VIBROTACTILE AIDS: A REVIEW

RBS.NO.M8912

AN INDEPENDENT PROJECT WORK SUBMITTED IN PART FULFILMENT FOR FIRST YEAR M.Sc. (SPEECH AND HEARING) TO THE UNIVERSITY OF MYSORE.

ALL INDIA INSTITUTE OF SPEECH AND HEARING: MYSORE - 570 006

MAY 1990

I DEDICATE MY PROJECT TO MY

POP AND MOM and

TO MY

DEAR FRIEND SONU

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CERTIFICATE

This is to certify that the Independent Project entitled: "Vibrotactile Aids - A Review" is the bonafide work on part fulfilment for the degree of Master of Science (Speech and Hearing) of the student with Register No.M8912.

Mysore
May 1990

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CERTIFICATE

This is to certify that this Independent Project entitled: "Vibrotactile Aids - A Review" has been dene under my supervision and guidance.

GUIDE

DECLARATION

I hereby declare that this Independent Project entitled "Vibrotactile Aids: A Review" is the result of my own study under the guidance of Dr.(Miss) S.Nikam, Professor and Head of the Department of Audiology, All India Institute of Speech and Hearing, Mysore-6 and has not been submitted earlier at any other University for any other Diploma or Degree.

Mysore **Reg. No.M8912**
May 1990

ACKNOWLEDGEMENTS

I am indebted to Dr.(Miss) S.Nikam, Professor and Head of the Department of Audiology, All India Institute of Speech and Hearing, Mysore for her valuable guidance - during the course of work and allowing me to undertake this project.

Thanks to the Director, All India Institute of Speech and Hearing, Mysore for giving me an opportunity to undertake this project.

I thank the Library staff for the search of books, journals and periodicals.

I thank my dear friend Sonu who stood by me in the Good and Bad times and also helped me in finishing this project.

I thank Geetu and Jyothi for their frequent enquiry about the progress of my project.

I final 'thank you' to Ms.Rajalakshmi R Gopal for helping with keys and notes.

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INTRODUCTION

Sensory capability ia the capacity of the organism to exhibit relatively simple behavioural or physiological response to a set of simple and well controlled stimulus conditions.

For people who have suffered a profound loss of hearing either congenitally or adventitiously in later life, the necessity for alternative pathways from the acoustic world to the brain ia urgent. Such people ordinarily cannot profit from the use of a conventional hearing aid of the air or bone conduction type and must be instructed in the use of cues either naturally available or made so by the application of technology. Communication through the skin offers possibilities for adding to the ways of receiving information because the ability to perceive through the skin a variety of patterns of pressure and vibration has suggested itself as an exploitable talent that can provide one such functional exploitable channel.

A majority of children lose their hearing from illness or birth trauma or are bom with hearing impairment due to foetal insult. When hearing losses are due to insult and or trauma there may be related neurophysiological or perceptual disorders. The disorders of integration may be visual, auditory tactile, vestibular or kinesthetic. Perception takes place at high levels of the brain bat problems in sensory integration, a lack of processing at lower levels at the brainstem can interfere with learning. Vibrotactile stimulation has been found to be beneficial as an augmentation for rehabilitation in children and adults.

Tactile sensation may be elicited by direct electrical stimulation of the skin. When a vibrotactile stimulus is presented to the skin, quickly adapting mechanorecepters are stimulated The primary afferent fibers transmit the information from the mechanoreceptors to the dorsal horn of the spiaal cord, where they ascend ipsilaterally in the dorsal column and terminate in the nuclei at the level of the medulla in the brainstem. At that point the Bibers decussate and continue up the medial leminiscus to the thalamus. From the thalamus the vibrotactile information ascends to the somatosensory area of the cortex (Martin, 1985).

A number of secondary sources in research reviews site the accepted values and functional relations for psyehophysical measures as absolute and differential thresholds for touch, vibration and electrocutaneous stimulation as well as for the effects of adaptation, temperature, masking and stimulus level on thresholds and sensory magnitude. For example the measure of tactile spatial activity known as the two point limen is 2.5 - 4 mm on the finger tips (Weinstein, 1968). When a 2-AFC (alternative forced choice) detection method is applied, the observer eta always discriminate two stimuli from one even when the stimulators are side by side occupying a total space of 1 mm (Johnson and Philips, 1981). Both of these were made with simultaneous application of the stimuli. With temporal offset between them complexities of perception may arise. For example the offsets of lower values (0-2 msecs) may result in the perception of single lows where as that of higher values (20-200 msecs) may yield a perception of two stimuli phenominally closer together (Geldard and Sherrick, 1983). If body sites other than finger tips are examined the static two point limen changes, generally becoming larger on hairy skin and especially over the thorax and abdomen. The temporal effects however remain fairly constant over a sizeable range of distances: i.e. upto 10 cm. or so depending upon the region stimulated. The cutaneous receptor sheet is analogous to the retina and the basilar membrane in that the orderly distribution of integsitive, spatial and temporal values over its surface gives rise to a large number of stable and discriminable qualities for which the conditions and their relations are not readily predicted from unidimensional measurement.

With tactile stimulation,acoustic signals that have been transposed into vibratory patterns on the skin are used to augment or replace conventional air-conduction amplification. Both hearing and touch respond to mechanical forma of energy but they do not seem to be very closely related in the human anatomy. The inner ear is an insular organ with aa intricate geometric design that accepts a spectral flux of mechanical energy performs a rapid preliminary analysis of it, then converts it to a nervous message. In constrast the skin is a diffuse system occupied by myriad entities other than mechanoreceptors and hence serving many other functions not the least of which is to keep the environment where it belongs At the receptor level, the skin is leas sensitive than the ear by perhaps 14 orders of magnitude. Another notable difference between the ear and the skin is the nature of the message normally imparted through them. For the neonate, the tactile message is warmth, caresses, support aad the nearness of food. The auditory message is also comforting but it soon takes on signalling aspects because it often precedes the contact phase. Throughout infancy, the auditory system becomes the harbinger of pleasure or of relief from discomfort. It also means whereby the parent encourages the child to discriminate environmental events of all kinds through speech and language.

Since the cues utilized by deaf individuals for speech reception are not necessarily isomorphic with those used by the normal-hearing population, the ultimate goal of a tactile communication system is to extract relevaat acoustic speech information from the speech signal and to transpose it to the individual in a tactile mode as a means of supplementing or replacing the auditory reception of speech.

Tactile stimulation on the skin has been accomplished mainly in 2 ways.

1. Using vibratory (vibrotactile stimulation)
2. Electrical (electrocutaneous stimulation).

A combination of the two has been attempted bat only limited information is available on this approach.

Vibrotactile devices are electromechanical transducers that mechanically vibrate the skin surface. Vibrotactile stimulatores use either electromagnetic or peizo electric actuators.

The interest of a number of organization and agencies in sensory aids for the handicapped has significantly accelerated the pace of research in this area. The needs of the profoundly hearing impaired have received considerable attention with the advent of cochlear implants and the recent introduction of wearable tactile aids. The availability of these devices as well as other assistive devices, is changing the role of the dispenser and challenging him to expand his services to meet the demands of the changing marker.

"While the use of tactile information by the hearing impaired is certainly not a new concept, recent technological advancements have resulted in the development of wearable tactile devices. The availability of these devices offers the profoundly hearing impaired new opportunities for the development of effective and meaningful communication skills as well as an increased awareness of their environment. Numerous research projects and studies are underway exploring various aspects of benefits, function and application of tactile aids. Some of the more important issues being investigated are:

1. The number of tactile channels for optimal enhancement of tactile communication.
2. Mode of delivery of the tactile information.
3. Location of the vibrators from both a function and cosmetic standpoint.

Finally its important to call upon the electrophysiological data as regards vibrotactile sensation in planning rehabilitation programmes.

HISTORICAL BACKGROUND

For several centuries teachers hare attempted to convey information on their speech by encouraging their pupils to use the sense of touCh.

Greene (1783) reported that Braidwood enCouraged hiS children to sEE and feel the movements and effects of speech.

Abbe 'del' epee (1784) stated that he worked with his pupil's finger always in his mouth.

Arrowsmith(1819) used the term "feeling movements of the tongue". This form of tactile input remained for well over a century.

Attempts to develop electrical devices to channel acoustic messages to the sense of touch (i.e. the tactile system) date in an informal way from the invention of the telegraph and a publication of the use of direct electrical stimulation which appeared early in this century (Dupont, 1907).

The use of tactile sensation was advocated by Story in 1917 who felt that the child should be allowed to touch the teacher's face and larynx but warned against the teacher touching the child's. This point was that the drive to apeak should come from the child, and not be imposed by the teacher.

Formal efforts in studying tactile stimulation began with Gault in the 1920s. In a series of experiments over a period of 13 years he and his co-workers used devices ranging from a crude 14 foot "speaking tube", designed so that the subject his or her hand over the end, to a single hand held vibrator (Gault, 1924; Gault, 1926 a; 1926 by Gault and Goodfellow, 1937). Preliminary work was also reported with a multi unit teletactor which contained five vibrators one for each finger and thumb on the hand (Gault and crane, 1928).

Gault (1936) modified the output of his system to provide several loci of vibrations on the finger tips, each having a restricted band of frequencies from low to high.

Alcorn (1945) putforth the 'Tadoma method' that has been universaily used ia the education of children who are both deaf and blind. Here the child places both hands on the speaker's face so that the thumb rests on the lips index on the nose little fingers on the throat and the remaining fingers on the cheeks. Thus both touch and kinesthesia are involved since the fingers also bend with the movement of the speaker's lips and jaw.

Wedenberg (1951) employed the 'adconcham' method When the teacher provides with tactile, breathstream cues on the ear and surrounding surfaces in addition to the auditory pattern.

Gruner (1955) blindfolded the hard of hearing child in order to permit him to attend more readily to haptic touch patterns.

Boothroyd from 1963 to 1970 devised a high power hearing aid with extended low frequency response. This was fitted with a bone conduction oscillator and an air conduction receiver on the two arms of the 'Y' cord with a patch of velcro glued to the back of the oscillator ao as to be attached easily to a mitt worn on the hand.

Pickett (1963) developed a 10 channel analyzer which converted the information into 10 vibration channels.

Risberg, Martony (1968), Dolansky, et al (1969) devised and tested visual displays. Their prototype pitch detector quantises the pitch into 8 channels and tactile feedback is provided by 2 or 3 solenoid pockers or tactors. The first seven channels correspond to a range of 100 to 240 Hz in bandwidths of approximately 20 Hz each. The right channel corresponds to all pitch frequencies above 240 Hz. Rogers (1970) experimented with sets of air however more information has not been catalogued.

Willemain and Lee (1972) employed a tactile display driven by a pitch detector to improve the intonation patterns of the deaf speakers.

Keidel (1974) developed the electromechanical cochlea with a spatial type of display. The configuration of array being the travelling wave and the location of stimulation being the forearm.

Kerman (1974) developed a frequency versus time display type known as the foremant code. The location of stimulation being the fingers.

Miller et al. (1974) developed the feature indicator with a temporal type of display. It had 3 vibrators and could be placed either on the hand or on the fingers.

Engleman and Rosov in 1975 developed the tactile vocoder consisting of 23 channels with a spatial type of display. The location of stimulation was on the arms and the legs.

Ling and Sofin (1975) used a single vibrator to signal fricatives.

Scott and Defillippo (1976) described a system that divided the spectrum of speech into the low and high frequency range. The low frequency being delivered to the palm surface of the thumb as vibration and the high frequency portion to the skin on the thumb as electrocutaneous sensation

Spens (1977) described the optacon which had a frequency vs. time display sad 24 x 6 vibrators matrix, the hand being the site of the stimulation.

Trauamuller (1977) developed the sentiphone with a single vibrator on the jaw bone and the type of display being temporal.

Yenikomshian and Goldstein (1977) used the optacon with an 18 x 6 vibratory matrix. The type of display being fre-queney vs. intensity and the location of stimulation being the fingers or hand.

Sparks et al in 1978 and 1979 developed the Multipoint electro tactile speech aid (MESA) with a 36 x 8 matrix of electrodes placed on the abdomen and the type of display being frequency vs. intensity.

Scott and DeFilippo (1979) developed the speech recogni-tion and (SRA-10) with a temporal type of display with three vibrators placed on the abdomen.

A modified version (Aid 2) was also developed with a spectral type of display. Three electrodes and one vibrator were used to convey the signal. An Aid 3 was also developed with an added noise generator, a low pass filter and a peak clipper. The transducers consisted of 2 Radio Bar B-70 vibra-tors and a third suyag vibrator.

The development of electrotactile devices for the deaf using electrocutaneous stimulation has been pursued by Saunders in 1983.

CANDIDACY FOR A VIBROTACTILE AID

Solutions to the problem of communicating with deaf people have taken many forms over the last two centuries. Those that have survived and been moat frequently used have been of two general types natural unaided systems and synthetic unaided systems (sherrick, 1978). The lipreading or speech reading method is the best known natural system and the language of signs in various forms is the most familiar of the synthetic systems. Natural is meant to convey the fact that the talker need not recode his or her speech for the listener to perceive it, "synthetic" implies that the talker must recede the message (eg. in sign language to body or limb movements) to be understood by the listener.

When an individual has a hearing impairment too severe to benefit from amplification ancillary methods must be considered to assist in overcoming the two primary factors germane to spoken communication: the reception of speech from others and the production of speech by the hearing impaired person. One technique to improve speech reception and production in profoundly deaf persons in tactile stimulation.

Sensory channels accessible by electronic aids are

1. Visual system/visual aids.
2. The acoustic nerve and implant stimulating devices.
3. The mechanoreceptive systems of the skin.

Aids using visual presentation of speech information have been developed, for speech feedback in voice training as well as for aiding speech reception. Tactile aid development has focussed more on reception. Auditory implanted electrodes provide a very rudimentary form of hearing via surgical approaches to the inner ear (cochlea).

Tactile displays have been favoured over visual as aids to speech reception because the eyes are often occupied with other tasks while one is receiving speech messages.

The use of touch can be used as a supplement to residual hearing Maudition.

On the contrary, the two systems are being compared and the comparisons have focussed mainly on the limitations that the akin has as a sensory receptor of acoustic information when vibrotactile stimulation is used. For example - the normal auditory system has a dynamic range of 130 dB but the vibrotactila system range is only 30-35 dB.

Moreover while the auditory system is responsive to frequencies ranging from 20-20000 Hz and has an optimum frequency range between 300 and 3000 Hz., the upper limit of the vibrotactile system is only 400-500 Hz, and the vibratory receptors are best stimulated by frequencies in 40-400 Hz range. The vibrotactile mode is similarly inferior to the ear in the time required for the fall development of sensation and difference limen for frequency. In addition to these psychoacoustic variables Kiedel (1974) also pointed out that the vibrotactile system has a poor memory compared to the highly developed one for the auditory system. That is there is a lack of ability to retain the images that are displayed on the skin either on a short or long term basis.

Vibrotactile sensitivity is vulnerable to aging like vision and hearing.

Various studies have been documented in literature.

Kenshalo (1979, 1986) and Verrillo (1980) have reported the findings dealing with peripheral aspects of vibrotactile sensation.

Verrillo (1980) reported a progressive decrease in sensitivity at frequencies between 80 and 700 Hz. These frequencies are typically referred to as high frequencies in the literature but this is relative to the frequency response of the skin. A decrease in sensitivity as demonstrated over the entire age span with the sharpest decrease occuring between 50 and 65 years of age. He speculated that the reduction in vibrotactile sensitivity with high vs. low frequency stimuli indicates that the high frequency receptor system is more susceptible to changes with aging. In contrast with Verrillo's study Kenshalo reported significant reductions ia sensitivity for both low and high frequency stimuli, although there was a greater decline at 250 Hz than at 40 Hz. His subjects also demonstrated greater reduction in vibrotactile sensitivity in the lower extremeties than in the upper extremities.

In a cross sectional study of males aged 20-80 years conducted by Terry (1983) brought to light the result that there was a 40 to 60% decline in the vibrotaetile sensitivity in the upper extremeties and greater than 60% decline of the same in the lower extremities.

In addition to diminished sensitivity there is also a decrease in the transmission speed of vibrotaetile stimuli peripherally - (Schaumberg, et al. 1983).

Doffman and Bosley (1979) who studied 60-85 year old subjects and a group of younger controls reported a reduction in conduction velocities of 0.16 m/sec per year for the upper extremeties. It was also found that conduction velocity in the spinal cord declines sharply after 60 years with a decrease of 0.78 msec per year but no change ia velocity from the medulla to the cortex.

Desmedt and Sheron (1980) reported slower conduction velocities of afferent fibres in people by the 8th decade.

Verrillo (1982) found that with inter stimulus intervals leas than 150 maecs., the older subjects were unable to perceive two separate stimuli where as the younger group did not experience difficulty with discrimination.

Although apparently not used to any great extent with older individuals vibrotactile stimulation has still been found to be beneficial.

There has been no culmination in the production of a sensory aid for widespread use among the population of deaf persons. In contrast many deaf persons are being equipped with cochlear implants. Auditory implanted electrodes provide a very rudimentary form of hearing via surgical approaches to the inner ear (cochlea). Auditory implants are electrode systems fixed surgically in the cochlea so as to stimulate fibers of the auditory nerve. These fibers are found to be stimulable in a very large majority of profoundly or totally deaf persons. Because such systems are not able to stimulate the normal sound to neural conversion process the sound perceived implants is highly abnormal.

From the point of view of the client, implant aids immediately provide, at the least rough sensations of sound from the environment. However implants entail major surgery and high associated costs. Tactile aids entail a learning period but are low cost, easily replaceable aids. Both types of aids typically provide only a modicum of information about speech. However the information received through these two aid modalities is partially non-redundant. This suggests that further gains might be obtained with a hybrid system combining a hearing implant and a tactile aid.

It is important in testing severely or profoundly deaf subjects to know at What levels one should expect responses to vibrotactile stimulation. Vibrotactile are conduction thresholds may lead to the assumption of residual hearing when none exists, while reporting similar thresholds in bone conduction testing may lead to the faulty diagnosis of a middle ear condition through the presence of an apparent air-bone gap.

The data of Wegel (1922, 1932) and that of Fletcher (1953) were obtained from normal listeners reporting "feeling" sensations as a result of high energy stimulation.

According to Barr (   ) vibrotactile thresholds for frequencies of 1 and 2 KHz were obtained at 100 dB. He further felt that these responses cooled equally well have been to vibrotactile or auditory stimulation.

In bone conduction audiometry the problem of vibrotactile stimulation becomes more acute. This is because the vibrator is specifically designed to transmit mechanical vibrations to the mastoid region. In the survey of a population for the school of the deaf, Rughson, et al. (1939) felt that the bone conduction thresholds obtained at 128 and 256 Hz were defenitely the result of vibrotactile stimulation although they were satisfied that the higher frequency thresh-olds were auditory.

Portmann and Portmann (1961) suggested that one must explain to the patient that with low tones, for example, it is the threshold of auditory sensation which is being looked for i.e. sonorous and not the threshold of taetile sensation (vibratory).

Reger (1965) stated that patients with severe hearing losses for bone conducted sounds may respond to the vibrator with the vibration sense (Pallesthesia) before the bone conduction threshold is stimulated, thereby giving a false result.

Several workers have referred to the possibility of other types of response to sound vibration. For example Bocca and Perani (1960) have suggested that the bone conduction thresholds of severely deaf patients may represent vestibular hearing. Similarly the"Feeling" thresholds for air-borne sounds found by Wegel (1932) were reported by his subjects to produce sensa-tions which could be related to vestibular disturbance.

Nober (1964) does not accept the theory of vestibular hearing, however one of his strongest arguements being baaed on the similar configuration of bone conduction threshold of profoundly deaf subjects and their vibrotactile thresholds at the fingertips.

Van Uden (1958) has stated "All deaf children can react to sound in the ears", in a certain percentage of the deaf children these reactions seem to be very similar to vibration feeling. It seems to be probable that these children have only vibration feeling in the ears. He has however developed educational techniques to make maximum use of this sensitivity.

Emphasis on vibrotactile sense has also been placed by Guberina (1963) who has transmitted information through vibrators placed on various parts of the body. He has stated that it is not by pure chance that a deaf person remains sensitive to the low frequencies which are commonly called vibration.

The point in question is not the physical nature of the stimulus, which is undoubtedly vibratory but of the sensory modailty through which it is perceived.

Independent measures of the information processing capacities of the skin affirms that the sensory system possesses the channel capacity for decoding a eocherant and time varying symbol set of great complexity such as speech. Of particular concern to developers of tactile aids is the question whether the processing skills exists only in the hands or whether other akin areas are equally capable. The literature supports the position that the hands are unique both structurally and functionally. The comparitlve amount of cortical area devoted to the hands is very large. - Sur et al.(1980) and the absolute sensitivity and spatial acuity of the area rank among the highest among the entire body (Weinstein, 1968). To the degree that the saltatory effect is a measure of independence of pattern varying in both time and space among skin regions, recent measurements on the hand, the arm the thigh and the thorax suggest that the region with best resolving power is the finger tip.

Finally in examining the thresholds for responses to vibrotactile stimulation two points have to be kept in mind. Firstly, normal hearing subjects must experience a simultaneous auditory sensation when exposed to sound intensities sufficient to produce vibrotactile stimulation within the usual frequency range of pure tone audiometry. Under these conditions the two are perceived as a whole and unless the observer is able to dissociate the sensations he may be unaware of the vibrotaetile element until it is well above threshold levels.

Secondly when using profoundly deaf subjects it is difficult to decide whether they are responding to an auditory on a vibrotactile sensation, since a person who is sufficiently deaf as to have no experience of auditory sensations will be unable to make the subjective distinction.

From the audiologlcal consideration the vibrotactile client is typically one whose hearing impairment is so profound that tranditional means of amplification by way of power behind-the-ear or body aids have been unsuccessful. Mostly the research and development programmes have been carried out on the three distinguishable subgroups of available subjects.

1. Normal subjects deprived of auditory input.
2. Deaf mutes and adults with partially or fully developed language skills.
3. Deaf skills without language skills.

The first group is commonly used in preliminary analytic testing for determining the fidility of the device in processing sounds. The other two groups are those for which the aid is intended. Both must be represented in the subject samples when field testing is done if the aid purports to be of completely general use.

The client who has some residual hearing and receives minimal benefit from amplification however may be a good candidate for a tactile aid. As with traditional amplification systems, the client who is motivated by a desire to improve communication with family and friends will be more successful in the use of the device over all. In addition the client must be willing to wear the device on a daily basis. He will need to be able to adapt to the size, appearance and functional aspects of hearing the device and be willing to master the basic operations and maintainance requirements.

Finally the client must be willing to commit to an extensive programme of rehabilitation aimed at enhancing his Interpretation of vibrotaetile information and improving his communication skills.

EVALUATION OF TACTILE AIDS

The amount of useful information that a tactile aid user can obtain from these devices is largely determined by external factors such as training and whether the user is post lingually or pre-lingually deaf, it is not possible to precisely measure the usefulness of the device or even to predict the outcome for a given user. It is possible however to describe the kinds of information which can be expected to be transferred and to compare those expectations to the results.

The frequency-lowering processing causes the sensation of sound to become independent of frequency. Because of this the audiogram of a tactile aid user taken with a free-field method will result in an essentially normal no loss result. This does not mean that normal comprehension is restored but rather that normal comprehension and sound awareness are not the asmething. In effect the usual relations between the audiograms taken this way and the subject's ability to comprehend the information in sounds is destroyed for tactile-aid users.

Erber reported a series of studies which had lead him to the conclusion that the audiogram is an inadequate predictor of speech recognition in the case of some profoundly deaf children. Many of these children give responses to puretone signals on the basis of vibrotactile sensation and not hearing. First, he reported a study that he had conducted in which the Manchester University Monosyllabic word list was presented to 40 deaf children at the "Central Institute for the Deaf". This list being a phonetically balanced word list, employed a vocabulary appropriate for the age range of the children in the study. The words were presented monoaurally through a high quality amplification system at comfortable listening levels. Data from the investigations suggest that an average hearing level greater than 95 dB is quite predictive of poor performance on this test. Erber again constructed a list of 25 spondaic words which were carefully recorded to provide similar patterning and stress within each word. The 12 children who were tested had the list of words kept in front of them and they selected from that set the spondaic word they perceived. The distribution of scores was a striking one revealing a dichotomy between high scores (70-100%) and low scores (0-30%). The finding suggests that the pure tone audiogram is not a perfect predictor of the group into which the children's monoaural responses to spondees will fall. Erber regarded the high scoring group as severely hearing impaired, most of them would be similarly claesifiedon the basis of the audiogram. The low scoring group the regarded as the profoundly deaf; many of these children would not be so classified on the basis of their pure tone audiograms. ia short the "word- recognition". The scores were used as a means ofclassifying children as severely and profoundly hearing impaired. He believed that the children in the severely impaired group are those who posses true residual hearing there by having normal ability to discriminate between frequencies at least in the low frequency ranges and that the profoundly deaf group of children perceive achustic stimuli through vibrotactile sensation with their ears. They have the ability to perceive time and intensity cues in speech but not to discriminate small differences in frequencies or rapid frequency changes which are characteri-stic of speech (spectral changes).

The tactile sense can be made to serve as a distance modality by the use of electronic aids. The devices so far created for transforming speech for tactile presentation have provided relatively simple displays.

Pioneer Gault's (1924) primary hypothetical construct was to "graft an ear to the skin". It was indicative that Gault was attempting to develop a sensory substitute for the defective ear rather than a sensory aid to assist the hearing impaired person in the communicative process.

In working with the simplest device, the speaking tube he found that one subject after 35-40 hours of practice could recognize 34 words through tactile stimulation alone and * great number of sentences that were made op by combining these words. Moreover the subject had aa accuracy of 88-95% ia the recognition of 200 tactile impressions of familiar words. With the single unit vibrator, the subject attained an accuracy of 58% when using 100 tactile impre-ssions he had learned with the speaking tube, but after an additional 8 hour of practice attained about only 70% accuracy in discriminating among 4 sentences.

Preliminary work of Gault was also reported with the multi-unit teletactor in 1928. The teletactor contained five vibrators one for each finger and the thumb; each having a restricted band of frequencies from low to high. The skin does not respond well to higher frequencies and energy differences may have masked information from other bands, Hence various modulations of teletactor designs have been made but nearly all have applied the place principle in distributing speech frequencies over the skin.

The major modification incorporated a vocoder in the transmission system. The channel vocoder derives a stream of spectral data using a bank of filters to analyze input speech. The tactile display consists of a row of stimulators, one for each filter band arrayed along the skin surface. The stimulation intensity of each stimulator ia controlled by the sound energy detected in its filter channel.

Tests of tactual speech perception were conducted using a special frequency analyzing vocoder by Pickett and Pickett in 1963 in the Gunnar Fant's Laboratory in Stockholm. The Vocoder presented a running frequency analysis of speech mapped into a spatial array of tactual vibrations which were applied to the fingers of the receiving subject. Ten vibrators were used, one for each finger. The position of a vibrator represented a given frequency region of speech energy, the total range covered was 210 to 7700 Hz; all the vibrations had a frequency of 300 Hz; the vibration amplitudes represented the energy distribution for the various frequencies. Discrimination and identification tests were performed with certain consonants including those that might be difficult to lipread. Performance with vowels appeared to be related to formant structure and duration as measured on the test-vowels and to tactual masking effects. Consonant discrimination was good between steps and continuants. Consonant features of nasality, voicing and affrication were also discriminated to some extent. Hence it can be concluded that the skin offers certain capacities for transmitting speech information which can be used to compliment speech communication where only an improved speech signal is normally received.

Van Uden (1967) identified a special group of children whom he labelled "vibratory-tactual" children. These are hearing impaired children whose impairment is so great that the audiometric configurations obtained are probably aot reflective of geguine auditory activity but rather of vibro-taetile stimulation.

Various modifications to the teletactor design ware supplied by Kiedel (1968) who applied Von Bekesy's model of the cochlea to this task. In this apparatus, the speech frequencies are distributed over the skin according to the parameters of the model. In order to transpose frequencies from 300 Hz to 3000 Hz. down to 40 Hz to 400 Hz, where they would be felt. Kiedel played back recorded speech sounds at one half to one-eighth normal speech. He reported excellent recognition of new words after a 32 hour training period on phonetically balanced word list. The major problem with the system is in the sluggish transmission rates. The observer has difficulty retaining initial patterns over the duration of a word. A major additional feature provided by the Bekesy model is a time delay in the development of patterns of vibration over the skin (van Bekesy, 1967).

All the previously cited tactile speech analyzers lacked this processing characteristics which separates the pitches of speech sounds in an orderly manner along a contiguous spatio-temporal surface. Thus the lateralization capacity of the skin afforded by inhibition of the delay over very short times is added to the localizing capacity of the skin over the longer times between phonemic and syllabic utterances.

Suzuki, Kagami and Takahashi (1968) trained children with 10 vibratory outputs. Better additional information enhanced special reading. High frequency consonants like /s/ and /t/ could be differentiated by speech reading supplemented by touch. Suzuki found no difference in speech reading of vowels (in words and in isolation) but certain homophonous words (patto-manto-batto) were discriminated significantly when vision was aided by touch. The investigators concluded that the vibratory stimulus they provided supplied gross features of spectrum time and amplitude.

Kringlebotn (1968) successfully worked with a vibratory system to teach articulation of the /a/ sound. Ten profoundly hearing impaired boys were tested under two conditions.

1) Audition supplemented by lipreading.
2) Audition and lipreading supplemented by a vibrotactile cue.

The subjects performed well when the tactile cue was presented which provides continuing evidence of its effectiveness. Similar supporting evidence was also provided by Willemain and Lee (1972).

For better pitch control various researchers (Kisberg, 1968; Martony, 1968 and Dolansky, 1969) devised and tested the pitch detector. The prototype of the pitch detector has a throat microphone which detects voiced speech. The output is amplified, low pass filtered and converted to a square wave pulse train by a Schmitt trigger. The pulse train is gated for a fixed time and the pitch frequency is determined from a zero-crossing count on the gated pulse train. The pitch measurement is quantized into one of the 8 channels. The first 7 channels are adjusted to correspond to the range of 100-240 Hz in bandwidths of approximately 20 Hz each. The eighth channel corresponds to all pitch frequencies above 240 Hz. The speech input is sampled periodically for duration of 50, 100, 200 or 400 milliseconds. The quantized feedback as a function of display rate in steps of hundred, 150, 250 and 450 milliseconds can be investigated. The display is also quite simpler. The solenoids poke the finger of the speaker to provide tactile feedback. The displays employed only two or three pokers/tactors because the eventual goal of research is a wearable speech aid and that it be simple and inconspicuous to the user. Switching circuits allow the experimenter to assign counts inany channel to any tactor. Thus the e channels can be OK bends when three pokers are used or into high and lew bands when two are used.

Experiments were conducted with a total of 25 profound aensori-neural loss boys and girls; 13-17 years old at the Boston School for the Deaf. Each spent one half hour per weak with the device upto a period of four weeks. The subject would place his hand on the display and attempt to sustain a hum at the selected target level. Humming was ased to avoid linguistic influences of speech on voice pitch. Further more names or certain text passages were also used to stimulate the conversational environment 2 pitch problems were manifested. Martony (1968) noted that deaf speakers tend to begin breath groups at abnormally high pitch; then to quickly slide down to a more natural level. The other is a tendency to increase average pitch when the difficulty of the required utterance is increased. These pitch changes were explained by Pickett in 1968 by the kinesthetic referrant hypothesis which acts as a monitor or feedback to the individual (at high pitches).

The use of the aid in helping monitor the right pitch and intonation patterns indicated the necessity for the development of a wearable aid.

The best data available for calculating the capacity of the vibrotactile channel are derived from studies of blind readers using the optacon (Bliss et al. 1970). The optacon is a device that transforms print of vibration on the distal pads of the index finger, studies done by Craig et al in 1984 am sighted and blind subjects also seems to indicate it. The fastest reading rate obtained was about 90 words per minute with the optacon. It further appeared that this limit was due to the temporal and apatial resolution of the skin of the finger pad (Phillips and Johnson, 1984).

Boothroyd et al (1970) hypothesized that a totally deaf child with only tactile sensitivity responded better at the low frequencies. Thereby a high power hearing aid with extended low frequency response was fitted with a bone conduction oscillator and an air conduction receiver on the two arms of a 'Y' cord.

Free field pure tone tests showed an average increase in sensitivity by 23 dB when both vibrators and air conduction receivers were used in comparison to air conduction receivers only (these tests were performed on young children who did net benefit from a standard hearing aid and gave little or no response in audiometric testing.

Syllabic patterns and voicing were distinguished using this aid and voice control was noticed to be lost if the aid was out of action for more than a few days.

Another eventful development in the history of tactile aids of the non-wearable type was the Kostic's apparatus.

This apparatus had an intensity indicator, a friction indicator, a nasality indicator, vibrator, selectors and a selective auditory filter amplifier (SAFA). The vibrator is a box fitted with a membrane which transmits the filtered vibrations of laryngeal voice. Several vibrator boxes could be used by the teacher at the same time for training several children. Each child had to work with two boxes. By placing gently all the fingers of One hand on one membrane and all fingers of the other hand on another membrane, the child had ten points of tactual contact with the vibrations associated with the laryngeal voice. The teacher/child can speak into the microphone and the child can tactually recognize variations in the laryngeal voice.

BLOCK DIGRAM OF THE VIBRATORUNIT OF THE SAFA

The signal from the microphone is first amplified and filtered so that all frequencies above 500 Hz are suppressed tad cut. The resulting signal is sent to the vibrator boxes.

The vibration of the membrane is silent and free from amplifier disturbances.On some models amplification and filtering stages are built within each box to make the unit compact.

Bessy (1972) evaluated the usefulness of this system. It was found that the Child could perceive the difference between voiced and voiceless consonants, fundamental tone of an adult male and female and even children's voices. Furthermore, even minute differences in pitch level could be distinguished.

Duration of each speech sound syllabic stress and overall intensity pattern could be discriminated.

Aside from these prosodic elements, the child was reported to distinguish between major categories of speech sounds, vowel vs consonants, affricates vs. other consonants, fricatives vs. other consonants and nasals and laterals vs other consonants.

The multipoint electrotactile speech aid for the transmission of segemental features of speech was evaluated by

Kirman (1973). He discussed two plausible explanations for the filure of the tactile speech processing transforms to provide reliable information about speech events. First he cited the complexity of the "speech code" including the notion that speech sound processing is inextricably tied to the auditory system. Second, he discussed the generally accepted notion that the skin is too slow to accomplish the temporal-spatial analysis of the rapidly changing patterns of running speech. However, later Kirman rejected both of these notions concluding that tactile devices had not been designed to extract the higher order invariances of speech, for example many spectral analysis devices have been designed to provide maximum resolution for single phonetic units. The stimulators associated with the channel outputs for such devices have been spaced for apart on the skin surface in order to avoid the effects of cross channel masking. He pointed out that this design characteristic may result in a device having sufficient resolution for individual speech signals. The user has difficulty integrating the various components of running discourse into a complete and meaningful message.

Evaluation of a tactile vocoder for word recognition was done by Erber (1974). The purpose of the experiment was to evaluate the usefulness of a tactile vocoder in a study that was designed to combine many features considered to be partially successful. Some of these features were l/3rd actave filtering, a linear array using solenoids as the transducers and a carrier frequency for the solenoids of 100 Hz. In addition, the words were used as stimuli. Presentation was live voice by several speakers and the subject was provided with a microphone enabling feedback from the subject's own vocalizations. From the analysis of probability of correct responses, significant confusions and phonetic identification, it appears that the majority of consonant phonemes can be identified. The confusions that are found through the cutaneous sense are similar to those that occur in addition or in visual representation of the Speech signal. Nasals are interconfuaed and so are voiced stop consonants. However in evaluating the tactile vocoder, it may not be a sensible strategy to prove that all phonemes can be identified before the system is adopted for use.)

Engelman and Rosov (1975) demonstrated the performance of a 23 channel vibrotactile vocoder in various words and sentence-learning tasks with young normal adults and deaf children. The tactile reception learning of four deaf boys was studied. The best subject (8-year-old) achieved 80% correct (60 of a pool of 75 words) in a test after 34 weeks of training; he then accelerated his progress to achive - 90%

correct (122 of a pool 6f 135 words) in 13 more weeks of training. One deaf boy was trained wearing hi* hearing aid in addition to receiving speech via the tactile vocoder; he learned 35 words to 94% correct (in 8 weeks) when tested with hearing only, he scored 65% correct and 40% correct with tactile only, indicating that he had been able to integrate tactile with auditory information to identify among his first 35 words. At 21 weeks, he achieved 90% of 60 words and at the end of 26 weeks scored 78% of 100 words (tactile + hearing). They concluded that hundreds of correct repetitions are required to learn simple tactile discriminations but that given good learning conditions, the rate of learning could accelerate "once an initial set of 30-40 words has been mastered

Ling and Sofin (1975) devised a tactual system with a single vibrator to signal fricatives. Though fricatives were signalled or much more complex circuitry was necessary to provide information as to which fricative was spoken.

A similar device providing only one aspect of speech that is the pitch contour was designed by Willemain and Lee in 1975. It was that a more complex array was necessary to display the detailed segmental information.

From 1973 to 1977 a variety of tactile aids ware designed aad tested. The simplest of these was the single channel aid modified by Bergueese, 1976. It generated a single frequency at which the skin was most sensitive i.e. 250 Hz. The amplitude of the signal was then modulated by the speech signal power to yield a prosodie sequence that mirrored the speech.

The year 1976 saw the advent of spectrally oriented aids. Goldstein and stark (1976) were the ones to evaluate it. They attempted to provide the skin with a spatio-temporal vocoder type transform of the original speech spectrum using 15-25 frequency channels. These aids were reported to be useful for training profoundly deaf persons in the reception and production of short speech segments. However none have been found to provide perfect resolution for these short segments. These shortcomings led to the development of the feature intraction-described by Scott and Filippo in 1976.

Yenikomshian and Goldstein (1977) conducted a study for the identification of speech sounds displayed on a vibrotactile vocoder. This study was a part of a larger endeavour concerned with aids to help profoundly deaf infants to acquire speech and language skills. The main aim was to investigate the factors and the identification of different types of speech signals presented on a vibrotactile vocoder. The investigation showed that subjects over an extended training period learned to identify the vibrotactile patterns of vowel durations, steady, state vowels and spondee words, though performances never peaked.

The speech recognitlon aid developed in 1976 by Scott and DeFilippo was simple 2-channel device. It had a high frequency channel above 4 KHz and a low frequency channel below 1 KHz.

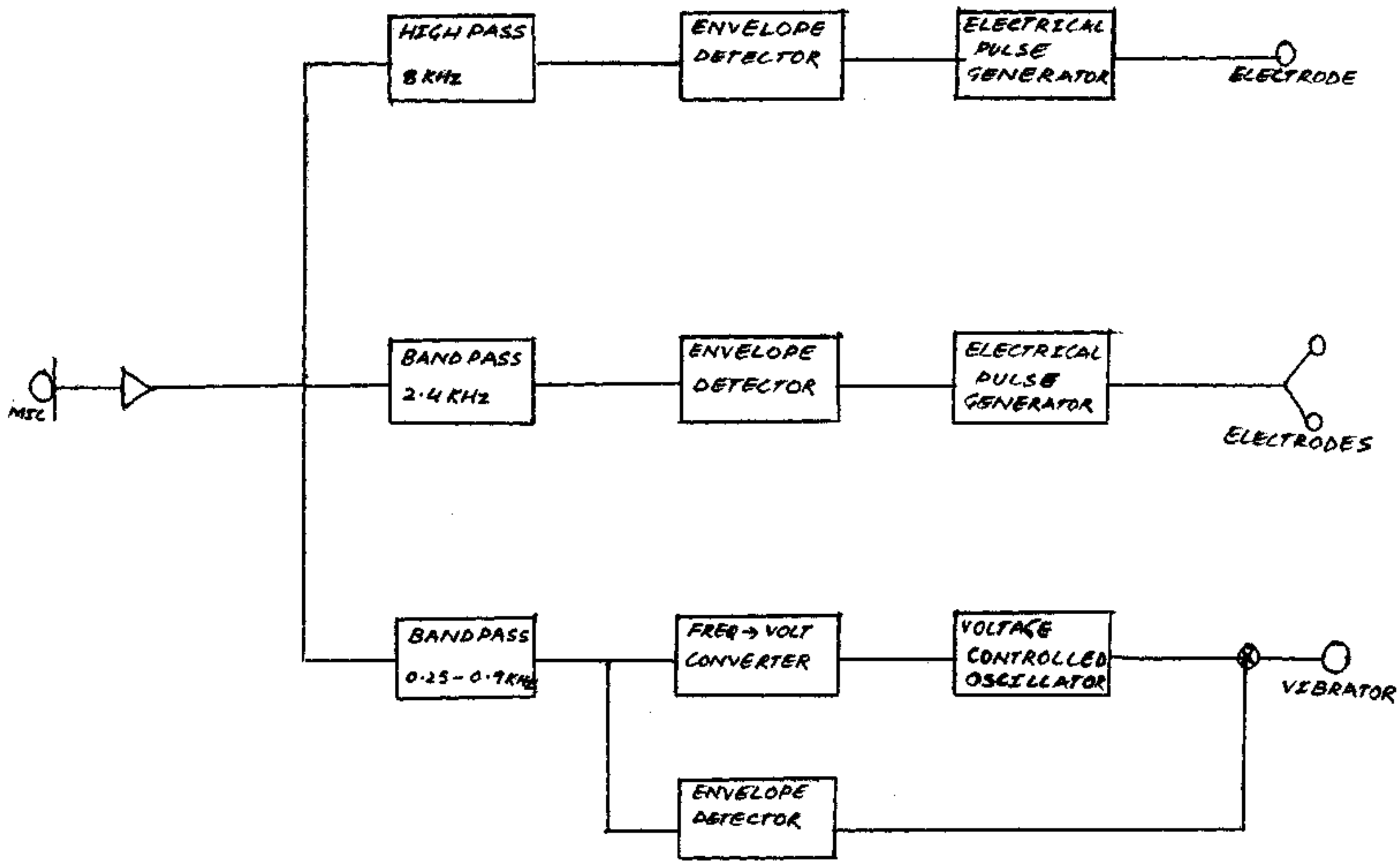
The high frequency information was delivered via an electrode where as the low frequency information via a mechanical transducer (vibratory stimulation). Though the transducer location did not matter in particular, high and low frequencies were discriminated because they felt different. The evaluation of this aid was first done by Scott and DeFilippo in 1978 using a tracking procedure which they described as an objective measure of the speech reading of continuous discourse material. Performance was measured in correct words per minute score (mean number of words per minute). Data were usually displayed in one hour units.

It was found that when normal hearing subjects were masked with White noise or when ear plugs were used, lip-reading performance increased by 20%. As a note normal hearing persons average about 100 to 120 words per minute when no ear plugs are noise are used. From the above results it was felt that spectral information be considerably enhanced which led to the development of the hybrid Electrical vibratory and (aid-2).

Three electrodes and one vibrator used to convey the signal were placed on the back of the hand.

As in the figure (next page) the center electrode corresponded to electrode 3 (the top electrode in the figure). This electrode was activated by the output of an 8000 Hz high pass filter. The phonemes / s / and / t / produced a maximum signal at this electrodes thus these sounds produced a puncuate aperiodic sensation.The surrounding electrodes correspond to electrodes one and two as in the figure. These electrodes were maximally activated by sounds / / and /t /. The reason for using 2 electrodes for this channel was critical to the design objectives. By using 2 electrodes positioned on either side of the high frequency transducer, a broad diffuse sensation perceived at the same locus of stimulation as the high frequency channel was achieved. The important part of the design approach was to make different sounds feel different and also to keep the sensation at the same location. By using 2 electrodes to code mid frequencies a broad electrical stimulation was achieved as opposed to the narrow punctuate sensation from the single high frequency electrode. The electrodes conveyed the fricatives and affricates of speech as aperiodic sensations.

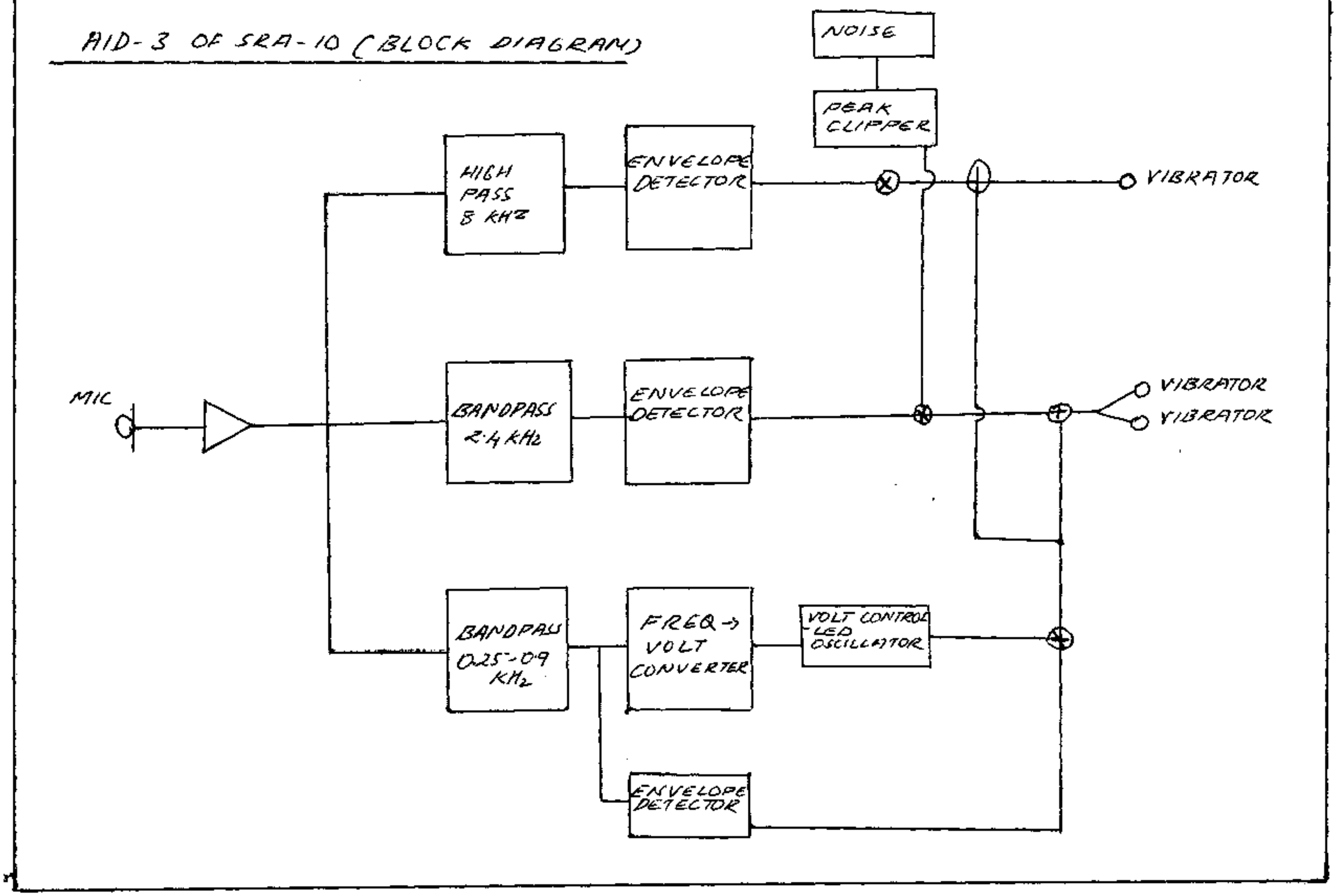
BLOCK DIAGRAM OF AID-2 (SRA-10)



The vibrators worn on the wrist conveyed the vocalic portion of speech as periodic diffuse sensations. Thus the amount of spectral information was increased compared to the single vibratory channel in the first aid.

The most serious drawback of this system was that the electrical stimulus presented was not particularly pleasant. So the resultant SRA-10, an all vibratory system with the basic electronics, bat with an added noise generator, low-pass filter and peak clipper was developed. The extra components in the circuit were meant to provide an aperiodic signal to the vibrators as a substitute to the electricl stimulators. The transducers consisted of 2 Radio-ear B-70 bone vibrators and a suvag vibrator which was worn between the 2B-70 vibrators. The high frequency channel was conveyed by the center transducer and the midfrequeney channel by the surrounding transducers. A / / was discriminated from a /s/ by a spreading, diffuse sensation as opposed.to a localized puctuate sensation. Vowels were felt the loudest since all the three vibrators were activated. The greatest weakness of the all vibratory version compared to the hybrid electrical vibratory aid was that the fricatives and vowels were not as instantly and clearly discriminate. The distinction between vibratory aperiodicity and periodicity was not as great as between vibratory stimulation and electrical stimulation. However the all vibratory sensations were more pleasant than the electrical sensation, so the trade off was deemed justified.

AID-3 OF SRA-10 (BLOCK DIAGRAM)



The efficacy of the SRA-10 was tested on normal hearing, functionally deafened and profoundly deaf adults and four profoundly deaf children for the reception of connected discourse (a) with hearing-impaired subjects the SRA-10 provided little or no benefit in speech reading as measured by the tracking procedure, (b) At least one of the normal hearing functionally deafened subjects appeared to benefit in speech reading connected discourse although not to the extent indicated by previous work. With children, a significant increase in the quantity of communication using vocalization plus sign language simultaneously when vibrotactile stimulation was seen with SRA-10 was used in individual language therapy sessions. This finding supports the notion that vibrotactile stimulation was positively associated with the communicative act.

A more refined experiment with single channel devices was carried out by Rothenberg and Molitor (1979). They found that the fundamental frequency could be recorded satisfactorily by lowering the average frequency without reducing frequency deviation. Their subjects were presented vibrotactile pulse trains related to the fundamental frequency. The sentences differed according to which word was stressed and whether rising intonation indicated a question or falling intonation indicated a statement. Performance with the vibrotactile signal alone (without lipreading) was as high as 50%.

Although long term training is necessary for the hearing impaired users to obtain maximum benefit from tactual vocoders (Oller, Payne and Garmin, 1980) demonstrated after limited practice (1 hour) profoundly hearing impaired adolescents can learn to discriminate certain hard to lipread word pairs (oral vs. nasal consonants, stop vs. fricative consonants or fricatives vs. nasal consonants). These results suggest immediate benefits with vibrotactile cues. In the study undertaken children made excellent improvements in production of speech contrasts, bat contrastive production does not necessarily imply perfect production. For many speech sounds improvement in pronouncation would be necessary to increase intelligibility. It was found that imperfect pronounciations were in many cases similar to normal hearing childrens phonological errors, but some specific errors typical of hearing impaired talkers persisted. Hence the future goal is of improved intelligibility through tactual vocoder's intervention.

Brooks and Frost (1983) reported a study of subjects who were learning to identify single common words presented on a 16 channel tactile vocoder. The subjects had normal hearing. The procedures wexe seimilar to those of Engelmann and Rosov (1975). Daily sessions of about half an hour were held 5 days a week, continuing to add new 5 word sets to the training or testing pool. The subject with the Most extended training reached the criterion on 150 words in 55 hours of training. With further training 250 words were identified at 80% correct and the words were also found to be identified as reported.

In a test of tracking the meaning of a connected speech discourse the subjects achieved a rate of 51 correct words per minute when lip reading with the aid of the tactile vocoder.

Friel Patti and Roeser (1983) carried out the study of the effects on communication by deaf children wearing a tactile aid (wearable) during class and therapy sessions. Four profoundly deaf children wore a three channel tactile belt for 10-11 hours per week for 16 weeks of their fall preschool semester. All children also wore hearing aids at all times. Every third week, each child participated in an individual half-hour communication therapy session during which a sample of the child's production (by video) of signed and spoken communication was taken. In the spring semester a no tactile aid condition was instituted for the same subjects. The subjects wore hearing aids alone. Over the Fall "tactile" semester the duration of communicative productions from the children increased from a mean of 1 1/2 minutes per 10 minute sample to about 4 minutes

In the spring semester the duration of communication decreased from a mean of about 3 minutes to a mean of 2 minutes per 10 minute sample. Informal comments also indicated that the tactile aid had a beneficial effect on the amount of communicative expression by the children. Teachers and parents spontaneously reported that it was much easier to elicit vocalization from the children then they were wearing a tactile aid.

Goldstein et al (1983) reported that a 3-year old child using a hearing aid and having only a signed vocabulary of 5 words greatly increased her communicative attention when fitted with a wearable single channel tactile aid. She gained a 400 word vocabulary over the following 7 months. This aid simply derived the rhythms of sound received and presented them to a single vibrator worn on the chest.

Multi-channel tactile aids are displays that provide the division of the speech code into several channels to be spaced over a number of skin sites. Such displays have often been intended to substitute the skin for the basilar membrane (i.e.) partitioning of energy in real time among and between channels is made roughly in a way that stimulates cochlear activity. There are two different types of multichannel stimulation.

1) Discrete
2) Continuous

Discrete means that the individual vibrations are percevied as separated. Recent work with discrete multichannel stimulati has emphasized coding of phonetic features of speech as an aid to lipreading (Patti and Roeser, 1983).

These devices have a communication potential which exceeds that of the single channel devices.

The continuous type of device has more vibrations and the spacing is closer. The perceptual result is of a patterned stimulus rather than of stimuli at separate loci. Continuous multichannel stimulation is usually by a linear array of stimulators. When the glabrous skin of the finger pad is used the vibratory elements must be very closely spaced because of the high innervation density as wall as the small size of the finger. For hairy skin, the relatively sparse innervation can be a great advantage to the designer because the stimulating elements can be more widely spaced than for glabrous skin.

The greater sensitivity of glabrous skin is however an advantage of power requirements are a limiting factor.

Coding of the spectral patterns of speech is also possible by the multichannel devices. Another efficient way of representing time-varying spectral information by sampled digital data is linear predictive coding (LPC). Results indicate that the LPC is as good as more conventional vocoder type spectral displays.

The use of electrocutaneous stimulation in the development of electrotactile devices for the deaf has been pursued by Saunders (1983). One problem with electrocutaneous stimulation is the small dynamic range between the touch sensation and a painful burning sensation, but by using bipolar pulses, Saunders has minimized the problem. An advantage of electrocutaneous stimulation is the low power requirement but along with it is accepted the disadvantage that all electrodes must make good electrical contact with the skin, which puts strong constraints on array configurations. Further skin irritation must be considered especially for wearable aids.

In 1984 (Boothroyd and Hnath) demonstrated gains in lipreading when vibrotactile representation of the fundamental frequency was provided (this is with reference to Rotheaberg and Molitor's study in 1979).)

In 1986, the integration of the visual and the tactile sensory aids in an ongoing speech training programme was done by McGarr, Head, Freedman, Behrman and Yandelmal. A systematic curriculum for remediating monotone voice was tested. Sixteen students with severe to profound hearing loss (7-8 years old) and six (speech) teachers participated. All students tested showed marked improvement in immediating monotonous pitch, with those using the curriculum in conjunction with a tactile display showing the most progress. It was found that a multichannel vibrotactile sensory aid was better suited in training intonation contours than a visual aid. which was more effective for remediating static aspects of speech. The tactile aid was partially useful when training focussed on terminal fall at the ends of phrases and sentences.

Youdelman, MacEachron and Behzman (1988) found that visual or tactile sensory aids facilitated remediation of phonation problems by providing another sensory modalities (in addition to hearing) by which students could be trained to recognize pitch changes. Further more these studies demonstrated the benefits of using sensory aids in conjunction with a systematic approach to speech training like - children who manifested inappropriately high average pitch and who received speech training with a visual aid showed more progress than did children using the tactile sensory aid.

Finally, in evaluating the performance and function of a vibrotaetile aid, the following additional features should also be looked for:- one of these being that "whether the unit utilizes an effective noise suppression circuit or net?" as it is a necessity for the unit to be of some benefit to the client in the presence of competing ambient noise. Automatic gain control should also be looked for so as to strengthen the incoming signal. Auxiliary input capability toe may be am important feature to a client who desires to couple the device with a tape recorder, TV, radio or other audio-sources.

Ultimately any system whether tactile, auditory implant or visual; the final stages of any system development involves the integration of seemingly disparate source to achieve communication skills for users.

ASSISTIVE "LISTENING" DEVICES

Assistive devices for the hearing impaired have recently generated considerable interest. One of the central concepts in speech conservation with the adventitiously hearing impaired is the effective use of amplification and auditory training to make maximum use of residual hearing. There are several cases however where additional sensory cues are needed to provide monitoring.

Several devices are commercially available that are designed to provide vibrotactile and/or visual information. Aasistive devices can be categorised under 2 types.

1. Assistive devices as aids to speech reception
2. Assistive devices for the enhancement of function of an individual at home, in the work force, at school and in the community.

Various assistive listening devices using a vibro-tactile cue have been catalogued here.

Recent advances in assistive devices as aids to speech reception include the body sonic system which is designed to restore the feeling portion of the music by transmitting the vibration or the music particularly the bass responses directly through the body through a chair/cushion. Compatibility with all other commercial grade sound systems is reported by the manufacturers.

On the other hand, the MT 80 SP body aid with bone oscillator is used as a vibro tactile eld, the best place being the wrist bone/sternum. This aid has an SSPL 90 of 152 and a peak gain of 92 dB.

The fonator auditory speech trainer has a maximum power output of 130 dB and a frequency response of 80-20,000 Hz It also features independent controls for each ear for frequency response, intensity and maximum power output.

Other assistive devices that aid in speech reception are catalogued in the next page.

BONE CONDUCTION RECEIVER

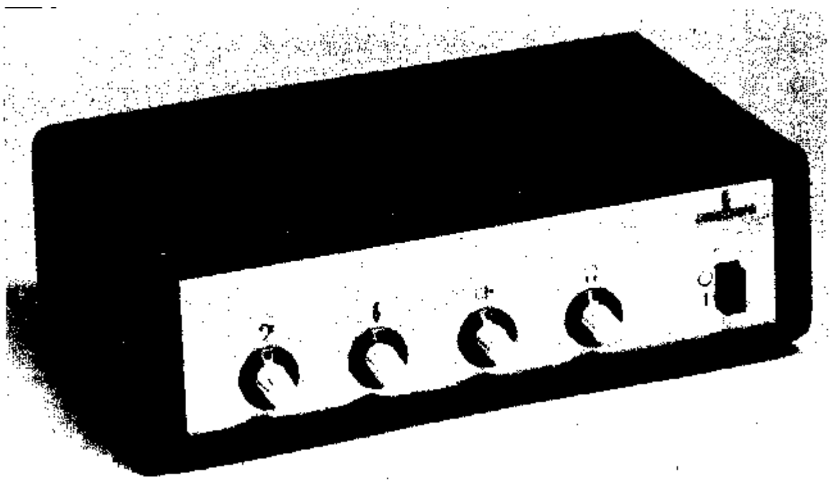
Price: Prices vary. Contact your local telephone company.	**Specifications:** None available
Source: A.T. & T.	

PURPOSE

This unit is used in cases of conductive hearing loss. Sound is transmitted by a bone conduction device.

DESCRIPTION

One end of this unit attaches to a telephone; the headband at the other end can be attached to a bone conduction receiver.



MONO-FONATOR SYSTEM

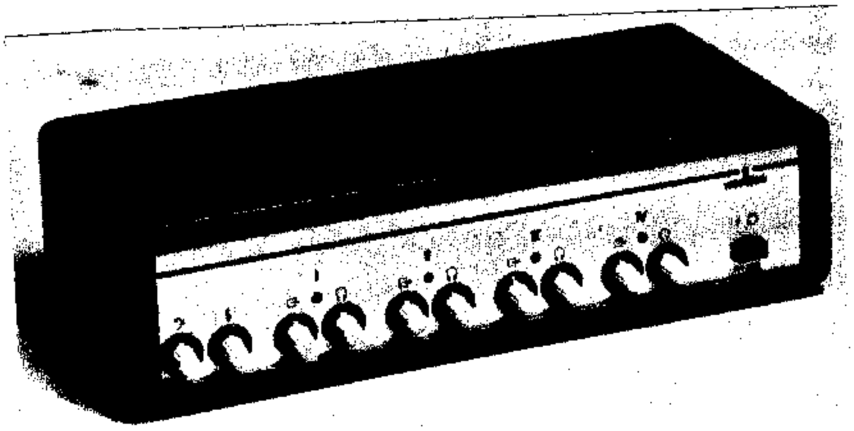
Price: $1,050.00 **Source:** Siemens Hearing Instruments, Inc.	**Specifications:** (With DT 96 headphone) Size: 31 cm × 17.5 cm × 10.3 cm Weight: 3 kg Frequency response: 15–16,000 Hz Gain: 35 dB at 1,000 Hz; 40 dB at peak Maximum power output: 132 dB SPL at 1,000 Hz; 140 dB SPL at peak Vibrator: Electromagnetic type with tone control of ±20 dB at 50–16,000 Hz Microphone: Dynamic type with frequency response of 40–18,000 Hz Power source: 110-v/60 Hz

PURPOSE

Using vibration, the Mono-Fonator System helps to stimutate, control, and structure a person's speech. This system can be used as a vocal-auditory means of sensory training, providing vocal cues to individual where amplification is of littl- benefit. It can provide the therapist with a controllable sensory input that gives reliable feedback for certain fundamental, distinctive features. The Mono-Fonator can be used to enhance therapeutic technique. The system assists in speech production training by providing additional information to help establish a same/ different criteria (correct/incorrect) for production. In the case of an auditory deficiency (perceptual or hearing loss), it provides the necessary cues for controlling pitch, loudness, duration, inflection, and rhythmical patterns, and for learning production and coarticulation of vowel and consonant sounds. The Mono-Fonator is also usefui in areas of autism, aphasia, auditory impercipience, mental retardation, and other centrally Located dysfunctions. It can assist in the identification of many important auditory cues that are needed to correctly identify a vocal message.

DESCRIPTION

The unit consists of an amplifier, a microphone with table stand, a singte vibrator with wrist strap, and a headset on an adjustable headband. The portabte amplifier and accessories are housed in a carrying case. Separate tone controls for high and Low frequency adjustments are provided for the vibrator. There are 2 separate output amplifiers for the vibrator and headset, each with an independent voLume contro). tn principle, this unit is similar to traditional auditory trainers. However, it also provides a vibrator output.



POLY-FONATOR SYSTEM

H
D
DB
P

Price: $2,428.00 **Source:** Siemens Hearing Instruments, Inc.	**Specifications:** Same as for Mono-Fonator System *except* Size: 45 cm × 21 cm × 12 cm Weight: 7 kg

PURPOSE)t performs the same functions as the Mono-Fonator System, described on page 211.

DESCRIPTION This system is identica) to the Mono-Fonator in principle. However, instead of a singLe unit, there are 8 output amplifiers that handle 4 headphones and 4 vibrators for group therapy or group instruction.

VOICELESS S-INDICATOR (model no. 703)

H
D
P

Price: $425.00
Source: Special Instruments America

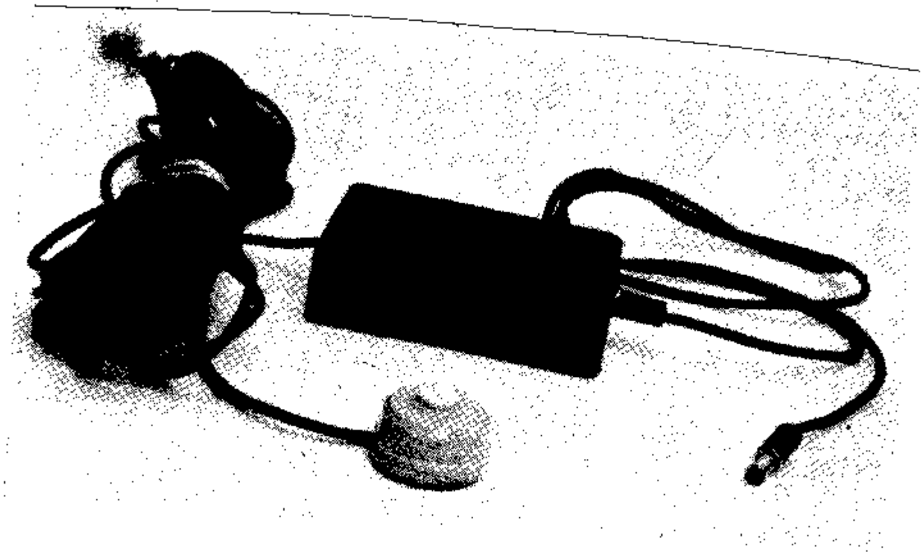
Specifications:
Size: 7½ in. × 7½ in. × 4 in.
Weight: 4 lb
Microphone: Internal electret-condensor type
Power source: 6 replaceable C cell batteries, 1.5 v each
Battery life: 150 hr without accessories

PURPOSE The Voiceless S-Indicator is designed for training the voiceless s sound, It is very usefui in articutation therapy.

DESCRIPTION The instrument contains a meter, a green lamp, and relay outputs to give visual indication of the quality of the s produced by the client. The instrument's circuitry uses a zero-crossing frequency-measuring technique that estimates the center of gravity of the energy on the frequency axis. It is recommended that this instrument be used with an auditory trainer so that auditory and visual feedback systems are both used in therapy. An optional wrist vibrator for tactile reinforcement of correct s production is available.

Assistive devices for the enhancement of function of an individual at home, in the work force, at school and in the community has been catalogued from pages 60 - 71.

Thus assistive listening devices are an integral part of a hearing impaired individual.



DOORBELL ACCESSORY FOR ELECTROALARM CLOCK (catalogue no. 2333)

H
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DB

Price: $30.00	
Source: Hal-Hen Co.	**Specifications:** None available

PURPOSE

The unit allows a hearing-impaired person to sense the doorbell is ringing through the vibration of the bed pillow. It also functions as a signalling and wake-up device.

DESCRIPTION

This is an accessory to the electroalarm clock described on p. 151. One portion is attached to the rear of the alarm clock with the other end of the cable attached to the doorbell. When the doorbell is pressed, the pillow vibrator is activated. The unit supplies its own power by two penlight cell batteries (not included).

NUVOX SENTINEL
(catalogue no. 909)

H
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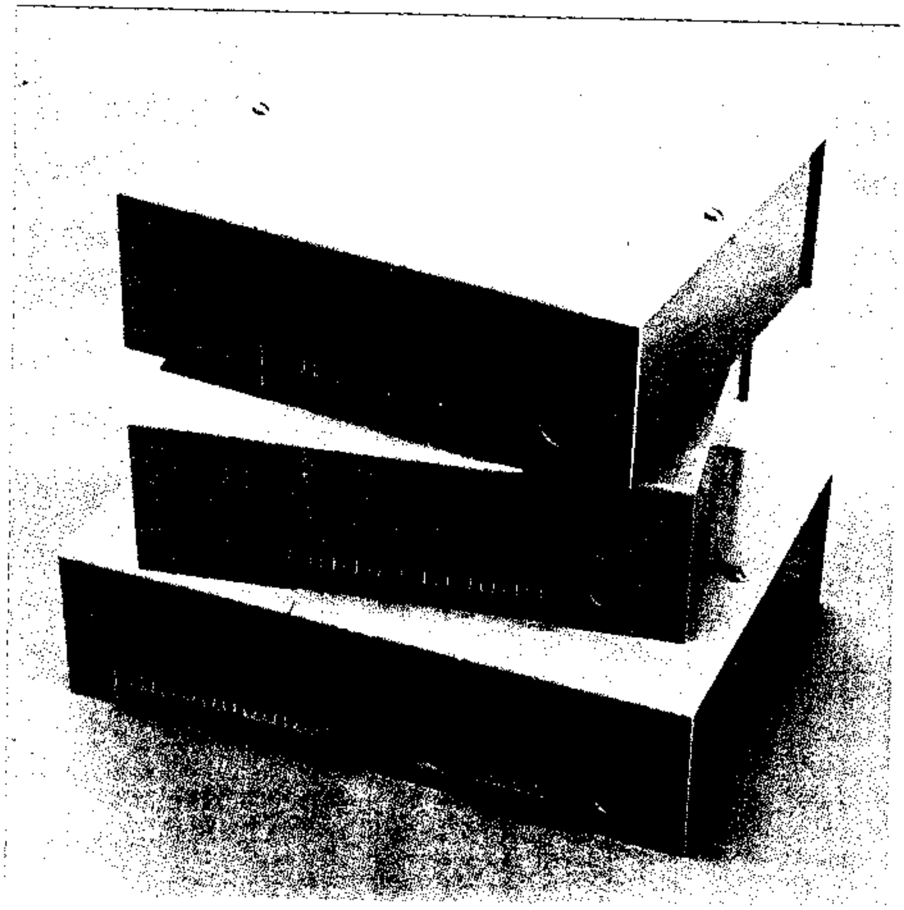
DB

Price: Without vibrator $135.00 With vibrator $179.00 **Source:** Hal-Hen Co.	**Specifications:** None available

PURPOSE The Nuvox Sentine) alerts an individual to the ringing of a telephone or doorbell, a crying baby, or other such sounds.

DESCRIPTION This electronic unit is activated by sound and can turn on a lamp or a chair or bed vibrator. It is transistorized and can be connected to any ordinary house tamp.



UNIVOX 36B

H

Price: $125.00 **Source:** LIC	**Specifications:** None available

PURPOSE

The Univox 36B (middle item) can alert an individual at home to a caller. In addition to performing the functions of Univox 36A, this unit can function as a signalling device.

DESCRIPTION

This model has all the capabilities of model 36A as well as an output voltage to drive an acoustic signal. The signal consists of a bell that is connected to a doorbell or telephone. When activated, the bell can be heard when the hearing aid is in the microphone (*M*) position. When the hearing aid is in the telephone (*T*) position, a signal can be heard via the loop. The frequency and volume of the acoustic signal can be controlled.

CODE-COM SET WITH A TOUCH-TONE TELEPHONE (and Braille typewriter)

DB

Price: Prices vary. Contact your local telephone company.	**Specifications:** None available
Source: A.T. & T.	

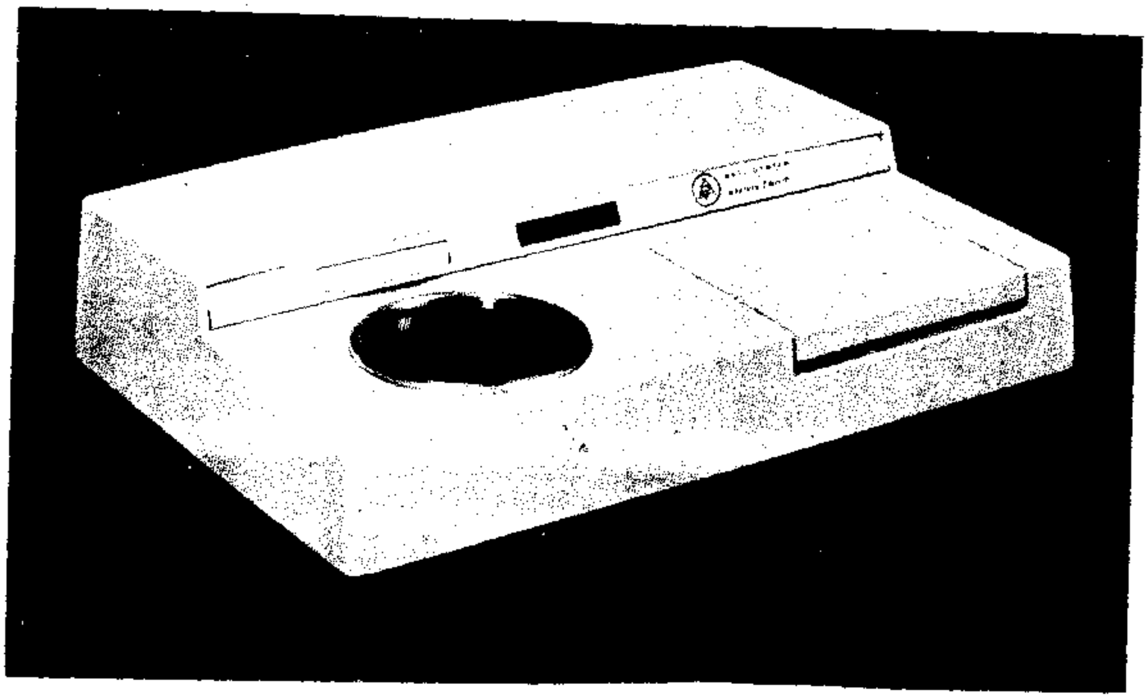
PURPOSE

The Code-Corn set allows the deaf-b!ind person to receive and send tetephone messages.

DESCRIPTION

An individual using a Braille-phone TTY places the tetephone receiver into the coupling unit and turns on the unit. The incoming message comes printed on a tape in braille, much tike a ticker tape machine. The braitte message is read by the user, and the response is handled through a typewriter keyboard on the machine that automaticatly prints the tetters in braitte. The same machine can be used with standard letters on the page for the sighted user.

The small round box on the desk supplies power to the apptiance that indicates the tetephone is ringing by a fan turning on, a vibrator activating, etc. When the receiver is picked up, the sender communicates either with a form of Morse code or a prearranged code. This message comes through a vibrating pad at the front of the Code-Corn and is interpreted through the fingertips. After receipt of the message, the receiver with speech production can answer the telephone in the usual manner.



CODE-COM SET

H
D
DB

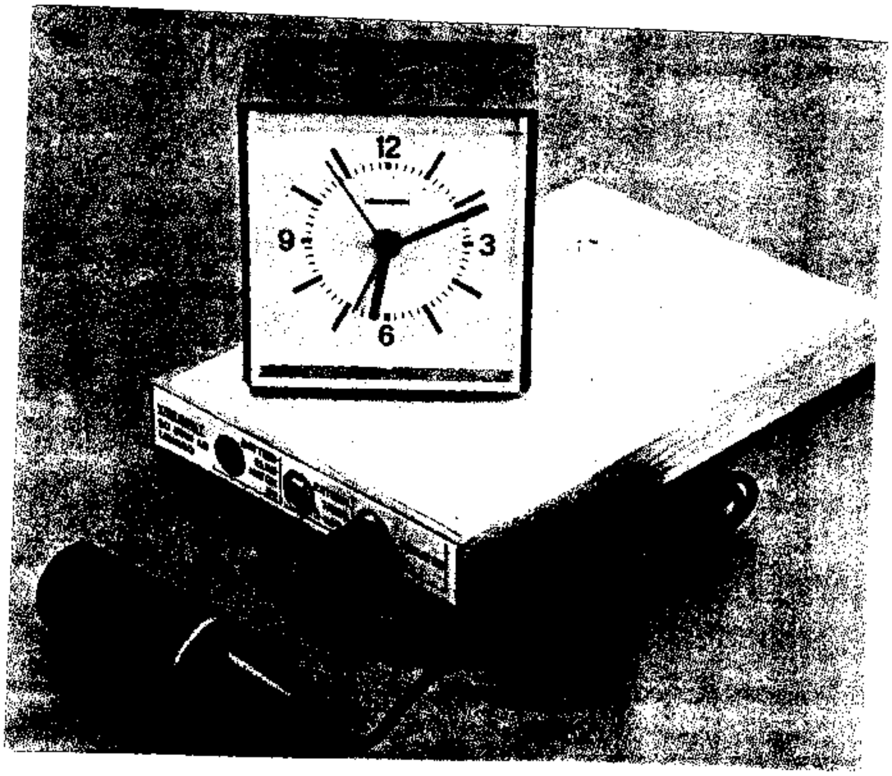
Price: Prices vary. Contact your local telephone company.	**Specifications:** None available
Source: A.T. & T.	

PURPOSE

The Code-Corn Set is connected to a conventional telephone and is designed to a!)ow a deaf person to "see" tetephone messages in coded flashes of tight or "feet" them in the vibrations of a finger pad.

DESCRIPTION

Light flashes come from a recess (black rectangte in photo) in the center of the raised portion of the set. The circular vibrating pad is on the left with the sending key on the right used tike a telegraph key.)f the deaf person has usable speech production, the tetephone handset may be used in the usual manner. The actual code can be a form of Morse code or a personal code such as 1 flash meaning Ves and 2 flashes meaning Mo, or any other combination.



VIBRAVAKT

H
D
DB

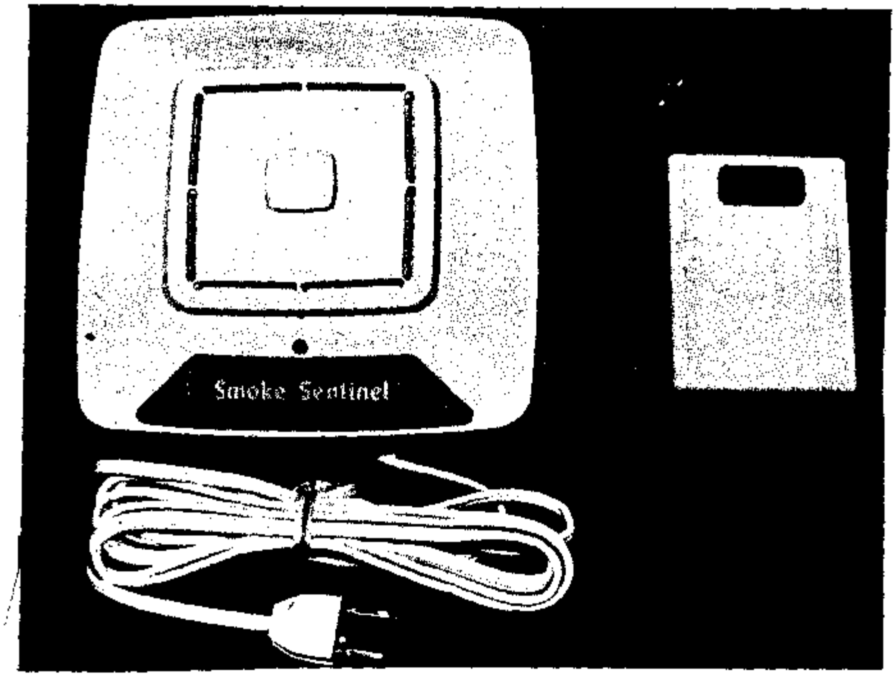
Price: $60.00	**Specifications:**
Source: LIC	None available

PURPOSE

The Vibravakt allows a hearing-impaired or deaf-blind person to be awakened by the telephone or alarm.

DESCRIPTION

This portable, compact device vibrates when activated by an acoustic signal such as an alarm clock ring, telephone ring, or fire alarm. It must be placed next to the sound source in order to detect and transfer the acoustic signal.



SMOKE DETECTOR
Switched Receptacle Type
(model no. 30-53R-RR1-C)

H
D
DB

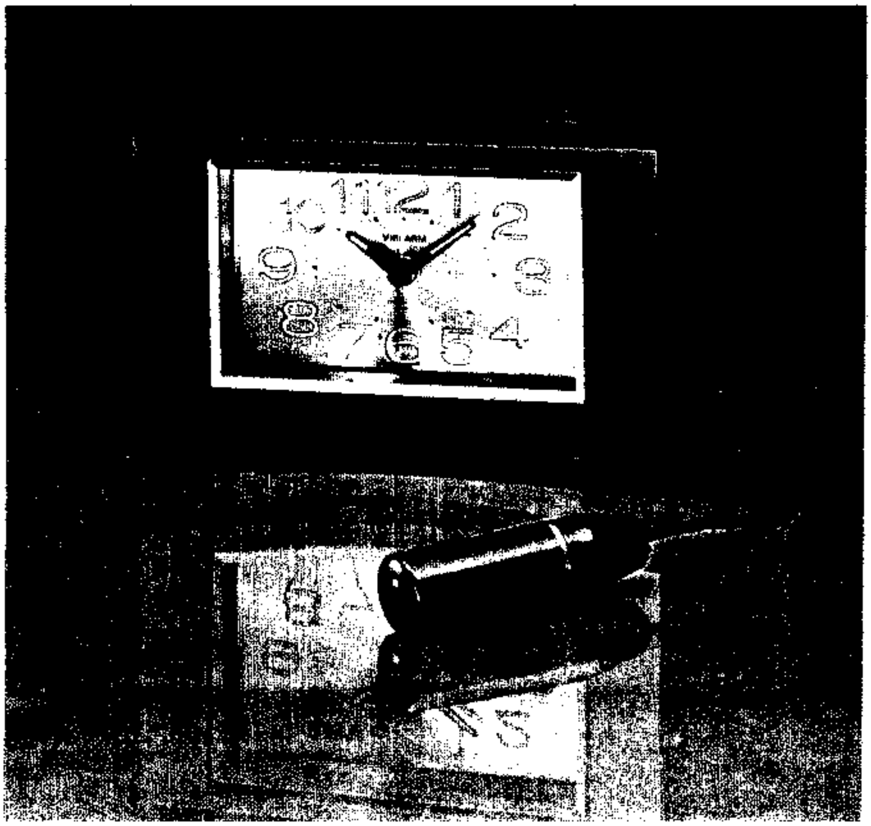
Price: $95.00 **Source:** Nationwide Flashing Signals System	**Specifications:** No electrician is needed for installation; it plugs into any household outlet. The receiver can handle up to 300 watts.

PURPOSE

This smoke detector allows a hearing-impaired or deaf-blind person to be alerted to smoke or fire in the home.

DESCRIPTION

This photoelectric, nonradioactive detector can be connected by either a wiring system through the wall or a wireless system. The unit can be wired to give a warning by means of a vibrator Or a lamp.



ELECTROALARM CLOCK KIT
(catalogue no. 2332)

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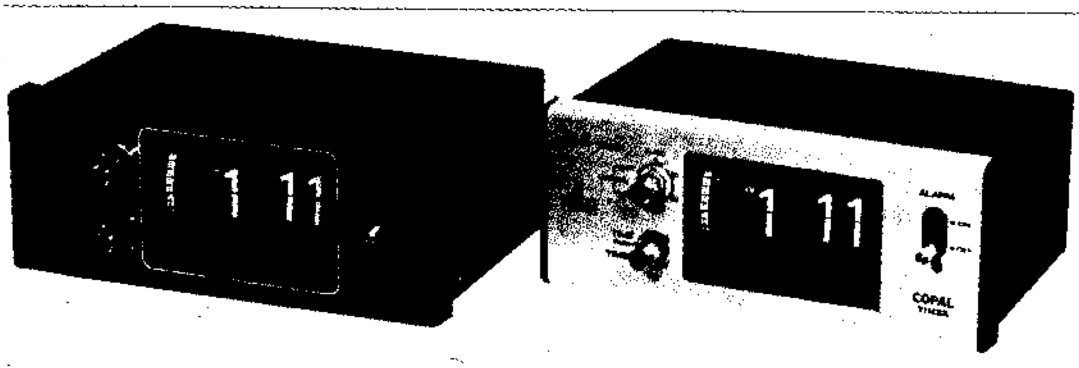
Price: $89.95	**Specifications:**
Source: Hal-Hen Co.	Power source: 1 C cell battery (not included)

PURPOSE

The Electroalarm Ctock Kit awakens a steeping individual with gentle vibrations.

DESCRIPTION

This portable kit includes a pillow vibrator. The clock has a large, easy-to-read luminous face. When the vibrator is disconnected, the unit may be used as an ordinary alarm ctock. The finish is woodtone plastic.



AUTODIGITAL VIBRATING ALARM CLOCK KIT (catalogue no. 2379)

H
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D

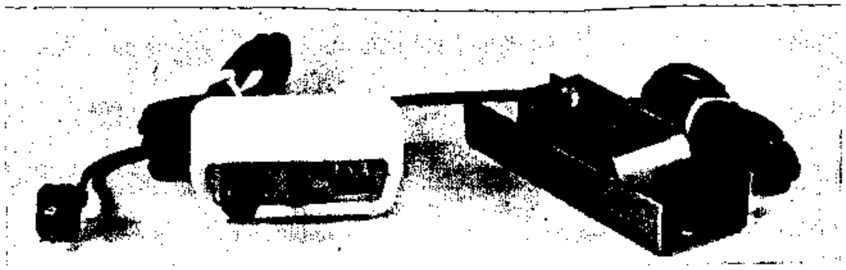
Price: $89.95	**Specifications:**
Source: Hal-Hen Co.	Power source: 110-v (60 Hz) AC current
	Color: Ivory

PURPOSE

This alarm clock kit awakens a person to a gentle vibration that is transmitted throughoutthebed.

DESCRIPTION

This kit consists of a luminous digital clock, a heavy-duty bed vibrator that is installed on a mounting board with brackets, and a set of instructions. Additional features include a steep switch that allows the person to awake within 2 hr white taking a nap, a snooze controt button on top that allows up to 1 hr of extra steep with intermittent wake-ups, and a 24-hr AM/PM alarm system.



RELAX 1 BED VIBRATOR

H
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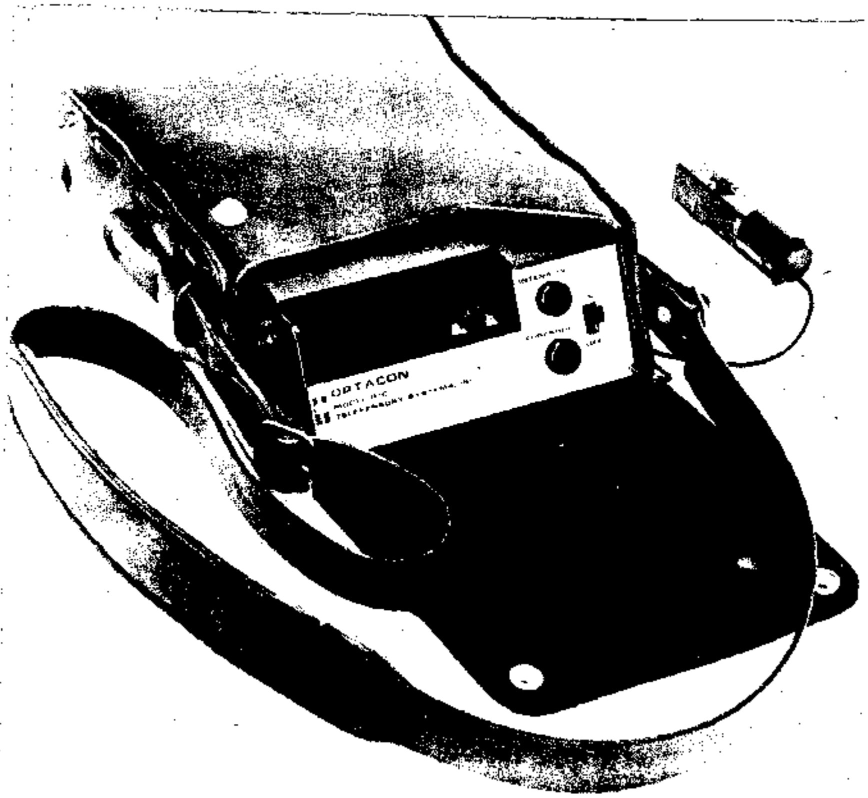
Price: $34.95	**Specifications:**
Source: Nationwide Flashing Signals System	None available

PURPOSE

The bed vibrator is designed so that tight or heavy steepers may adjust the speed vibration control from low to high. It may also be used as a body massage.

DESCRIPTION

This unit can be mounted under the bed frame or fastened with screws to the back of the headboard, it comes with a variabte speed contro) that signais when on with a red pilot tight to remind the user not to forget to shut it off. it is compatible with the Westclox and Copat ctocks, both of which have receptactes into which the vibrator can be plugged. The unit may also be used with Nationwide's smoke detectors, burglar alarm systems, or doorbell and phone devices to atert a sleeping individual within the home.



OPTACON (model no. R1C)

DB

Price: $3,500.00 **Source:** Telesensory Systems, Inc.	**Specifications:** Camera: Size of a pocket knife; contains 2 tiny lamps and a silicon integrated circuit with 144 light-sensitive phototransistors Stimulator array: Composed of 144 miniature rods, each corresponding to a single phototransistor in the camera module and capable of vibrating to reproduce an image

PURPOSE

The Optacon is a reading system that gives blind and deaf-blind persons immediate and independent access to the world of print. The unit converts the image of a printed letter or symbol into a tactile form that can be felt with 1 finger.

DESCRIPTION

Various type styles, symbols, and languages can be read with this unit because it converts exactly what is printed into an enlarged vibrating form. The blind person moves a miniature camera across a line of print with the right hand; the index finger of the left hand is placed on the unit's tactile array. As the camera is moved across a letter or symbol, the image is simultaneously reproduced on the tactile array by vibrating rods allowing the image viewed by the camera's lens to be felt by the user. Telesensory Systems provides a training course for students and teachers interested in this device.

MOWAT SENSOR

DB

Price: $475.00	**Specifications:**
Source: Wormald Corporation	This unit includes a battery charger, rechargeable batteries, a vinyl carrying case, and an owner's manual.

PURPOSE

The Mowat Sensor can be used as a supplement to the long cane or dog guide, since it does not detect drop-offs. Peopte with variable vision, reduced fields (tunnel vision, macular degeneration), or poor acuity can use the device to improve their vision.

DESCRIPTION

This unit is a handheld, electronic travel aid for visually impaired and deaf-blind persons. It is a clear-path indicator and orientation aid that vibrates in the user's hand pointing at objects within a range of 13 ft. Closer objects produce more rapid vibrations.

SUMMARY

Like the two sides of a picture, the tactile aids have advantages and disadvantages.

Dr.Jean Oyers listed out the results of his study on the issues of "General Sensory integration in the facilitation of learning". The disorders of integration that exist may be visual, auditory, tactile, vestibular or kinesthetic. It was found that hose who received sensory motor training showed greater gains in auditory language and reading skills than those who spent extra time in the classroom receiving special auditory and language training. This was further explained by 3 concepts:

1) Interdependence of the sensory systems. Maturation of auditory systems may be dependent on maturation of the other systems. Sensory motor integration may help in normalizing the other systems.
2) Development of higher intellectual function will not occur readily unless the hemispheres are. able to specialize in their functions and have good communication between them. Language is a bilateral function with both hemispheres working together.
3) Dependence of the cortex on lower brain structures especially the brain stem. Because the better the lower levels work, the better the cognitive levels function.

Tactile aids provide an increase ia communicative skills at a crucial period in the deaf child's educative period. First, he will be able to discriminate between silence and noise to develop an awareness of environmental soands. With training the client learns to interpret the tactile stimulation and identify soands such as door bell, telephone ringing, the presence of footsteps,knock at the door, water raaning, the signal of the smoke or fire alarm, traffic noises and emergency vehicle sirens. Additionally the client will become skilled in the localization of sound and also may demonstrate improved use of residual hearing due to tactile recognition of soands previously unidentified.

The user has the advantage of developing an improved awareness of the rhythm, pitch and intonation patterns of speech. Identification of speech sounds should also improve and depending on the vibrotactile device selected, the user will be able to discriminate between voiced aad voiceless phonemes by location of the stimulus alone. The improvement in each of these skill areas will contribute to improved speech and lipreading skills, improvement in speech training skills and improvement in the child's own speech production.

The manner features of speech (nasality, voicing and fricative properties) are difficult to lipread because their production is difficult to see. However since manner features are all well below 1 KHz they are easy to feel. Hence tactile aids are useful adjuncts to lipreading.

In contrast, considering speech from a spectral view point, the tactile aid cannot be used to comprehend speech to the extent that the second and third formants are required.

Electrocutaneous stimulation has several advantages. Electrodes used being small and compact, the power consumption being low and electrode life span being long, electro-eutaneous stimulation enables the use of a broad spectrum of stimulus parameters as compared to vibrotactile stimulations Another complaint the tactile aid shares with conventional hearing aids is the difficulty of use in noisy environments. Despite availability of tactile devices they have not been widely accepted by the hearing-impaired individuals and their educators. The inherent limitations include the use of atleast one hand which, may impede instead of enhancing communication. Most devices are bulky and cosmetically unattractive calling attention to the child if used beyond the school or home environment. Currently research and development projects are in progress to provide better devices, Wearable vibrotactile devices have potential benefits for profoundly deaf young speakers. In order to assess the full potential of the devices they must be made comfortable and invisible to the extent that they are readily acceptable to deaf children their parents and their teachers.

A final prediction boils down to the expectation that for very young deaf children, early use of a tactile device might prevent detachment from the world of sound from occurring.

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