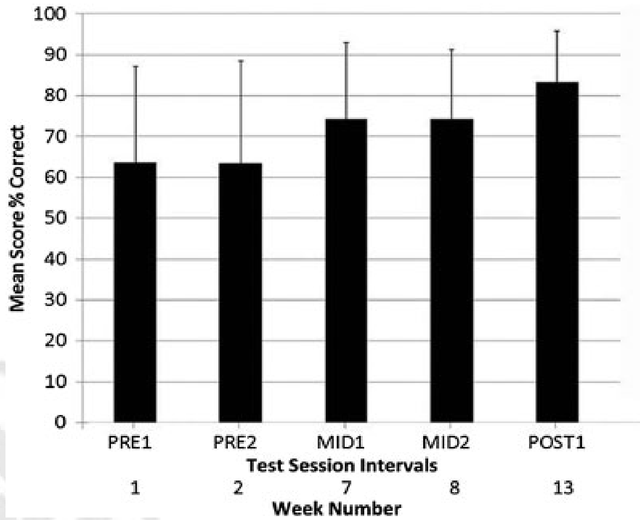

Figure 2 Sentence recognition improvement across test session intervals.

improvement in the second 4 weeks of training; two began with the KTH method, the other began with the TRAD method. These subjects were older and may have needed additional time to derive maximum benefit from training. The TRAD and KTH methods also were compared with respect to between-trial variability. The KTH approach was found to be significantly less variable than the TRAD method (F [1, 27] = 8.78, $p < 0.05$). Average standard deviation for a tracking trial was 3.8 wpm for the KTH approach compared to 5.1 wpm for the TRAD method, suggesting that the KTH method may be a more efficient approach to training.

Mean CasperSent sentence recognition scores based on four lists were obtained at all assessment intervals (see Fig. 2). A repeated measures analysis of variance showed a significant effect for assessment session (F [4, 36] = 13.89, $p < 0.001$). A post hoc analysis showed that sentence recognition scores were not significantly different for assessment sessions PRE1 and PRE2, and for MID1 and MID2, but the mean recognition score for assessment session POST1 was significantly higher than for sessions MID1 and MID2 and that the scores for these two sessions were significantly higher than for sessions PRE1 and PRE2. These results indicate significantly improved sentence recognition following training on the order of 15 to 20% performance gains.

The most important finding was that clinician-directed AT using speech tracking resulted in significant improvements in both TR and speech recognition for postlingually deafened CI users. The improvement in speech recognition performance was demonstrated within a short 8-week training period using a novel, untrained stimulus set of recorded sentence material. Nine of the ten subjects showed improved sentence recognition after 8 weeks of training with speech tracking. The one subject who did not show an increase scored close to ceiling at the start of the study, leaving no room for performance gains. Improvement following training also was seen on communication goals and psychosocial function as measured on the Client Oriented Scale of Improvement developed by Dillon et al,[12] and on the Communication Profile for the Hearing Impaired, developed by Demorest and Erdman,[13] respectively. See Bernstein et al for complete results and discussion.[3]

The second most important finding from this research was that subjects continued to show improvement in TR throughout the course of training and did not attain a plateau in performance. This lends support to the second aim of this article that longer-term AT training can yield additional benefit. The remainder of this article focuses on the second aim, illustrating the value of intensive face-to-face long-term AT with an adult CI user. The case study presented used the KTH approach and modifications of speech tracking to provide long-term training and a measure of the subject's performance over time.

MATERIALS AND METHODS

Subject

The subject (A.L.) was a 51-year-old woman with a severe to profound congenital sensorineural hearing loss. She was fit with hearing aids (HAs) in early childhood and continued to wear them throughout her school and adult life. A.L. was mainstreamed throughout her schooling and worked as a financial controller. She had highly intelligible speech and excellent lipreading skills, but reported that she was not able to understand speech via listening alone using her HAs (prior to cochlear implantation). She did, however, report that the use of HAs greatly enhanced her lipreading performance. A.L. received a CI in her right ear in mid-2011. A.L. has participated in an AT program since activation of her CI. All training has been provided with A.L. wearing both her CI and HA, which is the configuration she wears at all times.

Training

TRAINING PERIOD 1: SEPTEMBER 2011 TO JANUARY 2012

For the first months of training, sessions lasted from 1 to 1.5 hours per week. The major focus was on the auditory-only presentation of closed-set word and sentence materials, which were aimed at improving the subject's ability to recognize speech via listening. All materials were presented live voice, and an acoustic shield was used to ensure that the subject did not have access to lipreading cues. As the subject's ability to identify closed-set words and sentences improved, attempts were made to introduce some simple and predictable conversations via listening alone. Although extremely difficult for A.L. at first, the approach indicated that her ability to understand speech by audition alone was improving gradually.

TRAINING PERIOD 2: FEBRUARY 2012 TO OCTOBER 2012

After approximately 4 months of weekly training sessions, more complex open-set listening tasks were introduced, and the duration of each training session was extended to 2 hours. Materials used included TeenTrax,[14] a modified speech tracking task. A story was read line by line, and A.L. was encouraged to repeat as many words as possible. Each line was read twice, and following her response, she was shown the written segment, which was then read a third time, so that she could relate the spoken to the written form. At the end of one page of text (around 200 to 250 words per page), the number of words correctly identified was divided by the total number of words presented to obtain a percent correct score. The average score for four pages of text is defined as a *block*. A block was usually completed in each weekly session.

TRAINING PERIOD 3: NOVEMBER 2012 TO MARCH 2015

Following the completion of the previous phase of training, it was decided to introduce speech tracking using the KTH procedure. At first, the materials used were a series of short stories involving the characters from the TeenTrax story.[15] The subject's TRs for this task were in the range of 20 to 25 wpm, which is believed to be the minimum performance level for this approach. TRs of less than 20 wpm usually result in frustration for the listener and do not allow access to sufficient information to use context to aid in understanding.

"Kumanjayi," a 160,000-word story designed for speech tracking training, was first used with A.L. in November 2012. Kumanjayi was specifically written for speech tracking training and was told in the first person in an attempt to replicate normal conversational style. The aim of such a long story was to ensure that long-term training could be provided using the same material and level of complexity. Each tracking segment presented is a new part of the story. This is a distinct advantage of having such a long story, as it provides the opportunity to measure the subject's performance over an extended period of time using material of equivalent difficulty. Several clients

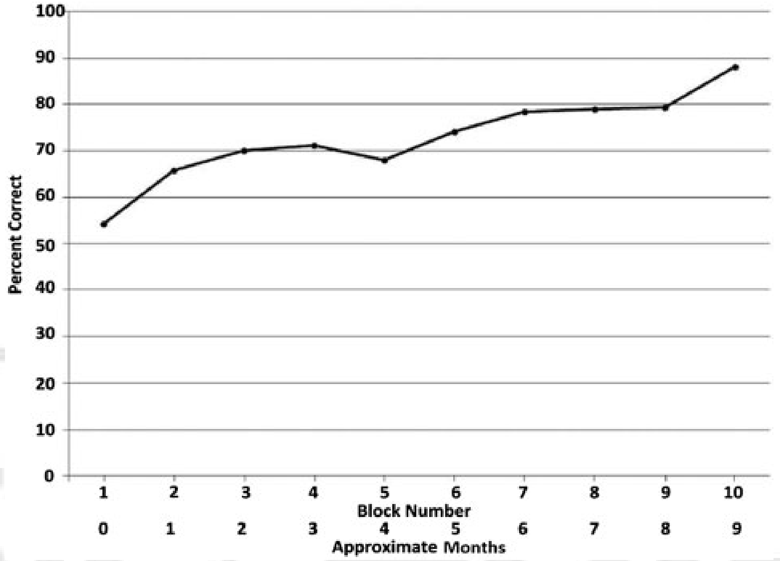

Figure 3 Percent correct scores obtained by the subject for auditory only presentations of TeenTrax. Each datum point (block) is the mean for four pages of the text—approximately 1,000 words.

have completed the entire story over the past few years, and all have reported that they enjoyed the plot and characters.

At first, the story was presented auditory-only, but it became apparent that this approach led to great frustration for A.L. Her TRs were in the range of 20 to 25 wpm, making it difficult for her to follow the story and use contextual information to aid speech perception. In April 2013, it was decided to alternate auditory-visual (AV) and auditory-only presentation conditions during training to ensure that A.L. was able to follow the plot more easily, thereby reducing frustration with the task. Typically, the subject was presented with four 5-minute tracking sessions in each condition on each training day.

RESULTS

A.L.'s performance increased from around 50% to over 80% correct across training sessions in training period 2, which occurred over a period of about 9 months. The data were grouped into 10 blocks with four replications within each block, where each replication is the percent correct score for a page of text. A one-way fixed-effects analysis of variance was used. Because the data were in the form of percentages, an arcsine transformation was used to stabilize the error variance. The block scores showed a statistically significant improvement over the training program (F [9, 30] $= 4.85$, $p = 0.001$). As shown in Fig. 3, the average percent score increased from 54.4 to 88.1% over the course of training.

Fig. 4 shows the results of an additional evaluation of training over 18 sessions. Material similar to TeenTrax auditory-only was used. An independent measure of intelligibility was obtained using sentence lists drawn up consisting of only the 500 most frequently occurring words in spoken American English.[16] Each list includes 25 sentences that contain a total of 200 words. Each sentence was presented twice by audition alone before A.L. was asked to repeat what she had heard. One sentence list was presented at each training session. The results are similar to those obtained with the TeenTrax material, with a steady rise in performance across the course of training. A fixed-effects analysis of variance was performed in which the data were subdivided into 9 biweekly training sessions. There were no significant differences between the two scores obtained within each biweekly session, and these were treated as replications. The average score improved significantly from 41.5% at the start of the training segment to 81.2% correct at its completion (F [8, 9] $= 8.92$, $p = 0.002$).

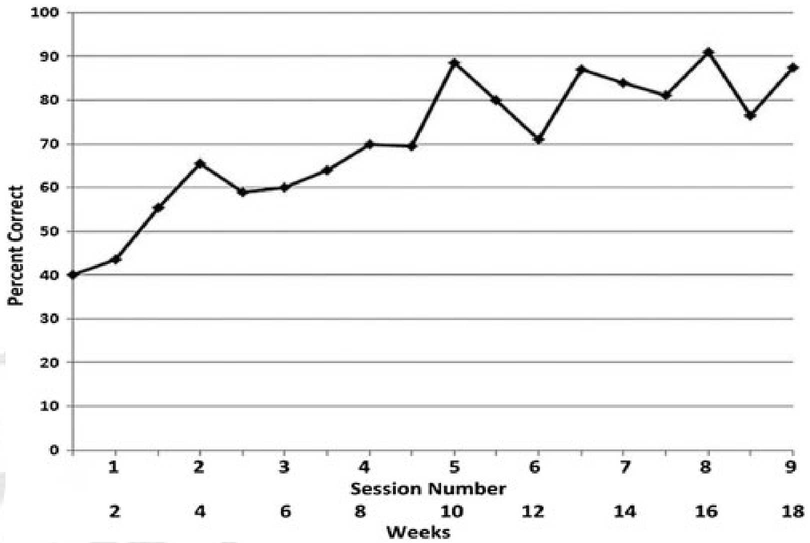

Figure 4 The subject's percent scores obtained for sentence materials.

Fig. 5 shows A.L.'s TRs in the auditory-only and AV conditions over the 23-month period from April 2013 to March 2015 (training period 3). During this period, A.L. attended a total of 48 training sessions, which is two sessions per month, on average. A.L. was presented with four 5-minute speech tracking trials in the auditory-only and AV conditions during each training session. Each datum point represents the mean TR for twelve 5-minute speech tracking trials. The total training time shown is 16 hours in each condition over the

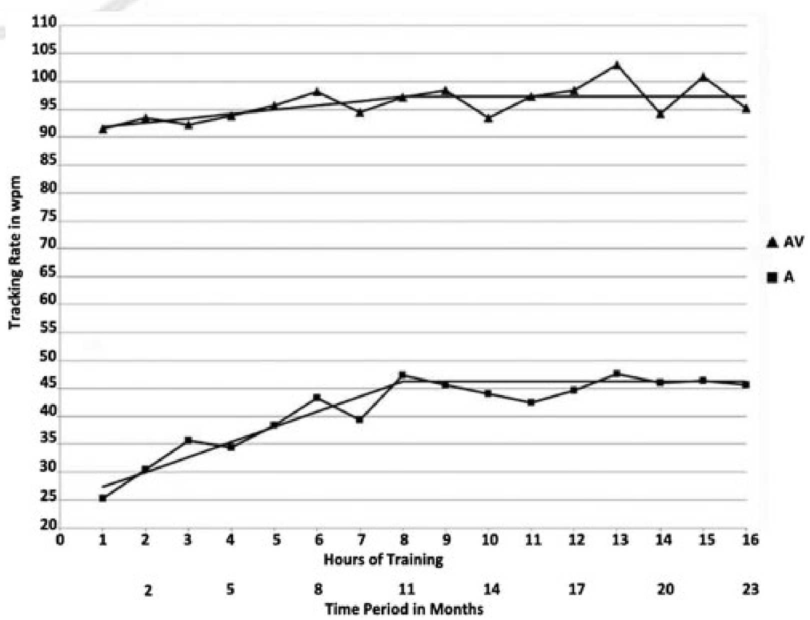

Figure 5 The subject's tracking rates for the ''Kumanjayi'' text auditory-only (A; squares) presentation and auditory-visual (AV; triangles) presentation. Each data point is the mean tracking rate for twelve 5-minute tracking trials. The lines represent a least squares fit to the data.

23-month period. A fixed-effect analysis of variance was performed in which the 5-minute speech tracking trials were grouped into 16 blocks of 12, each block of twelve 5-minute speech tracking trials corresponding to 1 hour of intense training over a 3-month period. A three-factor fixed-effects analysis of variance was performed consisting of presentation mode (AV, auditory-only), hours of training (1 to 16) and within-hour training (1 to 12).

As shown in Fig. 5, presentation mode (AV, auditory-only) was highly significant. Speech TR for the AV condition was substantially greater than that for the auditory-only condition ($F\,[1, 165] = 2{,}030.3, p < 0.0001$). There was also a significant hours-of-training effect ($F[15, 165] = 15.17, p < 0.001$). Within-block training was not statistically significant ($F\,[11, 165] = 0.42, p = 0.947$). The interaction between presentation mode and hours of training was significant ($F\,[15, 165] = 4.80$, $p < 0.001$).

For the AV condition, the rate of increase with training was small, beginning at 91 wpm and rising slowly to ~97 wpm. TR reached a plateau of 97 wpm after ~8 hours of training over 1 year's time, at which point A.L.'s TR showed considerable variability, which may be a function of difficulty with sustained attention secondary to a medical condition that arose at that point in time. Because of increased variability in the region of the plateau, two straight lines were fitted to the data. One line was fitted to the data showing an increase TR with training, and a second line was fitted to the more variable data in the region of the plateau. The two lines were connected at a join point, the location of which was obtained by finding the mean squared deviation of the data from the two fitted lines. The join point at 8 hours of training showed the minimum mean squared deviation. The line fitted to the first 8 hours of training showed a slope of 0.8 wpm/h of training, which differed significantly from 0 ($t\,[6] = 3.47, p < 0.005$). The slope of the line fitted to the remaining 8 hours of training was not statistically significant ($t\;[6] = 0.221$, $p < 0.4$; shown as a horizontal line in Fig. 5).

There appeared to be a plateau for the AV condition. There are two possible interpretations of the data. The first interpretation based on a statistical analysis of the complete set of data after completion of training suggests that TR plateaued after 8 hours of training. A second interpretation is based on an hour-by-hour review of the data, with knowledge of TR during previous hours of training but no knowledge of TR in later hours of training. This interpretation also finds that TR improved systematically up to 8 hours of training, but suggests that TR performance beyond the 8-hour juncture represented high variability and not a plateau. Increased variability may be attributed to A.L.'s medical condition and did not preclude the possibility of further improvements once the medical problem resolved.

For the auditory-only condition, TR increased rapidly at first, beginning at 27 wpm, and plateaued at 46 wpm after ~8 hours of training over 1 year's time. As before, two straight lines were fitted to the data and the least squares fit to the data showed a join point at 8 hours of training. The slope of the fitted line for the first 8 hours of training was 6.8 wpm/h of training and was significant ($t\,[6] = 6.84$, $p < 0.0005$). The slope of the line fitted to the remaining 8 hours of training was not statistically significant ($t\,[6] = 1.28$, $p < 0.1$; shown as a horizontal line in Fig. 5). TR improvements for the auditory-only condition were very impressive given A.L.'s inability to follow speech via audition only prior to her CI and commencing training.

It took almost a year for A.L. to attain a maximum performance level. After the juncture of 8 hours of training over a year's time, the most salient feature of her performance when reviewed on an hour-by-hour basis was not a plateau but rather great variability. Faced with this variability in performance, both A.L. and the clinician decided to continue training in the hope of maintaining her skill level. From a clinical perspective, it is important to recognize when a plateau in performance is truly observed and what its implications are. If there is no improvement in skill level, and variability is not the issue, the clinician may either modify the treatment or discontinue training for a period of time. Following the latter option, a reevaluation is needed to determine whether or not a drop in performance is observed. If performance has in fact dropped then further training would be warranted.

A.L.'s report of greater confidence to understand speech via listening alone was reflected in her ceiling rate, recorded by the KTH software, providing insight into performance and perceived abilities. Ceiling rate is calculated using only those lines that the listener repeats back correctly on the first attempt. The mean number of lines repeated back without error was calculated for A.L.'s first hour of speech tracking in the two presentation conditions, and was found to be 2.9 lines (auditory-only) and 51.8 lines (AV). For the final hour of training (see Fig. 5), the number of correct lines was 9.3 for the auditory-only condition and 59.9 for AV presentations.

Fig. 6 shows the percent correct scores for 11 data sets of speech recognition assessments. The subject's speech recognition performance during the 12-month period from April 2013 to April 2014, which corresponds with the first 8 hours of speech tracking training shown in Fig. 5, was evaluated by audition alone using the City University of New York (CUNY) sentence lists.[17]

Four CUNY sentence lists were presented live voice via audition alone during each assessment session. Each sentence was presented twice, and the subject was encouraged to repeat as many words as possible. No feedback as to the correctness of her response was provided and each list was presented only once. A total of 44 lists were presented over the period of 1 year, and during this time the subject's scores rose from around 50 to ~85% correct. The percent scores were subdivided into 11 sets with four replications per set and the data were subjected to fixed effects analysis of variance demonstrating a significant improvement in percent score ($F\,[10, 33] = 5.06$, $p < 0.001$).

Speech tracking was not the only form of training used with A.L. over this 2-year period. Several other stories using the same technique as that found in TeenTrax also were used during this period. The materials used included SpeechTrax,[18] a revised and expanded version of Hans Christian Andersen's The Tinderbox, and a revised version of Andersen's The Emperor's New Clothes.[19] Both these stories have been rewritten in a more complex conversational style and have been used in training with a large number of adult subjects.

DISCUSSION

This article summarizes a recent experimental evaluation of the KTH speech tracking procedure followed by a report of a long-term case study using the tracking procedure for AT. The experimental data show statistically significant improvement in both TR and speech intelligibility using an independent test of speech recognition. TR improved from 27 to 43 wpm, on average; speech recognition scores improved from 63 to 82%, on

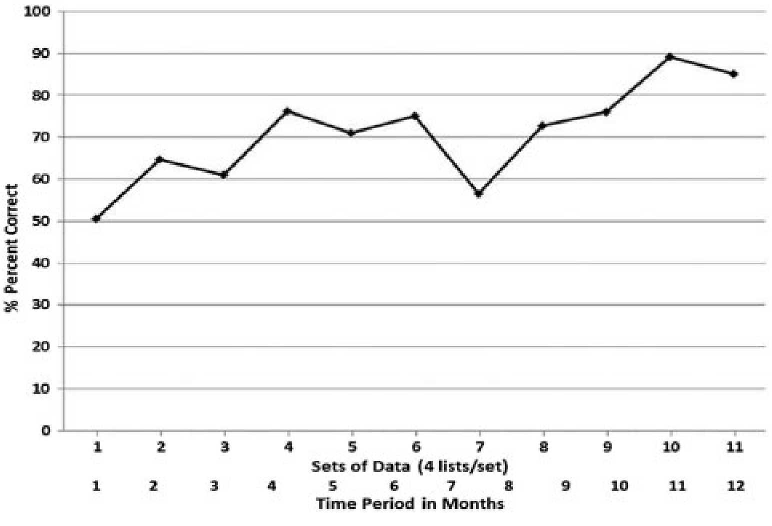

Figure 6 Percent correct scores obtained by the subjectAL for auditory only presentations of the City University of New York CUNY sentences. Each datum point is the mean score obtained for blocks of four lists.

average, for the 10 subjects with CIs participating in the study. These improvements were obtained after 8 weeks of training with no evidence of a slowing down in the rate of improvement for either TR or speech recognition. In contrast, the case study reported on improvements over a 3-year period in which there were significant gains in both TR and speech recognition over several years (see Figs. 3 and 4). The improvement in TR with training appears to approach a plateau after a year's time, about midway through the training program for the auditory-only mode of presentation (see Fig. 5). For the AV mode presentation, improvement in TR performance also appears to reach a plateau, but in this case, the TR is close to the expected TR for a person without hearing loss. When interpretation is based on an hour-by-hour review of the data after the juncture of 8 hours of training over a year's time, the most salient feature of her performance is not a plateau but rather great variability. It is important to note that A.L. developed a health problem in the latter half of the training regimen that altered her ability to concentrate efficiently and impacted her listening skills. In light of the considerable variability in her performance, both A.L. and clinician decided to continue training in an effort to maintain her skill level. This does, however, raise the issue of clinical implications of reaching a plateau that are addressed later in this section in relation to duration of training.

Overall, the case study and prior research summarized in this article support the first aim showing that clinician-directed AT using the KTH speech tracking procedure is an effective training approach to optimize speech recognition outcomes in adult CI users. The findings from the case study support the second aim on the value of intensive long-term clinician-directed training with adult CI users.

Aim 1: Clinician-Directed Auditory Training

CLINICIAN AS COACH TO HELP CLIENT OVERCOME DIFFICULT TRAINING DEMANDS AND SUCCEED

Results presented in this article demonstrate that clinician-directed AT using speech tracking can result in significant improvements in both TR and speech recognition for adult CI users, even in a short 8-week time frame. The clinician–client dynamic offers a unique training condition that can yield successful outcomes. To understand what may account for this we look to the role of the clinician as coach or even personal trainer. In comparing clinician-directed to self-directed training, it has been noted that although self-training programs are worthwhile, many people unfortunately find this form of training tedious or boring. It may be that lack of interaction with a clinician is an important reason for this. A key component is not merely to provide exercises for improving the client's auditory perceptual skills, but to also encourage the client to continue the training even when it becomes difficult. This encouragement and affirmation of the client's performance may be hard to quantify, but it may be a key factor in having the client continue to train over an extended period. It is not clear whether the KTH speech tracking training itself, or the role of clinician as coach, is responsible for reports of improved self-confidence following training. These areas warrant further study.

ROLE OF DELIBERATE PRACTICE WITH A CLINICIAN FOR FACILITATING COMMUNICATION SUCCESS AND EFFECTIVENESS

Colvin, writing of the critical role of deliberate practice in attaining the level of expert, listed several key attributes of such practice.[20] These are: "It is designed specifically to improve performance."[20(p.67)] This requires a therapist/teacher who assesses the client's individual strengths and weaknesses and develops a program to help improve performance. Other aspects include the following: "It can be repeated a lot," "Feedback on results is continuously available," and "Deliberate practice is highly demanding mentally."[20(pp.69–70)] As a result, this type of practice may be best accomplished in sessions of around 60- to 90-minute duration. Colvin contends that experts in any field are those who are motivated to continue with directed practice even when it is extremely difficult and even unenjoyable. Kimball, in concurrence with Colvin's work, emphasized the role of the teacher to select areas in which the student requires practice and to persevere even when it becomes difficult.[21] This, again, highlights the importance of face-to-face contact with a clinician. The KTH tracking procedure and other variants of speech tracking would seem to meet several criteria for *deliberate practice* and should be considered an important part of training with most adult CI clients.

ROLE OF COMPUTER-BASED AUDITORY TRAINING IN CLINICAL PRACTICE

Computer-based activities represent an important supplement, and in some cases, an alternative to direct face-to-face training. Studies of computerized AT by Sweetow and Sabes showed improvements in performance,[22] but other studies by Taylor and Shrive and Sweetow and Sabes found many users, one third and two thirds, respectively, failed to complete the training.[23,24] Thus, compliance with auditory self-training programs, or lack thereof, is a major issue. Chisolm et al further noted the important issue of compliance and its impact on outcomes.[25] A method for improving motivation and compliance reported by Levitt et al is to make training sessions entertaining.[26]

Aim 2: Intensive, Long-Term Auditory Training

DURATION OF TRAINING

A major question that seems to arise from these results concerns the duration of training required for the individual client to attain optimal performance with her or his CI. In looking at the results of research by Bernstein et al,[3] all of the subjects appeared to be continuing to improve across the training period and none seemed to have reached a plateau in their performance level after eight training sessions. This would seem to support the idea that increased training leads to improved performance and creates a conundrum for those working in this area. It is recognized that providing long-term training is extremely expensive and places great demands on the resources of clinical facilities, but it also needs to be recognized that as clients are provided with training they may continue to improve.

For the case study presented, findings regarding duration of training are more complex. Over a period of ~3 years, A.L. received 1:1 training once every 2 weeks, on average. Speech tracking data show a steady improvement in A.L.'s performance in the auditory-only and AV condition over the first 8 hours of this training, corresponding to midway through the training. From the complete set of data after completion of training, it would appear that there was a leveling off in her TR. This could be interpreted as limits of her performance, fatigue, and difficulty with concentration, secondary to a serious medical condition that arose at that time, impacting performance. A more salient feature of her performance when reviewed hour by hour was the great variability that was observed beyond the 8-hour juncture. However, A.L. reported that her improved TR generalized to better understanding of speech in daily life and greater self-confidence, thus encouraging ongoing training. It is not known whether 8 hours represents the maximum saturation of training for A.L., or whether additional practice sessions would have yielded greater TR rates once her medical issues were resolved.

The issue of plateau in performance warrants consideration. A client can work hard, but sometimes progress can stagnate. When this is the case it means that training is no longer effective or that the client's abilities have reached a plateau. For clients where a plateau in performance is observed, one option is for the clinician to change either the difficulty of the material, the conditions for training, or other parameters in an effort to help the client extend their abilities further. If this does not result in improved performance then training should be stopped for a period of time and a reevaluation performed to see whether or not a drop in performance is observed. If skills are not maintained and a drop is noted, then it would be appropriate to resume further training. Both Durity and Jacobs at the National Technical Institute for the Deaf observed that adult deaf students who took training courses in auditory speech comprehension and speechreading showed improved skills in these areas after training, but that these improved skills gradually declined over time.[27,28] An important implication is that AT skills need to be maintained by daily use and refresher training programs.

Ericsson et al presented the striking finding of the "ten thousand hour rule," which is cited as the amount of training required to reach expert level.[29] Gladwell cited the work of Ericsson and his colleagues to make a case for extended practice periods to attain the proficiency level of an expert.[30] It is, of course, unreasonable to expect that any adult CI user could practice for such an extended period, but Ericsson's work emphasized that performance level is correlated with amount of practice,[29] or as Boothroyd noted, "time on task."[31] Although the training period described in this article for the case study report was quite long, the client reported that she found the training challenging. She also reported that she enjoyed the story material greatly. The use of the same story serves to maintain the client's interest for an extended period of time, and the length of the story used (more than 160,000 words) ensures that long-term training can be provided using the same material and level of complexity. Furthermore, the KTH tracking technique provided immediate feedback that helped maintain motivation and confidence. Although repetition and practice are needed, it is clinician feedback and reinforcement associated with the training that seems most important.

INTENSITY OF TRAINING

The duration of the sessions provided to the client presented in the case study was typically around 2 hours and around half of this time was devoted to training using either the KTH tracking procedure, or one of the speech tracking modifications. Providing short breaks between sessions and discussing the client's TR and other measures helped to maintain the willingness to persevere with the task even though it was extremely taxing at times. Consideration should be given to providing copies of the KTH software and suitable texts for use at home with family members or friends acting as the talker, which would enable CI users to not only have more regular and long-term training, but have the benefit of training with their frequent communication partners.

Research Considerations for the Use of Clinician-Directed Auditory Training Using KTH Speech Tracking

Factors affecting the success of this approach need further study and will be important for shaping clinical practice. Are the improvements in speech recognition related primarily to time on task, the structured nature of the KTH technique itself, the role of clinician feedback and support on self-confidence, or perhaps the factor of sustained attention during a live, intensive training session with a clinician? Can improved speech recognition performance be obtained in a shorter time frame, and will those improvements generalize to critical areas of participation, personal communication goals, and psychosocial function for the individual with hearing loss? These are some of the areas that warrant further study.

CONCLUSION

Clinician-directed KTH speech tracking is an effective AT technique for maximizing speech recognition for adult CI users. The ability to optimize outcomes for adult CI users through clinician-directed training, particularly long-term training, suggests that there is an untapped strength in providing hearing therapy for our CI clients that warrants greater consideration in the overall rehabilitation of adult CI users.

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KTH speech tracking software can be found at: http://hearingresearch.org/software/KTH/.

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