Early Versus Delayed Speech Perception Training for Adult Cochlear Implant Users: Initial Results

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Subjects were 13 post-lingually deafened adults who received a Symbion or Nucleus multi-channel cochlear implant. Auditory and auditory-visual testing of syllable, word, and sentence perception was conducted at 1 and 9 months after initial stimulation. Five subjects received intensive aural rehabilitation (AR) after the 1-month test; 8 received training after the 9-month test. Each group was retested immediately after training. Trends in the group mean data suggest that gains following early AR may exceed those achieved through implant use alone. Future research issues include relative contribution of specific training components, optimal intervals between training sessions, and generalization of training.

Since the development of cochlear implants (CI) in the 1960s, more than 3,000 people have been implanted with a variety of these devices. A large majority of CI users report improved communication skills as a result of implant use (*Cochlear Implants,* 1988). With rare exceptions, CI users evaluated at The University of Iowa Hospitals and Clinics ($N = 54$) report that skills continue to increase over time, implying that the immediate effects of implantation may not represent a complete picture of potential benefit to the CI user. The assumption is that CI recipients learn to use the electrical stimulation over time, and it is generally agreed among professionals that a systematic rehabilitation program will enhance the learning process (Abberton et al., 1985; Eisenberg & Berliner, 1983; Hochmair-Desoyer, Hochmair, Burian, & Fischer, 1981; House et al., 1976; Owens, 1983; Owens, Kessler, & Raggio, 1983; Owens & Raggio, 1987; Porter, Lynn, & Maddox, 1983). Activities commonly provided in AR

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programs for CI users include setting the device and managing it mechanically; monitoring their speech; discussing information about communication, assistive devices, and the speech signal; training in specific audiovisual skills; and listening to controlled acoustic stimuli.

Accountability is a central issue in AR. Ross (1987) suggested that robust evidence is needed to conclude that AR training is responsible for improvement in communication performance. While pre/post assessment scores suggest measurable improvements following AR (Clark, Tong, & Martin, 1981; Engelmann, Waterfall, & Hough, 1981; Maddox & Porter, 1983; Thielemeir, Brimacombe, & Eisenberg, 1982), these data may be confounded by the implant user's experience in daily communication situations. A major limitation in the experimental design of most studies is the absence of a control group. Ethical considerations of withholding therapy from some subjects have been cited as reasons for not establishing control groups (Rubinstein & Boothroyd, 1987).

In an attempt to differentiate between the effects of (a) training and (b) CI use without training, we evaluated performance on a variety of speech perception tasks for subjects receiving an early versus delayed course of intensive AR. Additionally, the subjects receiving early AR were evaluated 9 months after AR to determine if training effects were maintained. It was not the purpose of this study to compare devices.

METHOD

Subjects

Subjects were 13 consecutively admitted participants in the University of Iowa Cochlear Implant Program Project. Prior to implantation, all had profound (pure tone average $\geq$ 95 dB HL), bilateral, post-lingually acquired hearing losses. Subject characteristics are presented in Table 1. None scored higher than 4% when NU-6 word lists were presented at 60 dB HL in the sound field with appropriately fitted hearing aids. Under aided conditions, three subjects demonstrated improved performance on recorded audiovisual sentence material compared to that achieved in the vision-only presentation. None understood more than 10% of the words from the auditory-only presentation of the Iowa Sentence Without Context Laser Video Disc Test (Tyler, Preece, & Tye-Murray, 1986). No subject continued to use a hearing aid after implantation. Full-scale IQ scores, assessed by the WAIS-R, were low average or better. Psychometric testing did not reveal significant psychopathology in any subject.

Subjects were alternately assigned to receive either a Nucleus or Symbion cochlear implant and a course of intensive AR at 1 or at 9 months after initial stimulation. Initial assignments for pairs of subjects (one Nucleus and one Symbion user) were to the delayed AR group. At the time of this report, the number of subjects in each group was unequal.

Table 1

Characteristics of Subjects Assigned to Receive Aural Rehabilitation (AR) at 1 mo (Early) and 9 mo (Delayed) After Initial Stimulation

Subject	Age at Implantation	Age at Onset of Hearing Loss[a]	Years of Bilateral Profound Deafness[a]	Years of Hearing Aid Use[a]
Early AR				
1	68	14	3	20
2	67	51	8	5
3	31	21	8	0
4	44	21	23	0
5	67	14	3	42
Delayed AR				
6	62	27	35	0
7	71	70	1	1
8	65	23	7	32
9	65	20	44	0
10	68	26	4	41
11	62	37	1	0
12	29	birth	19	20
13	52	8	21	16

[a] Case history supplied by subject and verified by medical and audiological records when possible.

Implant Type

The Nucleus implant (Blamey, Dowell, Clark, & Seligman, 1987) delivers a sequence of pulses to an intra-cochlear array of 22 electrodes. The current level, pulse rate, and places of electrical stimulation correspond to estimates of amplitude, voicing frequency, and the first and second formant frequencies, respectively. The Symbion implant (Eddington, 1980) divides the acoustic signal with four filters centered in different frequency regions. The output of each filter is amplitude compressed and delivered to one of four intra-cochlear electrodes.

Training

Three long-term goals were pursued for each subject: (a) development of realistic expectations, (b) development of audiovisual and auditory-only speech perception skills, and (c) effective communication coping behaviors. Procedures related to all goals will be described but results are reported only for goal #2. The geographic location of patients, and employment and family commitments, necessitated an intensive training program. The same clinician (first author) conducted 40 hours of intensive AR training over a 10-day period with each subject.

Realistic expectations. Counselling regarding appropriate expectations from CI use was conducted at the initial contact with potential candidates. They and their families were informed of advantages and limitations of implants as indicated by data reported in the literature and collected in our program. The variability in degree of benefit among implant recipients was underscored. Subjects were encouraged to meet a variety of implant users. We cautioned subjects not to expect to regain or develop normal auditory perception. They learned that the majority of our CI recipients demonstrate improved one-to-one audiovisual communication functioning, and continue to depend upon visual cues in groups and noisy reverberant situations.

As the subjects gained experience with their implant, individuals' expectations changed. Subjects were advised in setting realistic short-term communication goals to enhance interpersonal, educational, and/or vocational growth.

Audiovisual and auditory-only speech perception. All subjects completed a series of 10 self-administered auditory training exercises during the first month of implant use. These exercises progressed from the detection of a stimulus within a specified time interval to same/different discrimination of words with contrasting phonemes (e.g., bat, mat). Stimuli were recorded on language master cards. Subjects documented the number of attempts and percent correct score attained for each exercise.

At their assigned time of AR, subjects received a combination of analytic and synthetic auditory and audiovisual training. An individual subject's program was determined by performance on pretraining criterion measures. Training exercises were designed to elicit 80% correct scores. Response tasks included: (a) 3-interval forced-choice, (b) same/different, (c) category recognition, (d) closed-set recognition, and (e) open-set identification. These tasks are described in Appendix A.

Training consisted of drills contrasting individual speech sounds, sentence-stress patterns, and intonation patterns. Stimuli used for testing were consistently omitted from all AR training measures. Consonant, vowel, and diphthong training used target words embedded in phrases or sentences. Target words were designed to contrast phonemes that the subject confused in audiovisual and/or auditory modalities. Both recorded and live voice stimuli were used to train recognition of suprasegmental features. Some subjects required a visual display of the suprasegmental information afforded by a Visipitch.

Additional exercises consisted of sentence recognition and practice using context. Context was provided in related sentences organized by topic, situation, and clue word. Recognition of unrelated sentences and tracking (De Filippo & Scott, 1978) were also incorporated into training. Materials were presented in auditory and audiovisual modalities in quiet and in the presence of noise (multispeaker babble).

Communication coping behaviors. Subjects were assisted in analyzing their feelings regarding their communication performance and specific communication difficulties because data from Elfenbein, Lansing, Davis, and Kallus-Gay

(1987) suggested that implant candidates, independent of the duration of hearing impairment, reported a limited repertoire of communication coping strategies. Techniques included role playing, video simulations of difficult communication situations, self-assessment inventories, and discussions of past communication difficulties.

One task used a question format in a series of situational contexts (Lansing & Davis, 1986). A videotaped speaker presented information and directed a question to the subject. Environmental factors, speaker-specific behaviors, and linguistic factors were controlled to vary communication difficulty. Subjects were to assess how well they understood the speaker, respond to the question, identify any communication difficulty, and prioritize repair strategies. A sample exercise is included in Appendix B.

Assessment

Assessment included recognition of CID Everyday Sentences (Johnson, 1975), tracking, and selected tasks from the Iowa Laser Video Disc Battery (Tyler et al., 1986). Auditory and audiovisual speech perception data were analyzed for four tasks: (a) medial consonant recognition, (b) vowel recognition, (c) four-choice spondee word recognition, and (d) primary sentence stress recognition. Subjects were not trained on the test materials which were recorded by male speakers unfamiliar to the subjects. The Communication Profile for the Hearing Impaired (CPHI) (Demorest & Erdman, 1987) and The Communication Strategies Test (Elfenbein & Davis, 1986) were administered to assess feelings regarding communication performance and specific communication difficulties. Transcripts of a communication interaction with an unfamiliar speaker were analyzed for communication breakdowns, repair strategies, and turn-taking behaviors.

Assessment occurred pre-implant, at 1 and 9 months after stimulation, and immediately following AR. This schedule of testing, shown in Table 2, allowed us to differentiate between the effects of implant use without training and effects of early versus delayed training.

RESULTS

Speech perception scores before and after AR are shown for individual subjects in Appendix C.

Consonant Recognition

Figure 1 shows results for the two treatment groups, early and delayed AR, on auditory-only consonant recognition. This task is part of the Iowa Laser Video Disc Battery. It consists of 13 /iCi/ utterances presented 12 times each. Data are displayed as group mean difference scores referenced to performance at 1 month after initial stimulation. (The standard error of the mean, SEM, is also shown). The early-AR group (squares) demonstrated a gain of 17% (±3)

Table 2
Evaluation and Training Timetable of Aural Rehabilitation (AR)

	Group	
Activity	**Early AR**	**Delayed AR**
Pre-Implant Evaluation	×	×
Stimulator Adjustment	×	×
Home Program	×	×
1-Month Evaluation	×	×
Training	×	
Post-AR Evaluation	×	
9-Month Evaluation	×	×
Training		×
Post-AR Evaluation		×

immediately following AR. Performance was maintained after 9 months. The delayed-AR group (circles) showed a gain of 4% (±3) after 9 months of implant use. Immediately following training (AR), the group showed a gain of 8% (±2) compared to their performance at 1 month.

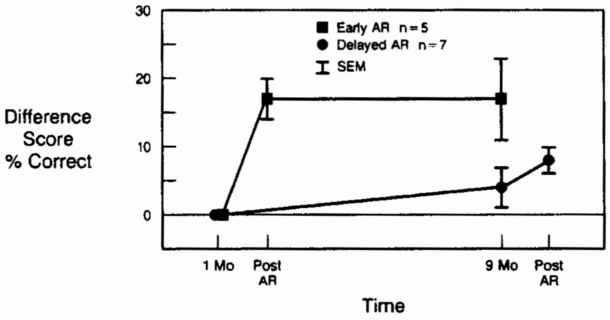

Figure 1. Mean difference scores for auditory-only consonant recognition.

Figure 2 shows results on audiovisual consonant recognition. This task is identical to the one previously described, with the addition of speechreading. The number of subjects in each group varies from that of the previous figure because subjects missed some testing sessions. The early-AR group showed a gain of 11% (±6) following training (AR) and an additional 8% following 9 months of implant use. In contrast, the delayed-AR group demonstrated a gain of 4% (±6) at 9 months without training. Immediately following AR there was an additional 8% gain.

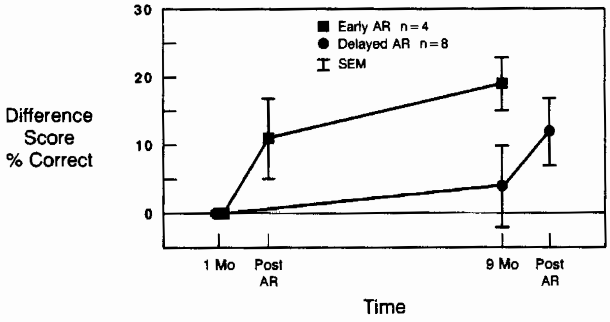

Figure 2. Mean difference scores for audiovisual consonant recognition.

Vowel Recognition

Figure 3 shows results on auditory-only vowel recognition. This task is part of the Iowa Laser Video Disc Battery and consists of 9 vowels in an /h-V-d/ context presented 12 times each. Note the early-AR group made a gain of 15% (±4) following AR, and maintained it at 9 months. The delayed-AR group made a similar gain of 11% (±3) without training. We do not know how soon the delayed-AR group made this gain. Immediately following AR, they improved an additional 6% (±4).

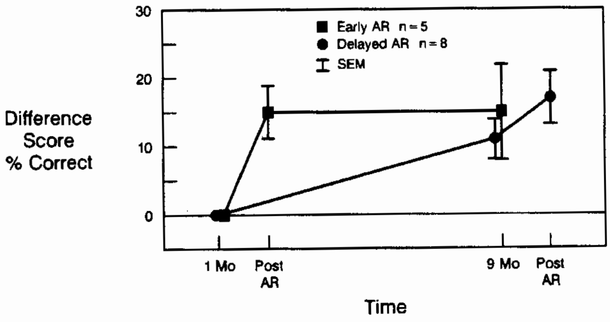

Figure 3. Mean difference scores for auditory-only vowel recognition.

Four-Choice Spondee Recognition

Figure 4 shows results on the auditory-only 20-item four-choice spondee test of the Minimal Auditory Capabilities battery (Owens, Kessler, Telleen, & Schubert, 1981). The early-AR group demonstrated a small gain of 4% (±7) after training, and continued to improve with implant use. At 9 months the total gain was 14% (±9). The delayed-AR group scored 4% (±3) worse after 9 months without training. Immediately after AR the gain was 9% (±5).

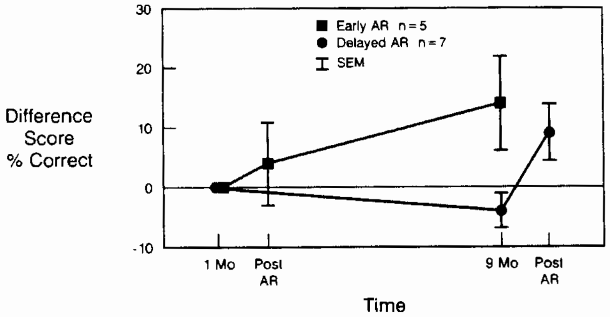

Figure 4. Mean difference scores for auditory-only four-choice spondee recognition.

Accent Recognition

Figure 5 shows results on the auditory-only Iowa Accent Test, a subtest of the Iowa Laser Video Disc Battery. It consists of 4 sentences, such as "Ray bought a big dog." One content word receives primary stress (accent). Each sentence is repeated 6 times. The subject sees the sentence on a screen and touches the word that was accented. The early-AR group made a gain of 11% (±6) immediately following AR and 19% (±4) 9 months later. The delayed-AR group mean difference score at the 9 month testing was -1 (±3). Immediately after training there was a gain of 24% (±5) compared to performance at 1 month.

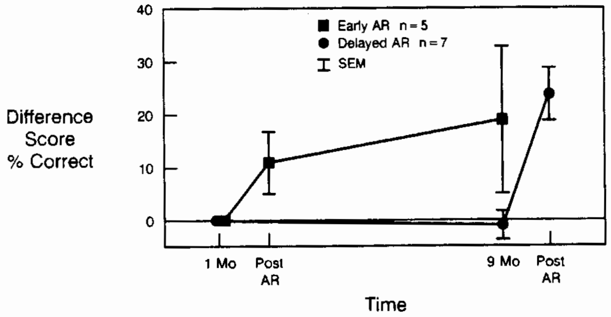

Figure 5. Mean difference scores for auditory-only recognition of accent in sentences.

CONCLUSION

The results of the present study are based on data from 13 multi-channel cochlear implant users and a specific set of training procedures. The degree of benefit obtained from the implant and the rate at which new speech perception skills were acquired varied for individuals. Not all individuals experienced gains following training. The trends in the group mean data, however, with the possible exception of vowel recognition performance, suggest that early training plus implant use results in gains that exceed those from implant use alone. Additionally, training effects (gains immediately following early AR) appear to be maintained or augmented after 9 months. Our initial results, supporting training effects, suggest larger average gains than those reported by Boothroyd, Hanin, and Waltzman (1987). Their five Nucleus CI users were trained and evaluated on computer-controlled video recordings of the Speech Pattern Contrast Test (Boothroyd, 1986) and Topic-Related Sentence Test (Boothroyd, Hnath, & Hanin, 1985). Variables such as the type of training tasks, assessment measures, and subject attributes may have contributed to the differences in findings between the present study and that of Boothroyd et al. (1987).

The AR program described in the present study was highly eclectic. Training in one activity may have contributed to progress in another. For example, tracking may have influenced vowel recognition. Research is needed to evaluate the relative contributions of the various components of AR. Additionally, we do not know if multiple periods of AR spaced over a considerable time period are better than a single intensive course of AR.

Another area of research is generalization to untrained stimuli. A variety of communication tasks that include speech perception performance (phonetic through sentence levels; synthetic, modified, and natural speech) and communication management techniques warrant study. The effectiveness of interactive computer-controlled techniques that might reduce clinician-contact time also requires study. We also need to document rates of learning utilizing newly available technology.

We must strive to quantify communication behaviors for both treatment and control groups. Individual-subject designs, using subjects as their own controls, may be useful. Stable baseline data must be collected prior to intervention and longitudinally. These measures are necessary if we intend to justify the commitment of resources, time, and effort in responsibly providing AR.

We are in the process of analyzing patient performance on additional audiovisual speech perception tasks (e.g., sentence perception) and communication coping behaviors. With a large group of subjects followed for an 18-month period, it may be possible to gain insight into the contributions of the specific implant system (i.e., Nucleus vs Symbion) to audiovisual speech perception performance as well as the timing of intervention.

ACKNOWLEDGEMENTS

This work was supported by NIH Grant #CDR 5 P01 NS20466, Grant RR59 from the General Clinical Research Centers Program, Division of Research Resources, NIH.

Portions of this paper were presented at the NIH Consensus Development Conference on Cochlear Implants, May 1988, and at the 1988 Summer Institute of the Academy of Rehabilitative Audiology in Winter Park, CO.

We gratefully acknowledge Holly Fryauf-Bertschy, John Knutson, Mary W. Lowder, Nancy Tye-Murray, and Richard Tyler for assistance in data collection.

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APPENDIX A

DESCRIPTIONS OF RESPONSE TASKS

1. *3-Interval Forced Choice*
   Two identical and one contrasting stimulus are presented. The subject selects the stimulus that is different from the other two.
   Sample: Which one is different: the first, second or third?
   Listen: church, church, search.

2. *Same/Different*
   Two stimuli are presented. The subject decides if the second is identical to, or contrasts with, the first.
   Sample: Are these the same or different?
   Listen: *I* didn't recognize him.
   I *didn't* recognize him.

3. *Categorical Response*
   A small set of stimuli is presented. The subject compares each to an internal representation of the category type specified.
   Sample: Tell me when you hear a word beginning with a nasal sound.
   Listen: CAT, BAT, FAT, GNAT.

4. *Closed-set Recognition*
   The subject recognizes a given stimulus from a known set of alternatives.
   Sample: Known choices: boot, beet, bait, bit, boat. Please repeat the last word in the sentence.
   Listen: He found a very old *boat.*

5. *Open-set Identification*

The subject identifies a stimulus from an unknown set of alternatives.

Sample: Please repeat the word you hear.
Listen: booth.

APPENDIX B

EXERCISE TO DEVELOP COMMUNICATION COPING BEHAVIORS

Clients watch a videotape in which communication difficulty is intentionally increased. They then analyze the situation by responding to the following questions.

I. How well did you understand this speaker?
   1. I understood every word the speaker said.
   2. I understood all but a few words.
   3. I understood the gist of what the speaker said.
   4. I understood only a few words.
   5. I did not understand a single word.

II. If you understood the gist of the question, please write out your answer to it.

III. If you had any difficulty understanding the speaker please explain what caused the difficulty.
   Examples of responses:
      The speaker's back was turned.
      Background sounds made it difficult for me to hear the speaker.

IV. Review the suggestions below and decide what you would tell the speaker to do to help you understand.
   a. Nothing — go on.
   b. Say it again.
   c. Tell me the most important word.
   d. Say it in a different way.
   e. Repeat only the words I missed.
   f. Write it down.
   g. Other. (Please explain.)
   1st choice: ______________________________
   2nd choice: ______________________________
   3rd choice: ______________________________

APPENDIX C

INDIVIDUAL SUBJECT DATA

Table C-1

Percent Correct Scores for Cochlear Implant Users Before (Pre) and After (Post) Receiving Aural Rehabilitation (AR) at 1 mo (Early) and 9 mo (Delayed) After Initial Stimulation

		Stimulus Type and Condition									
		Consonant Auditory		Consonant Audiovisual		Vowel Auditory		4-Choice Spondee Auditory		Accent Auditory	
Subject	Implant Type[a]	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Early AR											
1	Sym	18	38*	[b]	34	32	52*	55	80	70	65
2	Sym	24	43*	54	74*	25	43*	65	70	54	83*
3	Nuc	19	44*	59	77*	54	81*	90	80	70	80
4	Nuc	6	14*	30	41*	17	24	50	40	20	35
5	Nuc	11	23*	49	42	39	44	55	65	88	92
Delayed AR											
6	Sym	40	60*	75	87*	50	58	55	80	50	75
7	Sym	28	36	48	63*	51	64	95	100	63	71
8	Sym	10	17	33	26	11	15	40	50	29	75*
9	Sym	22	25	38	39	18	26	30	50	38	71*
10	Nuc	21	21	44	50	53	48	60	75	40	55
11	Nuc	24	36	47	65*	54	62	90	100	80	92
12	Nuc	27	24	79	88	50	51	80	80	88	100
13	Nuc	32	32	65	72*	48	61	15	30	67	96*

[a] Nuc = Nucleus 22-channel cochlear implant; Sym = Symbion 4-channel cochlear implant

[b] Missing data

*Change from pre to post is significant ($p < .05$) as determined by the binomial model (Thornton & Raffin, 1978)