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ABSTRACT

Factors influencing the use of nonacoustic aids (such as visual displays and tactile devices) with the hearing impaired are reviewed. The benefits of tactile devices in improving speech reading/lipreading and speech are pointed out. Tactile aids which provide information on rhythm, rate, intensity, and duration of speech increase lipreading and therefore facilitate gains in language comprehension. Reported are findings of a study in which a vibrotactile aid was used with five deaf children (9 months-6 years old). It is concluded that the aid appears to assist with social communication and in the localization of the sound source. (SW)

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EFFECTS OF A WEARABLE, TACTILE AID ON LANGUAGE COMPREHENSION OF PRELINGUAL PROFOUNDLY DEAF CHILDREN

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EFFECTS OF A WEARABLE, TACTILE AID ON LANGUAGE COMPREHENSION OF PRELINGUAL PROFOUNDLY DEAF CHILDREN

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Since the 1920's (Gault, 1926), a variety of nonacoustic aids have been designed as alternatives to or supplements for conventional hearing aids (acoustic aids). Nonacoustic aids consist of visual displays and different types of tactile (cutaneous) devices. Although principles of signal processing are applied to hearing aid design, conventional hearing aids essentially stress amplification of sound, i.e., sound is made louder despite the presence of speech or noise. Other types of signal processing have been applied to sensory aid design, often with emphasis on speech only. The definition of terms section presents clarification of types of nonacoustic aids and four basic concepts of signal processing as applied to sensory aids for the deaf. Table 1 presents additional details on how sensory aids differ from conventional hearing aids.

TABLE 1. DIFFERENTIATION OF ACOUSTIC AND NONACOUSTIC AIDS

ACOUSTIC AIDS	NONACOUSTIC AIDS
1. Worn daily	1. Few wearable aids developed; do not know if daily use is required.
2. Rely on use of residual hearing	2. Stress use of visual and/or tactile modalities
3. Rely on use of auditory system	3. Used as supplements to hearing aids; do not replace hearing aids
4. Stress amplification of sound	4. Often designed specifically for speech training
5. Location on body - some type of auricular placement	5. Provide information that cannot be obtained through amplification alone, e.g., frication, nasality, voicing
	6. Location on body - varies from fingers, wrist and sternum to waist, abdomen and thighs
	7. Differs from acoustic aids in frequency range and amplitude modulation

Over 100 different types of nonacoustic aids have been discussed in the literature with the overall purpose being the enhancement of oral communication abilities of the hearing impaired. Experimental research (cf. Boothroyd, 1982; Erber, 1982; Plant, 1982) suggests promising results for use of nonacoustic aids with deaf children. However, sensory aids have experienced limited success beyond the laboratory environment.

Several factors influence the use of nonacoustic aids in clinic and classroom settings. For example, properties of the aids such as amount and type of information presented and the manner in which the information is displayed affects the deaf user and determines whether teachers/clinicians perceive the information to be useful in the training process. Ease of operation, comfort of aids and size, e.g., wearability, also influence the use of devices in daily living and learning situations. Cost is a prime factor prohibiting the widespread use of nonacoustic aids among the hearing impaired and in schools for the deaf. Since few aids have been compared and tested in relation to each other, cost effective data is virtually unavailable. In other words, it is unclear what nonacoustic aids can provide that the teacher cannot.

To effectively evaluate sensory aids with the intention of generalizing their use to a larger population, researchers must reconsider traditional research methodologies and allow for increased input from the deaf population and from those who interact with the hearing impaired on a daily basis. Keeping in mind that two general themes underlie sensory aid development: (1) to increase the rate and quality of language and speech learned by the hearing impaired child and; (2) to enhance oral communication skills of the deaf population generally, a recent survey on tactile aids was completed.[1] Analysis of this literature survey revealed that 66% of the studies employed subjects who were 15 years and older. Of this percent, less than half (21%) tested devices on hearing impaired persons. While some reported the use of hearing impaired school aged children as subjects, few cited teacher participation in the evaluation process. Interestingly, only .06% (three studies) were identified which evaluated deaf children from 0-3 years - the prime time for learning language. Still, others failed to provide subject criteria, including chronological age and audiologic data. Therefore, it was difficult to determine when subjects were severely or profoundly hearing impaired.

Consideration of specific and consistent subject criteria and input from teachers, clinicians and parents open several areas requiring additional research on nonacoustic aids. This is particularly important to the development of therapeutic protocols and curricula which incorporate the use of such instruments. Moreover, a number of studies measured device effectiveness with stimuli appropriate for hearing adults, or for those hearing impaired who have acquired some language. Both the stimuli used and the designs of much of the research were structured to yield immediate results. For the hearing impaired child, this may not be a realistic expectation, since language learning is a <u>process</u> requiring a longer time frame than may be allowed by cause-effect experimental research. In recent years, child language researchers have demonstrated the adequacy of descriptive, naturalistic research designs, particularly when video and audio tape are used to complement behavioral observations. The approach to measuring the effectiveness of a wearable, tactile aid discussed in this workshop uses such a naturalistic approach.

ASSUMPTIONS RELATED TO USE OF A WEARABLE, TACTILE AID

It has been found that tactile devices are beneficial in improving speechreading/lipreading (Erber & Cramer, 1974), positively effect pitch patterns (Imai & Arakawa, 1977) and in some situations improve the speech of deaf users (Englemann & Skillman, 1977). Even the earliest research (Gault, 1926; Gault & Crane, 1928) has shown that when the deaf tactually receive suprasegmental information, lipreading scores show significant gains. Since speechreading is the primary means through which the oral deaf receive language, increasing lipreading abilities, increases language comprehension. Because the skin is not particularly good at frequency discrimination, Kirman (1973) argues that larger linguistic units, e.g., words vs. phonemes, should be used when tactually presenting language information.

Educators also believe it crucial to initiate communication training for the hearing impaired as early in life as possible. It logically follows, then, that the use of special devices, which present suprasegmental information, should be employed as early as possible and especially during those years when children normally learn language. If the child, family and teacher are to develop a positive attitude towards the use of nonacoustic aids, the device must be incorporated in the child's daily routine as soon as possible. Therapeutic protocols and curricula employing nonacoustic aids must also be designed with consideration to the child's emotional, social and physical environment. A wearable device allows for fewer restraints on the child, allows the child to move freely about the environment and language teaching occurs in a natural manner. Speech perception and production can be encouraged and reinforced in natural communicative situations in which young children are typically involved.

ASSUMPTIONS RELATED TO LANGUAGE COMPREHENSION

For hearing children who are acquiring language, it is postulated that at least some comprehension precedes speech production (cf. Ingram, 1974; Nelson, 1973). It is also argued that language comprehension may be a primary prerequisite to speech production. Hardy and Hardy (1977) interpret this to mean "learning, then doing" or "one must (should) have something to say before he talks" (p.108). For the deaf child, it appears that language comprehension occurs in a similar manner, but at a slower rate than for hearing children (Blanton, 1968; Smith, 1972). However, less is known about the developing comprehension abilities of the prelingual profoundly deaf child, since a traditional method for studying comprehension has been to measure understanding by the child's ability to produce speech. For the deaf child, it is exceedingly difficult to compare production against comprehension, because the nature and quality of the vocal output is nonnormal. Therefore, nonverbal or gestural responses must be interpreted.

In an attempt to decipher the comprehension-production controversy, Benedict (1976) completed a naturalistic, longitudinal study on eight 10-16 month olds. Children's nonverbal behaviors were employed as an acceptable response mode. She found that language comprehension emerges in stages, emerges earlier and intially at a faster rate than production and word content differed in the receptive and productive vocabularies. A hypothetical model for language comprehension was proposed that included two precomprehension stages and three comprehension stages.

In summary, for the oral deaf, language is received through speechreading. Tactile aids which provide information on rhythm, rate, intensity and duration of speech increase lipreading. When there are gains in lipreading, there are gains in language comprehension. Tactile aids may be most beneficial in teaching large linguistic units such as words. One strategy observed in language acquisition of hearing children indicates that comprehension precedes production and emerges in stages. One cannot easily teach speech to the deaf child if the child does not understand what s/he is supposed to do/say. Perhaps a major strategy for the deaf child is that some language <u>must</u> be understood before speech work begins.

Children acquire a large portion of their communication and language skills between 0-3 years. If a hearing impaired child is identified in this age range, language instruction should begin immediately and the introduction of a tactile aid should be incorporated within this same time frame. The child's progress and effectiveness of the aid may be measured by comparing words understood, via speechreading, with the developmental stages Benedict proposed. Word categories and content may be compared with those initially understood by hearing children. Rate of increase in understanding words, using a nonverbal response mode, may be taken as a measure of aid effectiveness.

THE STUDY

<u>THE AID</u>:

A single channel, vibrotactile aid was developed by a team of researchers at the Johns Hopkins University in 1976 (Golstein et al., 1982) The aid is essentially an envelope detector, i.e., detects when the speech signal is present. The amplitude is modulated so that gross sound patterns can be felt on the skin. Basically, rhythm, stress and duration patterns of the child's own speech and that of others are tactually perceptible. The first device was made in the form of a vest. Batteries and electronic parts were placed in pockets in the vest, the microphone was clipped to the shoulder strap and the vibrator was situated to press gently against the sternum. The second device, constructed in 1982, places the electronics, batteries and microphone in a leather pouch. The pouch is connected to sturdy elastics which hold the vibrator in place at the sternum. The pouch may be attached to a belt or straps on pants.

DATA COLLECTION:

Longitudinal data are collected on subjects' changing communcative abilities via audio and video tape and written observational notes. Recordings are made at home and school while the children are in speech-language therapy and interacting with other familiar people. Pre- and post-tests of understanding single words and connected discourse are administered while children are aided with the tactile device and without the device. Hearing aids are not removed. The reader is referred to Proctor (1983) for procedures used in home visits.

SUBJECTS:

One profoundly deaf female was followed for 10 months from ages 33-43 months. Intensive work with this child, Tabitha, was terminated when the project funding was depleted. However, the aid was left with the teacher and parents for continued use and her progress was followed informally. Based on results with Tabitha (Proctor & Golstein, In press), additional funding was generated [2] in 1981. A group of hearing impaired children was recruited from the Boston School's parent-infant program. These children are currently using the device. Type of loss, sex and age at the time each started use of the aid are as follows: (1) profoundly deaf female, 9 months; (2) profoundly deaf male, 6 years; (3) profoundly deaf male, 3 years; (4) severe-profound loss, male, 4 years and (5) moderately severe loss, male, 3 years. All subjects are currently tested to have bilateral losses.

RESULTS:

After 10 months of training, Tabitha showed a gain for understanding single words from five to 469 words, through speechreading only. During that same time period, she progessed from understanding five words to understanding relations between words. Relative to Benedict's stages she demonstrated understanding of three linguistic units in an utterance. A year later, she received a mental age score of 70 months at a chronological age of 52 months on the Peabody Picture Vocabulary Test.

Only preliminary and anecdoctal observations are available for the second group of children since they have been followed for a shorter period of time.

When using the device the first goal is to develop the child's awareness of sound - speech and environmental sounds. Secondly, the child must recognize that when others produce speech the vibrations are felt. Then, the child must associate his/her own speech production with the vibratory sensation felt. With respect to these objectives, the aid has assisted in significantly reducing the amount of time spent in auditory training. The children with the moderately-severe and severe-profound losses were able to do this after 10 hours of training. The 6 year old profoundly deaf child achieved these goals after 5 hours of training. The profoundly deaf 3 year old required approximately 20 hours of training to reach the objectives. The infant seems to be aware that her mother and brother produce sounds, but does not seem to relate sensations felt with speech produced by the speech-language therapist. At 12 months, she was observed to imitate the mother's production of "ma ma." She repeated the imitation three times, but without voice. The infant is now more vocally active, participates in vocal play with the therapist and carries on conversation-like routines with the mother. She is visually quite alert and attends to speech and language games structured by the mother and therapist for a full hour. The aid appears to assist with social communication in that the children are able to localize the sound source and appropriately acknowledge the speaker. Parents report that the children are more vocal at home and some are producing more intelligible speech. With the exception of the infant, all children are working on discrimination of one, two and three syllable words. Words taught are selected from Benedict's categories of first words understood, Plant's program and from the child's environment, e.g., names of relatives or pets.

In conclusion, preliminary observational results with the second group of deaf children appear promising. Parents and teachers in the school are enthusiastic and constantly provide feedback on the children's behavior. Because only one aid is available, each child's use must be carefully scheduled. The infant is seen at home and the other children are seen at school. Parents frequently visit the school and participate in their children's program, using the aid and offering suggestions. Future reports will be presented discussing test scores and analysis of language comprehension as well as changes in speech production. In future reports, associations will be drawn between type of loss, age and amount of progress noted.

FOOTNOTES

1 Available from the author.

2 The current research is supported in part by Grant No. RR07143, Department of Health and Human Services and by funds from the Northeastern University Research and Scholarship Development Fund.

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DEFINITION OF TERMS

Nonacoustic aids - also called sensory aids, sensory substitution devices, speech training aids and augmentative devices; generally refers to visual and tactile displays; tactile aids are further classified as electrocutaneous and vibrotactile; definitions are as follows:

visual displays - present speech patterns on screens and allow the hearing impaired to see configurations of their own speech or that of others.

vibrotactile aids - convert sound energy or the acoustic waveform into a movement or vibratory sensation felt on the skin through use of an oscillator or vibrator.

electrocutaneous aids - convert sound energy into electrical energy and stimulation is felt through electrodes placed on the skin; if there is more than one electrode, the sensation felt has been described as dynamic.

Basic principles of signal processing underlying sensory aid design include:

1. Direct application of the acoustic waveform to some type of transducer; considered the least complex of signal processing.
2. Vocoding - sound spectrum is divided into several bands, energy for each band is averaged over a short period of time and the averages are coded for presentation on a visual or tactile array.
3. Feature extraction - specific features of speech sound are isolated for presentation on an array; features of voicing, pitch, nasality or speech features known to be difficult for the hearing impaired to produce are isolated and presented on either a visual or tactile array.
4. LPC - linear predictive coding - a complex form of signal processing; recently used by Becker (1982) to evaluate different types of speech-to-tactile transforms; treats vocal tract as linear filters and computes its parameters.