Application of a Vibrotactile Aid in Improvement of Speech Production in Deaf Children

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The use of tactile stimulation to enhance the speech reception/production skills of profoundly deaf children is not a new concept. However, it has not been until the last few years that concentrated effort on developing adequate instrumentation for that purpose has been made. Such instrumentation must provide hearing-impaired subjects with acoustic transformations that can be easily discriminated on the skin so that the segmental and suprasegmental aspects of the speech message can be detected. The SRA-10 (De Filippo & Scott, 1978) is such an instrument. Whether or not the SRA-10 is as efficient in providing relevant speech cues as an acoustic form of amplification was the primary focus of the present investigation. Two profoundly hearing-impaired eight-year-old male subjects were trained on phonetic reception and identification tasks and on discrimination of multisyllabic words. Each subject served as his own control, wearing the SRA-10 for fourteen 30-minute sessions and a Bioacoustics 70-B auditory training unit for the same period of time. For both subjects, the results obtained from both of the aided conditions indicated a greater correct performance gain function over 14 trials with the SRA-10 than with the 70-B. The results suggest that speech perception/production training using the SRA-10, or similar vibrotactile unit, may be superior to the same type of training using acoustic amplification in children who have similar hearing losses.

"I cannot speak the way you do, because I cannot hear the way you do." These are the actual words of a frustrated deaf child to a frustrated but well-meaning therapist. This simply stated profundity sums up that with which those involved in the teaching and training of severely and profoundly hard-of-hearing individuals have been dealing on more complex levels for years. There certainly is no dearth of literature describing the many aids and devices that have been developed and utilized to supplement or replace a

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severely limited or nonfunctioning auditory sense. The attempts to enhance or transpose acoustic events into useful, meaningful information for hearing-impaired people have ranged from seashells to cochlear implants, but as ingenious as these devices have been, the perfect "artificial ear" has yet to be found.

Perhaps the perfect "artificial ear" is not a realistic goal, at least in the immediate future. A more realistic goal for the present may be to train an intact sense to make use of some form of acoustic energy transformation. Then the problem to be solved would be which sense to use and what form of transformation to impose upon that sense. Whether this can be effectively accomplished has been argued (Stark, 1974). However, the research to date does not categorically refute the ability of vision and/or taction to aid in decoding auditory stimuli. One of the problems with investigations into the use of the visual and tactual senses as aids to perception and production of speech may be the short-term training of the experimental subjects. Since the senses being examined did not develop as auditory decoders, it stands to reason that long-term training is necessary before the ability of those senses to adapt to the perception of auditory information is known. Long-term training with experimental devices, using profoundly hearing-impaired children as subjects, is often difficult to justify since a concern of many of us is that these children may be denied what may be more practical and beneficial procedures.

The research being conducted at North Texas State University is focused upon tactile response to speech by profoundly deaf children. What we are attempting to do is not a new concept. Investigations of cutaneous response to tactile transformation of acoustic signals has been ongoing with varying degrees of intensity since Gault's (1926, 1936) early work. As pointed out by Kirman (1979), most of the current work is primarily concerned with the development of reception aids rather than production aids. However, a current study being conducted at the Callier Center for Communication Disorders (Roeser & Scott, 1979) is attempting to examine the effects of vibrotactile stimulation on both speech reception and production skills, as well as progress in language development, for profoundly hearing-impaired children. The North Texas research is also concerned with speech reception and speech production skills.

The skin has been found to be most receptive to the time and intensity domain; i.e., fairly small time and/or intensity changes can be discriminated fairly reliable on the skin. The skin does not appear to have the same facility for discrimination of small frequency or pitch differences (Goff, 1967). However, frequency resolution on the skin has been enhanced to a great extent by using square wave pulses rather than sinusoids as inputs to vibrators and by using energy within individual band-pass filters to amplitude modulate a low-frequency noise source (Pickett, 1963; Scott, 1979). Results from numerous investigations have shown improvement in speech reception/production skills with tactile stimulation utilizing frequency as the primary or complementary domain (Erber & Cramer, 1974; Goldstein & Stark, 1976; Sparks, Kuhl, Edmonds & Gray, 1978).

Tactile displays on the skin can be accomplished in various ways. They may be vibrotactile, electrocutaneous, or a combination of the two. The displays may be spatially arrayed in one or two dimensions (frequency, frequency + time, or frequency + intensity) or they may be temporally arrayed. In a special array, sets of band-pass filters deliver their outputs, which vary in amplitude as a function of the energy in the corresponding band-pass, to different loci on the skin thus attempting to provide frequency discrimination analogous to cochlear function.

Recently Scott (in press) argued that although a spatial array appears to be a logical approach given the mechanics of the cochlea, *perception* of acoustic information is accomplished by changes in quality, not location. Since tactile instruments utilizing spatial arrays result in perception of changes in location, not quality, Scott suggests that a temporal display, which results in changes in quality of perception, is a more efficient approach. An aid developed by Scott (De Filippo & Scott, 1978), the SRA-10, uses such a temporal display. Consonants, for example, appear as aperiodic sensations on the skin with the width of the skin area stimulated being a function of the amount of low-frequency energy present in the signal. Vowels produce periodic sensations over a large area of the skin, and the sensation changes in "roughness" depending upon the extent of low-frequency energy present. Data from studies with this device have shown it to be an effective aid to improving lipreading ability for continuous discourse (Scott & De Filippo, 1979).

Our interest in tactile reception as a method for enhancing the speech training of profoundly deaf children was due to our work with children enrolled in the Denton Regional Day School Program for the Deaf. We believed that several of the children in that program were not making as much progress in the development of speech skills as we thought they could. In a trial observation of two profoundly deaf children wearing the vibrotactile aid developed by Scott, the SRA-10, we were convinced that the tactile unit provided a more discriminating input channel for the speech signal than the children's own hearing aids or auditory trainers. One of the children, age 7, was essentially nonverbal. He also had difficulty attending in one-to-one or group habilitative sessions. When the SRA-10 was placed on him, his attending behavior improved, and his verbalization attempts increased.

The second child on whom we placed the aid, also age 7, though audiometrically equal to the first child, was considerably more verbal. However, we believed we should be able to improve his articulation skills. In the first two sessions of training with the tactile aid, we were able to improve his imitation ability for certain phonemes that he had previously been unable to produce.

Since these were merely random observations and the improvement we observed in these children may have been due to an increased effort to participate on their part as a result of wearing a novel device, we began a more systematic investigation of the value of the tactile instrument as an aid to improvement of speech skills. Of major interest was the usefulness of the tactile aid in providing improved speech reception, thereby improving speech production. In addition, we were interested in the vibrotactile aid's ability to improve the discrimination of certain suprasegmental aspects of speech, specifically multisyllabic words. Because the rate and amount of improvement in skills we elected to examine might be just as easily obtained with acoustic amplification, we elected to examine progress under two conditions, vibrotactile stimulation and acoustic stimulation.

METHOD

Subjects

Two subjects were selected for the investigation. Both were profoundly hearing-impaired, eight-year-old males. Warble tone, sound field unaided and aided thresholds are shown in Figures 1 and 2. The aided thresholds were obtained with a Bioacoustics 70-B auditory training unit which was used in the investigation. Subject 2 had no measurable hearing in the sound field.

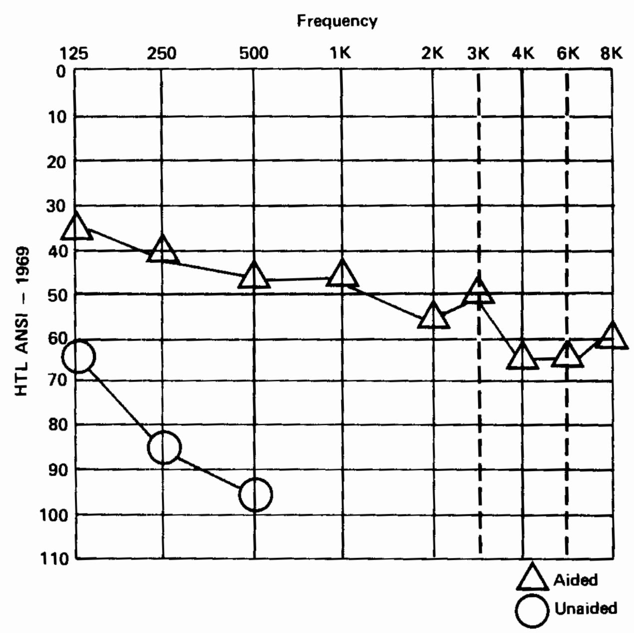

Figure 1. Aided and unaided thresholds in sound field for Subject 1.

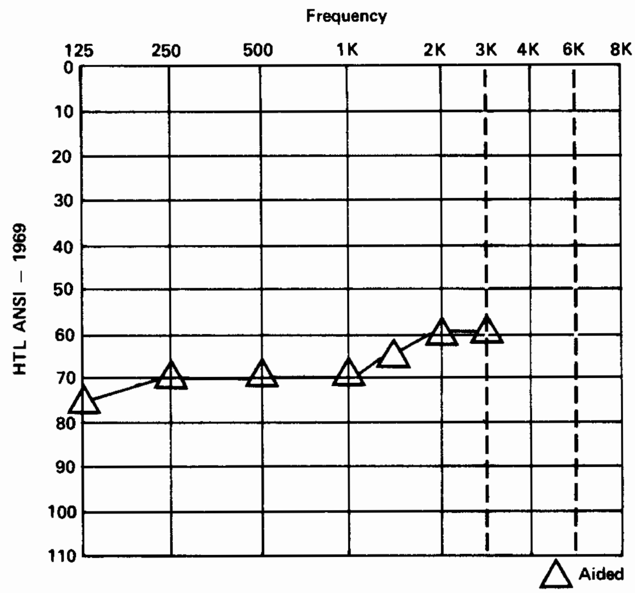

Figure 2. Aided sound field thresholds for Subject 2.

Subject 1 had the typical responses of profound hearing loss seen in the majority of such children. Subject 1 volunteered information about whether the signal was actually heard or felt. At sound levels above his designated unaided thresholds, he indicated that he felt the stimulus. He had more difficulty making such discriminations in the aided condition. Subject 2 was unable to understand what we meant when we asked him to indicate whether he heard or felt the sound in the aided condition. Consequently, we could not be sure of what kind of sensation he was receiving. We were surprised at the degree of threshold improvement in the aided condition for both subjects, particularly at those frequencies above 1000 Hz. Whether their individual thresholds were actual auditory thresholds, thresholds of feeling, or some other undefined sensation is open to question.

Both subjects were of normal intelligence as measured with the Leiter Test of Intelligence (Subject 1 = 96; Subject 2 = 109) and had no other known handicaps in addition to their profound hearing loss. The hearing loss of both boys was presumed to be the sequela of meningitis which had occurred prelingually.

The subjects were matched in terms of educational background, school placement, and previous aural habilitation training. Both were enrolled in the Denton County Regional Day School Program for the Deaf, and both attended the aural habilitation program at the North Texas State University

Speech and Hearing Center. The children who attend the North Texas program from the Regional Day School normally receive 30 to 60 minutes of aural habilitation two days per week for approximately 14 weeks per academic semester.

Instrumentation

The tactile device used in the investigation, the SRA-10, is shown schematically in Figure 3. It is a portable, battery operated unit measuring 8½ × 9 × 3½

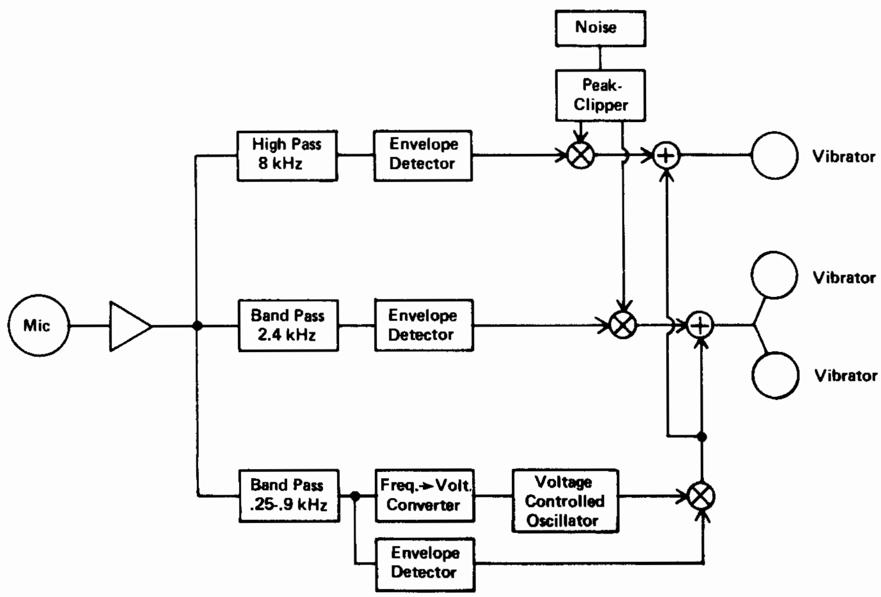

Figure 3. Schematic diagram of SRA-10 vibrotactile aid.

inches and weighs approximately eight pounds. Three vibrators are secured in a polyurethane mold and worn in an adjustable fabric belt. The dimensions of the transducer case are 6 × 2 × 1 inches. The three transducers were manufactured by Western Electric and are identical to those used in the Electrolarynx.

The SRA-10 has three spectral channels. The center vibrator carries both high-frequency information and low-frequency, vowel information. The two end vibrators carry mid-frequency information as well as low-frequency, vowel information. This results in a phoneme such as /s/ producing an aperiodic sensation, stimulating a small area (via the center vibrator) in the center of the torso. A /ʃ/ produces the same sensation spread over a larger area (via all three vibrators in the center of the torso). A vowel produces a periodic sensation over a large area that changes in roughness according to the first formant. Scott (1979) refers to this phenomenon as vibrotactile pitch. Thus closed vowels, having lower first formants, have a slow rate of vibration and feel rough; open vowels with higher first formants have a faster rate of vibration and feel smooth. A more detailed description of the SRA-10 and its development may be found in De Filippo and Scott (1978); Scott and De Filippo (1979); and Scott (1979).

Acoustic amplification was provided by a Bioacoustics 70-B FM auditory training unit with a Y-Cord receiver arrangement. Both receivers were wide band. The unit was used in the same manner as a body-type hearing aid. Prior to the beginning of the training period, the appropriate volume control setting of the 70-B was determined for each child. The selected setting ultimately turned out to be the same for both subjects and resulted in an average gain of 50 dB Sound Pressure Level (SPL) re $20\mu N/m^2$ from 100-6000 Hz with an average slope of 12 dB per each 1000 Hz increment from 6000 Hz to 9000 Hz.

Procedure

Each child received 28 thirty-minute training sessions; the SRA-10 was worn for 14 sessions, the 70-B for 14 sessions. In this way, each subject served as his own control for evaluation of the effects of one type of training over the other. No plans were made to compare absolute progress of one child with that of the other because of the inability to control unidentifiable variables between subjects. However, in view of the apparent difference that existed between the subjects' hearing thresholds, it was determined that relative progress between subjects would be examined to determine whether the degree of low-frequency hearing available would affect training with the acoustic amplification. If, in fact, the low-frequency, amplified thresholds of Subject 1 were true auditory thresholds and those of Subject 2 were not, then Subject 1 would be receiving auditory input under one condition and vibrotactile under the other while Subject 2 would quite possibly be receiving vibrotactile stimulation under both conditions.

The ultimate goal of training under both conditions of stimulation was to improve the subjects' articulation skills for certain phonemes as well as to improve their ability to perceive and produce varied syllable patterns of words. The approach used to teach correct production of phonemes was based on the procedure described by Ling (1976). The procedure involved a hierarchy of production skills beginning with the sound as a phoneme; e.g., in isolation for continuants such as /m/, /n/, /l/, and /s/; consonants paired with a correctly produced vowel; and then the phoneme used in words, phrases, and finally, sentences. The particular phoneme training for each child was dependent upon their individual production skills as determined by performance on the Arizona Articulation Proficiency Scale: Revised (AAPS) and the phonetic and phonologic evaluation procedure described by Ling (1976). The child's task for this procedure was to correctly produce a phoneme in imitation and then ultimately to produce the phoneme when prompted by a printed reproduction. Progress was measured by determining percent of correct productions per trial for each session. The formula reported by Yeni-Kamshion and Goldstein (1977) was used to adjust the obtained scores for ceiling effects.[1]

The syllabication training involved teaching the subjects to consistently discriminate and produce two-, three-, and four-syllable utterances in words. The child's task was to correctly identify, then produce a verbalization with the correct number of syllables after modeling by the therapist. Progress was measured by determining the number of correct productions (a correct response included identification and production). These scores were also adjusted for ceiling effects.

In the training sessions using the SRA-10, the belt that housed the vibrotactile transducer was placed on the child's torso in direct contact with the skin. The therapist then modeled the target phoneme or word for which the correct number of syllables was to be identified, speaking into the microphone of the SRA-10. The microphone was then held in front of the child's mouth, and he was prompted by the therapist to correctly produce the phoneme or word. Token and verbal reinforcement were used for correct production. Incorrect production was followed by the therapist letting the child know that his production was not correct and that he had to try again. The therapist modeled the target phoneme or word each time, unless training had progressed to the point that visual representation of the phoneme and/or sentence could be used. The same procedures were used during the training sessions with acoustic amplification. The child was encouraged to watch the therapist during both types of training to allow for full use of visual cues.

Prior to the initial training session, baseline data were collected for each subject. The data included scores on the AAPS, the Ling analysis for phonetic and phonologic skills, and syllabication ability for two-, three-, and four-syllable words. These tests were also administered after each 14-week training period. During these testing sessions, each child used his personal amplification system. This was done so that initial ability on these tests could be determined without benefit of the systems used in training. The testing after each 14-week session was also accomplished in this manner to determine the amount of carry-over from training with a given amplification system.

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[1]The formula for adjusting for ceiling effect is as follows: $(B - A)/(100 - A) \times 100$, where B is the percent correct at the end of 14 training sessions or mid-test/post-test scores, and A is equal to the percent correct at the beginning of a 14-week period or pre-test scores.

RESULTS AND DISCUSSION

Percentage scores for pre-training, mid-training and post-training tests are shown in Figure 4. The testing in all cases was accomplished with each subject's own acoustic amplification system. Scores on the AAPS and overall syllabication scores (average performance on two-, three-, and four-

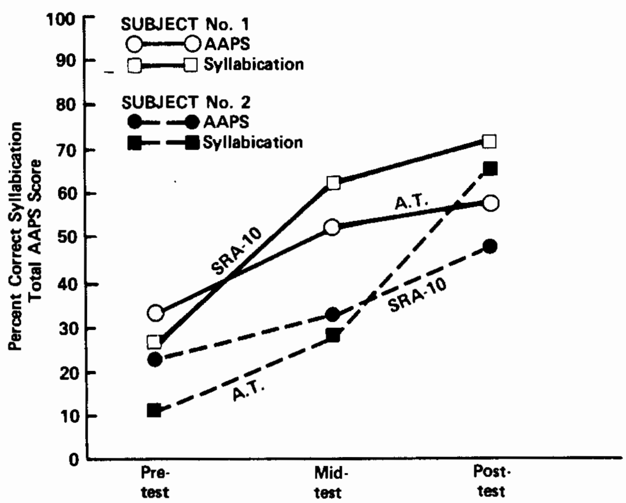

Figure 4. Pre-, mid-, and post-test results for both subjects on the Arizona Articulation Proficiency Scale and Syllabication task.

syllable words) are indicated. The pretest scores serve as baselines for performance gain following the first 14 sessions, and the midtest scores serve as the baselines for the second 14 training sessions. An overall increase in performance over the 28 sessions can be seen for both children. This increase reflects the effects of training in both aided conditions. The slope of the lines between pre- and post-training with the SRA-10 vibrotactile aid tend to be steeper than those between pre- and post-training with the 70-B auditory trainer for both AAPS scores and overall syllabication.

Subject 1 had an average increase between pre- and post-training with the 70-B of 4.5% on the AAPS and an 8.3% overall average increase on syllabication. With the SRA-10 he had an average increase of 18.5% on his AAPS scores and a 37.5% overall average syllabication score increase. This reflects a performance gain decrement after he began using the 70-B auditory trainer. Since Subject 1 wore the SRA-10 for the first period of training, it is possible that he had "topped out" during the second session; i.e., he had achieved his maximum performance for the AAPS since all production errors on that test were not trained during the course of this investigation. In addition, he may have reached his maximum potential for discrimination of multisyllable words. However, decrease in rate of improvement may well have been at least partially a function of the decreased discrimination capability afforded by the 70-B as compared with the SRA-10. Subject 2, in fact, performed in a reverse manner relative to the beginning of training. The rate of performance gain for this subject was greater for the second 14 sessions, when he wore the SRA-10, than during the first 14 sessions when he wore the 70-B. His average performance increase on the AAPS after training with the 70-B was 4% and after training with the SRA-10, 27%. His overall average syllabication performance gain was 16.7% with the auditory trainer and 37.4% with the vibrotactile aid.

It would appear that the SRA-10 had at least some influence on the rate of performance increase for both children. It should be noted that performance by Subject 2, who had poorer aided thresholds than did Subject 1, remained below that of Subject 1 for all three testing periods. However, the post-test scores of Subject 2 were much closer to the scores of Subject 1, while scores of the tests for both subjects given after the first 14 sessions were extremely different from one another. This phenomenon would appear to reflect the difference in training mode or instruments used during the initial training period.

Phonemes on which each child received training were consonants which were shown by the Ling (1976) evaluation to be incorrectly produced at the phonetic level. Continuants were initially trained in isolation, while other consonant categories were taught in a consonant-vowel (CV) or vowel-consonant (VC) context using a vowel which could be correctly produced. The vowels used in the various CV or VC combinations were: /i/, /a/, /u/, and /ʌ/. Once performance had reached the 100% level of correct production, the consonants were trained at the word and sentence level. Only results of syllable level production are reported here.

Table 1 indicates percentage of improvement for the final session relative to the first session for each different aided condition of phonetic training. Again, overall improvement in phoneme production skills was greater for the tactile training than for auditory training. Overall correct phoneme production gain (tactile over auditory) was 9.6% for Subject 1 and 22.3% for Subject 2. The large difference in performance gain between Subjects 1 and 2 may reflect the difference in their hearing ability; i.e., Subject 2 was able to make more use of the tactile information than Subject 1 because of his extremely limited auditory function.

Examination of the performance scores for individual phonemes shows that there was a large difference between rate of performance increase between the two phonemes, /m/ and /w/, both voiced bilabials with /m/

Table 1
Percent Correct Consonant Production Gain
for Each 14-Week Training Session
for Both Subjects[a]

Condition	Subject 1			Subject 2		
	Phoneme	%		Phoneme	%	
Auditory	/w/	100.00	(2)[b]	/w/	48.57	(1)
	/d/	23.08		/f/	82.01	
	/n/	57.40		/m/	46.88	
	Overall	60.16		Overall	59.15	
Tactile	/m/	73.59	(1)	/m/	48.53	(2)
	/d/	63.24		/d/	95.84	
	/f/	90.48		/w/	100.00	
	Overall	75.77		Overall	81.46	
% Difference		9.61			22.31	

[a]Percentages indicate adjusted scores.
[b]Number in parentheses indicates order of condition for each subject.

being nasal. When the tactile sensation difference between /m/ and /w/ was examined, the nasality which occurs in the production of /m/ could not be detected unless the microphone of the SRA-10 was held quite close to the mouth. Thus, variability in microphone position would appear to have a large effect on phoneme recognition for the particular vibrotactile aid used in this investigation, especially phonemes with the feature of nasality.

The phoneme /f/ (trained in the auditory condition for Subject 2 and tactile condition for Subject 1) appears to be easily discriminated in either condition as both children gave evidence of significant performance gain. This high performance gain for /f/ can probably be attributed to the fact that this phoneme is highly visible and the absence of voicing would more than likely be apparent in both auditory and tactile conditions.

The phoneme /d/ appears to have been facilitated by tactile information. Since it is low in visual cueing, the voicing information provided by the tactile mode would be important to reception. Subject 1, who began with tactile training, showed a marked decline in correct production of this phoneme during training in the auditory mode, substituting the unvoiced /t/ much more than he had in the period of tactile training.

Performance gain for syllabication is shown in Table 2. As with phoneme production, overall performance gain for tactile stimulation was greater than that for auditory stimulation. However, when looking at the degree of performance gain for two- and three-syllable words, there are obvious differences between the two subjects which may be a function of which mode of training occurred first. Subject 1 showed a decline in rate of performance

Table 2
Percent Correct Syllabication Gain
for Each 14-Week Training Session
for Both Subjects[a]

Condition	Subject 1		Subject 2	
	# of Syllables	%	# of Syllables	%
Auditory	2	33.18	2	44.96
	3	13.29 (2)[b]	3	-8.95 (1)
	Overall	23.24	Overall	18.01
Tactile	2	100.00	2	15.84
	3	15.28 (1)	3	77.05 (2)
	Overall	57.64	Overall	46.44
% Difference		34.40		28.44

[a]Percentages indicate adjusted scores.
[b]Number in parentheses indicates order of condition for each subject.

increase for both two- and three-syllable words during the second 14 sessions when he wore the 70-B, especially for two-syllable words. Although it may seem illogical to see a greater decline in performance on two-syllable word discrimination as compared to three-syllable discrimination, this circumstance was presumed to be due to Subject 1's much higher initial performance with two-syllable words than initial performance with three-syllable words. Subject 1's performance with three-syllable word discrimination had reached 80.6% during training with the tactile aid and had declined to 65.4% with the auditory trainer, a difference of 11.1%. His performance on two-syllable words declined from 100% to 78.6%, a difference of 21.4%. Another factor which may have had some bearing on Subject 1's difficulty with two-syllable word patterns in the auditory condition is that some of the two-syllable words may not have been perceived as bisyllabic (Erber, 1978).

Subject 2 showed significant performance gain in the reception of three-syllable words with the SRA-10 but appeared to show a decline in performance gain in recognition of two-syllable words in the tactile mode. This, too, may be a function of the speech envelope pattern of the bisyllabic words used. However, Subject 2 had a low score, 35.5% in the initial training session with the auditory trainer. At the beginning of the training sessions with the SRA-10, he had a score of 76.5% and progressed to 90.9% in the final session. Thus, it appeared he was able to achieve a large gain when training initially with the auditory trainer since it no doubt would have provided him with sufficient information (auditory or tactile) to aid his discrimination but not sufficient enough for him to achieve maximum performance during the 14 training sessions.

Figures 5 and 6 show syllabication discrimination performance gain for two-, three-, and four-syllable words for both subjects examined pre-training, mid-training, and post-training. Gain is plotted relative to a zero baseline for pre- and mid-test conditions. Again, gain as a result of tactile training is

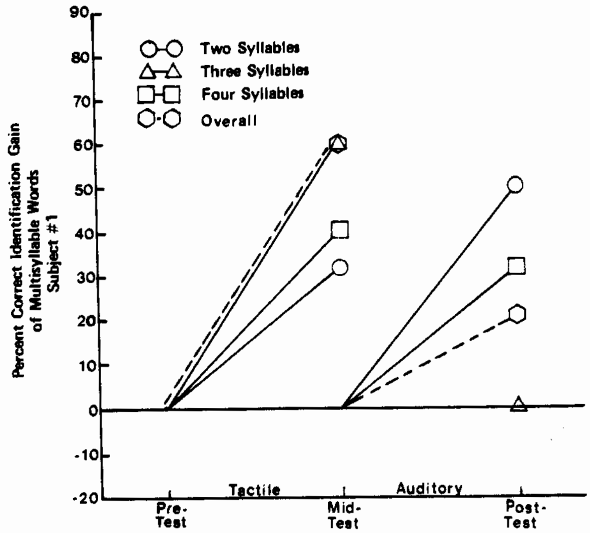

Figure 5. Percent of performance gain (adjusted scores) on two-, three-, and four-syllable words for Subject 1.

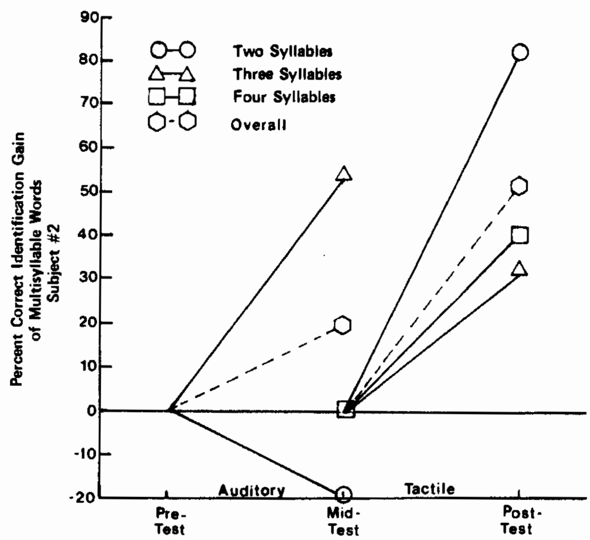

Figure 6. Percent of performance gain (adjusted scores) on two-, three-, and four-syllable words for Subject 2.

greater than the gain with auditory training. Although initially four-syllable word discrimination was included as a goal for training, it was not trained during either of the 14 sessions because of the degree of difficulty experienced in teaching three-syllable recognition, and we desired to keep the number of failures incurred in a task to a minimum. However, testing for four-syllable discrimination was included in the testing procedures to determine if reception skills had been enhanced for more difficult listening tasks in either aided condition. Subject 1 had a 40.0% performance gain on four-syllable word recognition in the tactile mode and a 33.3% gain in the auditory mode. Subject 2 showed no gain in the auditory mode for four-syllable words but a 40.0% gain with the tactile aid. Neither subject was able to detect the presence of four syllables during the pre-test period.

Although no training of four-syllable words had been done, the training that had been accomplished with two- and three-syllable words appeared to facilitate more complex discrimination. In addition, it would appear that initial training with the tactile aid had been more beneficial in this regard as evidenced by the fact that Subject 1 showed some facility for four-syllable detection and production after tactile training, and Subject 2 showed no acquired skills for the task until training with the SRA-10.

As shown in Figure 4, Subject 1 showed no improvement in the ability to discriminate three-syllable word patterns following the training period in which the auditory trainer was used but showed approximately 60% improvement after tactile training. This reflects a decrement in skills for three-syllable word recognition following the period of tactile training. The fact that post-testing (following auditory training) revealed a higher performance for four-syllable words may be a function, as suggested earlier, of the speech-envelope pattern of words used in testing. This again suggested to us that the speech-envelope pattern may be more easily perceived in the tactile mode than in the auditory mode by children with profound hearing losses similar to that of Subject 1.

The major question we asked at the beginning of this study was whether vibrotactile training would prove to be superior to auditory training for speech reception/production. Our results generally support the opinion that training is facilitated by the tactile mode of stimulation for the parameters investigated in this study. We are continuing our investigation to examine a broader range of segmental and suprasegmental speech reception/production with the SRA-10 to determine whether the same positive results persist. It did not appear that extensive training time was necessary for teaching the children to make use of the vibrotactile information. However, it should be noted that Subject 2, who had no measurable unaided thresholds and whose reception of aided auditory stimuli may well be vibratory in nature, had greater performance gain functions for both phonetic and syllabication training. This would suggest that this subject is accustomed to some form of tactile stimulation with acoustic amplification, although not to the same degree as that provided by an aid such as the SRA-10. If this theory is true, then an initial period of time spent adjusting to the vibrotactile form of stimulation might enhance performance gains for speech reception and production skills.

Presently, one of the major shortcomings of tactile training using the type of sophisticated instrumentation similar to the SRA-10 is that they are not portable. Conclusions about whether a vibrotactile mode of stimulation will facilitate speech and/or language development of profoundly hearing-impaired children will require an instrument that can be worn on the body for long periods of time. Although improvement in speech skills in structured one-to-one habilitative sessions with profoundly hearing-impaired children is evident, the decision as to whether tactile aids can replace auditory aids as facilitators of speech reception in other, non-structured situations awaits the development of a portable unit.

A second shortcoming is that instruments similar to the SRA-10 are not readily obtainable for widespread use either because of the cost (which is three to five times the cost of a hearing aid or single auditory training unit receiver) or because the majority of tactile units are experimental. It is expected that this situation will change in the near future in view of the growing body of research evidence which supports the benefits of a tactile stimulus in the training of speech skills for profoundly hearing-impaired children.

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