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VIBRATORY STIMULI PRESENTED AT THE FINGERTIPS
AS PERCEIVED BY EDUCABLE MENTALLY RETARDED
AND NORMAL CHILDREN

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the
Degree Doctor of Philosophy in the Graduate School of
The Ohio State University

By

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The Ohio State University
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Approved by

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CHAPTER I

INTRODUCTION

To instruct the deaf, no art could reach. No care improve, and no wisdom teach (7).

This remark, made by Lucretius some time between 96 and 55 B.C. illustrates how the people of that time felt when confronted by a deaf person. The hopelessness expressed in connection with the deaf seems to parallel that society's attitude toward the mentally regarded (7). One does not have to go so far into history, however, to recognize the abysmal hopelessness expressed in connection with education of the impaired child.

Contemporary society has taken a more positive attitude toward education of the impaired child as evidenced by Heck in 1953:

... to make each child capable of the greatest possible degree of self help, agreeable in habits and behavior, and sufficiently able to use muscles and senses to keep himself happily occupied at work and play (17).

From the negative attitudes of Lucretius' time to the present, the curricula in the schools have developed to teach classroom subjects to children with all types of handicaps. These curricula have resulted in an awareness that ALL children are entitled to an education commensurate with their abilities. As a consequence of this awareness, a movement to educate, not hide, the mentally retarded
has gained in momentum, especially since the White House Conference on Children and Youth in 1960. This conference dealt specifically with the problems and future of the mentally regarded. Although educational programs for the mentally retarded had been in operation, the attention which the conference focused upon the problems of the mentally retarded led to a rate of growth in relevant educational programs for retarded persons that was unprecedented in educational history. A brief chronology of this development follows.

Historical Review of Education for the Mentally Retarded

The history of education for the mentally retarded can be divided into three eras: ancient, medieval, and modern. Exerting important influence upon educational programs for the mentally retarded were the social attitudes of the time. In their summary of the treatment of the mentally retarded Frampton and Powell noted that the Spartans, although cruel, were honest (1).

Well-known for their physical prowess and fighting ability, the Spartans reasoned that bydiscardings the unfit members of the tribe they were preserving their "super-race." They left obviously defective infants exposed on the mountains to perish, or threw them into the river to drown. Abandonment of the unfit was practiced in Athens during the time of Plato (427-347 B.C.) and was approved by his pupil, Aristotle (384-322 B.C.). Idiots (this term is derived from the Greek word idios and means a person set apart
or alone; the term was applied to the mentally retarded during this time) were left alone by the people to roam the countryside at will because of their un-social actions.

The practices of persecution and abandonment of the mentally retarded underwent a slight change during the Roman Christian period. In 324 A.D., Emperor Constantine I, in accord with Saint Paul's charge of "comfort the feeble-minded," allowed the Bishop of Myra to recognize the mentally deficient and to care for them (6). This action appears to be the first attempt to accord actual care to the mentally deficient.

Even though there was no attempt at formal education of idiots it must be assumed that some sort of training took place in order for them to learn to take care of their self-needs. The Hebraic Law of this period is worthy of notice because it differed markedly from the harsh practices of previous societies. It recognized the unfortunate, the handicapped, the needy, and the dependent and indicated that they were to be cared for (1).

Programs for the mentally retarded underwent little change from the time of the Hebraic Law until the establishment of the first institution for the care of the feeble-minded in Paris in 1656. The institution, which became the Bicêtre, a famous Parisian hospital and asylum, was established by Saint Vincent DePaul and his Sisters of Charity (5).

Under the pall of ignorance and superstition that prevailed and the teachings of the Reformation, the mentally retarded were referred
to as "beings filled with Satan." Such notables as Luther (1483-1546) and Calvin (1509-1564) referred to imbeciles as "offspring of the evil one." This led to various types of persecution in which such labels as witches and wizards were used. At this time of great superstition anything that was unexplained was attributed to "black-magic." It was, therefore, logical that the mentally retarded be scourged and exorcised. It has been estimated by Barr that approximately 10,000 of the witches and wizards that were annihilated during this time were mentally deficient individuals (1).

Up to the last half of the sixteenth century, there had been two different schools of thought concerning the treatment of the mentally retarded. The first consisted of persecution and abandonment of the defective; the other showed compassion and care for the defective. During the last half of the century there was a brief but frantic return to persecution of the defective. However, it did not last long after the beginning of the seventeenth century for it was during this time that Francis Bacon (1561-1626) propounded a philosophy (based upon the inductive method) which led to a method of education and child study in which the child was the center of the learning process.

The full influence of Bacon's philosophy was not felt in education of the handicapped until John Locke (1632-1704), and much later Jean Jacques Rousseau (1712-1778) became prominent in the field of education. Locke held that the mind is a passive receptor of stimuli, and that knowledge comes only through the senses. The phrase,
"a sound mind in a sound body," indicated the emphasis that this early educator placed upon the diagnosis of the individual pupil's mental processes. The belief that children's minds differed just as their bodies did was a result of the emphasis that Locke placed upon individual diagnosis. Locke's contention that the mind is a passive receptor of stimuli also led to the following beliefs: (a) books were not the most important tools in the learning process; (b) all learning should be accompanied by pleasurable sensations; and (c) the senses should be strengthened by training.

While sensationalism was prominent, another development was afoot in France. This was the gathering of the mentally retarded and sheltering them at the Bicêtre in Paris while striving to improve their conditions. It was here that one of the first real attempts was made to educate the mentally retarded. Jean Itard (1775-1838), a French Physician and Chief Medical Officer of the National Institute for the Deaf and Dumb in France, tried to educate and train "Victor, the Savage of Aveyron." Victor had been found wandering in the forests, living like an animal, and was brought to the Bicêtre for observation. Itard became enthusiastic about working with him and followed the theory of the sensualists who felt that mental perceptions were merely sensations transformed.
Sense Training

The strong belief in sense training which resulted from Locke's influence had been further strengthened when Rousseau wrote in 1762, after visiting the school of Jacob Pereire (1750-1780) and seeing the work that he was doing with the deaf:

As our sense of feeling, when properly exercised, becomes the supplement to sight, why may it not also supply that of hearing to a certain degree; especially as sounds are known to excite, in sonorous bodies, vibrations sensible to touch? Lay your hand upon the body of the violin-cello, lay without the assistance of either eye or ears, to distinguish by the manner in which it vibrates, whether the sound it gives be grave or acute. . . . Were the senses exercised, with attention, in this manner, I doubt not but, in time, we might acquire such a degree of sensibility as to be able to distinguish a whole air by means of the finger. Upon this supposition it is plain, we might easily talk to deaf persons by music; for notes and time being no less susceptible of regular combinations than articulate words, they may be made use of in the same manner as the elements of speech (35).

Pereire was teaching that sound vibrations could be transmitted to sense organs other than the ear. This is the first known reference to the possibility of using sound vibrations transmitted to sense organs other than the ear in teaching speech (35). However, the sensationalism theory received its first real boost when Itard attempted to work with Victor at the Bicêtre in Paris. Before Itard stopped working with Victor, he had changed his method to one more nearly suited for the defective than for the "savage."

Edouard Seguin (1812-1880) carried on the work of Itard and further developed the system of sensory-motor training. Seguin's dream of a cure for mental retardation was not fulfilled, but his
influence in education of the mentally retarded cannot be denied. Another system of sensory-motor training was developed by Maria Montessori (1870-1952) as a method of educating young children. Montessori gave Edouard Seguin as her chief inspiration (27).

The Montessori materials for sense training were selected from those that Itard and Seguin had used in their attempts to educate mentally deficient and/or deaf children. In the Montessori method each sense is approached in isolation with no particular order accorded an individual sense. The training of the tactile sense, for example, is undertaken with such items as touch boards. These consist of wooden boards divided into equal parts, one part being smooth and the other being rough or covered with sandpaper of varying degrees of coarseness. The child is encouraged to discriminate between the smooth and rough surfaces by feeling them, thereby utilizing the sense of touch (27).

**Utilization of Sensory Training**

There have been examples, the most familiar being that of Helen Keller, which clearly indicate that the primary sense channels of vision and audition were not the only ones which could be utilized in the learning process or in appreciation of our environment. Grace Fernald reported that she had not found a case of reading disability which could not be improved by using her method of instruction. The Fernald method consists, in part, of having the individual trace the letters and words with his finger, thereby
utilizing the sense of touch (8). Another example of the use of a substitute vibratory transmission system was reported by David Katz. He told of the case of a German man who greatly enjoyed concerts even after he lost his hearing by feeling the sound vibrations transmitted through the back of his seat (20).

Helen Keller in her autobiography has reported that the most important day of her life was the day she met her teacher, Anne Mansfield Sullivan. She wrote:

On the afternoon of that eventful day, I stood on the porch, dumb, expectant. I guessed from my mother's signs and from the scurrying to and fro in the house that something unusual was about to happen, so I went to the door and waited on the steps... I felt approaching footsteps, I stretched out my hand as I supposed to my mother. Someone took it, and I was caught up and held close in the arms of her who had come to reveal all things to me, and, more than all things else, to love me (21).

Anne Sullivan opened a whole new world for this girl who was blind and deaf when, on the morning after her arrival, she gave Miss Keller a doll, held her hand in hers and with her finger spelled d-o-l-l in the palm of Helen's hand. This was the start of an educational program that was to utilize the sense of touch almost exclusively. Miss Keller also stated that when she met someone that she had not met before she could tell much about the person by running her fingertips over the person's face.
Rationale of Study

The illustrations above can be logically projected into an investigation of the possible use of sound vibrations in the training of educable mentally retarded children. The vibratory sensitivity, for example, of mentally retarded children needs investigating. This study will attempt to explore the perception of sound vibrations by educable mentally retarded children through their fingertips. Should they be able to perceive vibratory stimuli through the fingertips, it is felt that this channel could be utilized in teaching speech to this population. It might also be a possible source of stimulation and learning of various parameters of speech with normal children.

An area of behavior that can contribute greatly to the educable mentally retarded child's ability to be a more useful member of society is verbal communication. It has been found that speech problems are more prevalent among the mentally retarded than they are in populations having normal intelligence (36, 39). It has also been noted that mentally retarded children can benefit from speech therapy (25, 37). Schlanger reports: "In general, after one year of speech therapy most of the children talk more and better in speech class but content remains impoverished (36)." Hence, the ultimate goal of this study suggests exploring the vibratory sense channel as an adjunctive aid to vision and audition in teaching speech to the educable mentally retarded. Before one can arrive at this point, however, it is necessary to note the responses of a receiving
system to a series of psychophysical stimuli—vibratory sensations produced by sound vibrations transmitted to the surface of the skin at the fingertip.

Physiology of Vibratory Sensations

Sound vibrations can be generated by any sort of motion, usually a vibrating body, and transmitted in the form of waves. The usual medium of transmission for both sound and light waves is air. They can be transmitted, absorbed, or reflected, however, by such substances as solids or fluids. Man's senses respond to these vibrations in specifically adapted organs, for example, when sound vibrations are transmitted to the surface of the skin they produce a vibratory sensation. This sensation is the result of a combining of the reactions of pressure and touch receptors which are among the earliest of the sense organs evolved. These receptors, which inform the organism about the movement of its parts, vibration, and skin contact, are illustrated according to Wyburn, Pickford, and Hirst in (Figure 1).

There are two relay systems which carry stimuli from these receptors to the brain, the medial lemniscal and spinothalamic systems (Figure 2). The medial lemniscal pathway serves the cutaneous sense modalities of touch and kinesthesis with the spinothalamic pathway serving the modalities of pain, temperature, and other aspects of touch. In Figure 3, areas three, two, and one indicate the destination of all sensory information other than that from special senses.
Fig. 1. Pressure and touch receptors of the skin. (After Wyburn, Pickford, and Hirst.)
Fig. 2. A drawing of the medial lemniscal and spinothalamic pathways which carry impulses to the brain. (After Netter.)
Receiving area for touch, pressure, and pain

Fig. 3. The outer surface of the left cerebral hemisphere showing the sensory receiving areas for touch and pressure. (After Wyburn, Pickford, and Hirst.)
There are areas over the entire surface of the skin that are more sensitive to one kind of stimulation than another. For example, there are specific minute areas that are more sensitive to pressure than the area immediately adjacent to it. These spots are found where there is a concentration of pressure receptors or Pacinian corpuscles. There are also spots which are more sensitive to touch than a proximal area might be. These are located where there is a concentration of touch receptors or Meissner corpuscles.

Man has learned to use the normal tactile organ, the fingertip, to make very fine discriminations as evidenced by the Braille system which the blind use. The areas of maximum tactile sensitivity in man have been found to be the lips, the palms of the hands, and the tongue. The tactile sense responds to a range of pressure from .50 gm/mm$^2$ on the lips to 4.00 gm/mm$^2$ on the back. The senses of vision and audition also respond to a relatively wide range of appropriate stimuli. Auditory perception or "hearing" occurs when sound vibrations in the range of 20 to 20,000 cps impinge upon the hearing apparatus. Visual perception or "seeing" takes place when light waves in the range of 350 to 740 microns ($\mu\mu$) is one thousandth of a millimeter, and $\mu\mu$ is one thousandth of $\mu\mu$ are received by the eye (53).

There is evidence that the responsiveness of certain senses can be improved. Schlanger reported that with training mentally retarded children were able to use their sense of hearing more efficiently in a hearing test situation (38). While investigating the electrical
sensitivity of the eye in the mentally retarded, Clausen and Karrer found the mentally retarded to have, on the average, higher phosphene thresholds than normals of the same age. They also report,

While normal subjects have a tendency to increased thresholds with successive determinations, this was not found for the retarded. . . It has been concluded that the elevated thresholds in the retarded group reflects physiological rather than psychological factors (3).

These findings by Clausen and Karrer do not indicate that the visual responsiveness of mentally retarded children can be increased with training. Indirect evidence of this can be found, however, in the work of Lance (24) and Vargason (45). Lance reported that "Pictures of familiar objects give an equal level of association strength when retardates are compared with normals." In a similar study Vargason found that his subjects required fewer trials to criterion than did those of Lance.

From the above evidence one may infer that sense training, advocated by Rousseau (35), utilized with the mentally retarded by Seguin (27), and Montessori with intellectually normal children (although originally formulated from her work with the mentally retarded 277), may be augmented by the use of an adjunctive technique. It is possible that this method may be used as a part of a multi-modality approach in the perception of speech signals which might aid in improving oral communication. Therefore, it seems advisable to explore the efficacy of the vibratory system as a method of transmitting speech signals.
Statement of the Problem

The problem under investigation in this study is the perception of sound vibrations at the fingertips by educable mentally retarded children. The results obtained by determining vibratory sensitivity thresholds for this population will be compared with results obtained with a population of children having normal intelligence.

Purposes of the Study

The proposed study is not merely an exercise in psychophysics but one with specific purposes. Two of these purposes are (a) to determine the vibratory sensitivity thresholds at each fingertip of the left and right hands of a population of educable mentally retarded children and compare these with results obtained with a population of children having normal intelligence, and (b) to investigate that aspect of the cutaneous senses referred to as vibratory.

The theory of using the vibratory sense channel is not a new one but its utilization in teaching speech to the educable mentally retarded is. This method, involving tactile or vibratory sensations, has been used in the past with the blind and deaf, as indicated by the example of Helen Keller (21), and the deaf, as evidenced by Gault's work in teaching deaf children better vocal inflection patterns (10). Goldstein used tactile sensations in teaching "tone
perception and vocal tone expression to the child not possessing enough hearing to differentiate sound elements (14)." Although the above evidence supports the feasibility of using vibratory sensations in a communication system with impaired individuals, there is no known evidence that they can be used with the mentally retarded.

**Importance of the Study**

The potential importance of this study lies in the fact that it is an attempt to investigate the vibratory sensitivity thresholds of educable mentally retarded children at the fingertips and compare them with results obtained with a control group of children having normal intelligence. Sound educational principles suggest the use of a multimodality approach to the learning task. Therefore, the ultimate goal of adding the vibratory sense channel to those of vision and audition in teaching speech to the educable mentally retarded is desirable from the educational point of view as well as the speech therapy point of view. This will depend, however, upon the sensitivity of these children in perceiving vibratory stimuli. It is of interest in the present study to investigate whether other parts of the body, i.e., the fingertips, can react to sound vibrations in a manner that will allow this modality of the cutaneous senses to be used as an adjunctive technique in teaching speech to educable mentally retarded individuals.
Without vibrations there could be, for example, no music or speech as vibrations contribute to all sounds. Vibrations play an increasingly important role in our everyday lives. In addition to contributing to our pleasure by providing music, controlling them gives us smoother riding automobiles as evidenced by the pneumatic tire versus the solid rubber one. A reduction in vibration also contributes to better control of spacecraft during launch (32). The possibility of improved means of communication in which sound vibrations are used has been reported by Geldard. Geldard's system, referred to as vibrotele, has been reported as being capable of allowing a person with sufficient training to "interpret sentences at the rate of thirty-five lettered words per minute with an accuracy of ninety per cent (12)." Bell Laboratories reports that the laser beam, light waves which vibrate faster than either sound or radio waves, has the potential of carrying hundreds of millions of voices where the present microwave system carries only 16,000 voice signals (2).

The important role that vibrations play in our everyday lives has been pointed out not only by automobile manufacturers, space scientists, and communications experts but the medical profession has also made use of vibrations. Physicians have used sound vibrations as a clinical tool in diagnosing such cases as tabes dorsalis, a degenerative disease of the bones of the back (52).
Hypotheses

Four hypotheses were tested in the present study:

1. There is no difference in the vibratory sensitivity thresholds as measured at the fingertips between (a) educable mentally retarded children, and (b) children having normal intelligence.

2. There is no difference among the vibratory sensitivities as measured at the fingertips to the five experimental frequencies 250, 500, 750, 1000, and 1250 cps as perceived by (a) educable mentally retarded children, and (b) children having normal intelligence.

3. There is no difference in the vibratory sensitivity thresholds of the fingers of the left hand and the fingers of the right hand of (a) educable mentally retarded children, and (b) children having normal intelligence.

4. There is no difference in the vibratory sensitivity of the five individual fingers of the left and right hands of (a) educable mentally retarded children, and (b) children having normal intelligence as tested on the five experimental frequencies.

Definition of Terms

The following terms are defined as used in this study:

Perception—"... perception is the process of obtaining knowledge of external objects and events, by means of the senses (l2)."
Vibration—"is . . . periodic motion and can be measured by:
  displacement, the magnitude of motion, velocity, the time
  rate of change of displacement, acceleration, the time rate
  of change of velocity (29)."

Micron—"one-thousandth of a millimeter (29)."

Educable mentally retarded—"Educable mentally retarded children are
  those who, because of retarded intellectual development, are
  incapable of being educated profitably and efficiently through
  ordinary classroom instruction but may be expected to benefit
  from special educational facilities designed to make them
  economically useful and socially adjusted. . . it is necessary
  to recognize them as too low intellectually to succeed in
  the regular school program but still high enough to be able to
  make a good social and vocational adjustment. They are high
  enough in intellectual ability that they may become independent
  of immediate supervision (47)."

Mentally Retarded—"Mental retardation refers to subaverage intel-
  lectual functioning which originates in the developmental
  period and is associated with impairment in adaptive behavior
  (16)."

Speech—"Speech relates to the sounds or words used to convey
  thought and is primarily concerned with the processes of audi-
  tion, phonation, and articulation (32)."
Organization of the Dissertation

A review of related research revealed three interesting facts: (a) there has been and still is a controversy over whether vibratory sensations are mediated by the same end-organs responsible for touch and pressure or whether there is a separate vibratory sense having its own innervation; (b) there has been and still is a great interest in research concerned with vibrations; and (c) there is a lack of research supported information on perception of sound vibrations by educable mentally retarded children. This study was not concerned with determining how vibratory sensations are mediated. Rather, if was concerned with determining educable mentally retarded children's ability to perceive vibratory stimuli through the fingertips.

For more detailed information concerning devices used in measuring vibratory sensitivity the reader is referred to Peterson and Gross (29) and Harris and Crede (15). Also, the publication, Scientific and Technical Aerospace Reports is a source rich in information concerning the study and utilization of vibrations in this, the space age.
Early Attempts to Measure Vibratory Sensitivity

Early attempts to measure the skin's responsiveness to vibrations utilized such devices as rotating toothed wheels and perforated cards, vibrating strings, tuning forks, and variants of these (11).

G. Valentin is reported to have been one of the first persons to conduct and report research in the area of vibratory sensitivity. By using rotating toothed wheels and perforated cards Valentin found that sound vibrations of 640 cps were perceptible at the fingertips (11). Von Wittich, however, reported finding vibrations to be perceptible to the fingertips when the frequency was as high as 1552 cps (11). Tomson reported that two of his patients could perceive vibrations through the floor and was the first to suggest that sensitivity to vibratory stimuli was something other than touch sensitivity (11).

Researchers did not favor the use of rotating wheels and perforated cards or vibrating strings in measuring vibratory sensitivity as much as they did the tuning fork. The tuning fork test consisted of setting the fork into motion and applying the foot of the fork to the surface of the skin. The subject was then asked if he felt the vibration and what kind of sensation he experienced.

Using a tuning fork of 128 d.v., Treitel discovered that the same areas on the skin's surface produced different discriminabilities of touch and vibration. This was done by applying the foot of the vibrating fork to the skin and noting the time between application of the fork and the cessation of vibratory sensation. He concluded that touch and vibration must be separately mediated (11).

Two years later, 1899, Egger reported that the tuning fork test was one of bony sensibility. While tracing the development of sensory loss in Pott's disease (a form of vertebral caries), he found that vibrations produced by the tuning fork remained perceptible long after tactual anesthesia had become fully developed. This vibratory perception, Egger thought, was due to the fact that bones and periosteal tissue were the conductors of the vibrations (11).

**Improvements in Measuring Vibratory Sensitivity**

An improvement in the method of determining vibratory sensitivity was advanced by Minor in 1904 when he used an electromagnetically-driven tuning fork which vibrated continuously with undiminished amplitude (11). Using Minor's innovation with a tuning fork of 100 d.v., von Frey conducted a series of carefully controlled experiments. By attaching a bristle to the tine of a tuning fork von Frey was able to explore accurately an area of fourteen square centimeters on his own forearm. He located and marked 13 warm, 58 cold, and 208 pressure spots, then proceeded to investigate the
vibratory sensitivity of these spots. From the results of his experiments von Frey concluded that with small amplitudes vibratory sensations were aroused only on the pressure spots. He also found that with stronger stimulation temperature spots produced sensations described as, "continuous, slowly developing, remaining some time at the peak, and then gradually fading (11)."

Minor's innovation was further modified by von Frey when he used the electromagnetically driven fork as a circuit breaker in the primary of an induction system. With this modification, which included using a pointed brush soaked in a warm zinc solution and serving as an electrode, von Frey delivered a 100-cycle current to the skin and found that pain spots produced sensations of pain whereas electrical stimulation of pressure spots produced sensations of vibration just as they had under mechanical stimulation.

Up to this point measurement of vibratory sensitivity had been made primarily with the tuning fork or the electromagnetically driven fork. However, with the development of the vacuum tube oscillator, vibration meters, and the piezoelectric accelerometer the measurement of vibratory sensitivity could be much more accurate. Currently the most commonly used vibration pickup is the piezoelectric accelerometer, in which a piezoelectric element is deflected by its own inertia when the pickup is subjected to vibration. The signal which the accelerometer picks up is amplified, measured, and analyzed by electronic instruments. Most of the instruments had
their genesis in auditory research but have been utilized in tactual studies. Such is the case with the pure tone oscillator which was used in this study to generate a signal that was delivered to the surface of the skin by a bone conduction vibrator.

Medical Uses of Vibratory Sensitivity

During the early part of the twentieth century measurement of vibratory sensitivity was still being done using the tuning fork in which the subject reported when he felt a sensation and detailed what kind of sensation he felt. This test, the most popular in England, was brought to the United States and popularized by E. J. Wood when he demonstrated the extreme reduction in time of perception of vibratory sensation at the sacrum in cases of tabes dorsalis (52).

Egger's view that bone and periosteal tissue were the conductors of vibrations went unquestioned for several years. The von Frey experiments which seemed to demonstrate quite conclusively that vibratory sensations were an aspect of the arousal of pressure and touch receptors did little to change that view. The mediation of vibrations remained as a controversial subject even though the tuning fork test continued to be used by the clinician to help determine sensory loss in various types of pathologies.

Williamson had clearly indicated the value of the tuning fork test in such cases as tabes dorsalis. It was also found to be a sensitive indicator in spastic paraplegia, diabetes, and peripheral
neuritis. A diminution of vibratory sensation could be detected in these cases long before other sensory disturbances (48, 49, 50, 51). The tuning fork test was also used by Piercy when he made the statement, "The vibratory sense is the last to disappear and the first to return in disease of the brain, whereas in diseases of the cord it is usually the first to be disturbed and the last to return (31)."

Use of Vibratory Sense Channel in Deaf Education

Measurement and utilization of vibrations continued to be within the realm of the neurologist until 1927 when Robert Gault focused attention upon the deaf as a population that could benefit from the use of sound vibrations transmitted to their fingertips. Gault reported that when the "vibrations of a speaker's vocal apparatus are transmitted through a suitable electrical device to the skin of a 'listener', a person can learn to distinguish colloquial speech in all its tonal range; he will be able to distinguish words and sentences by the criteria of touch and to associate meanings therewith." Gault's work indicated agreement with Rousseau's ideas in 1762 concerning the sense of touch (9).

It was reported that Gault was able to identify the vowels /a/, /e/, /i/, /o/, and /u/ 91 times out of 100 trials. It was felt that the bases upon which the sounds were identified were rhythm, tempo, and emphasis. Tests that Gault conducted with normal hearing subjects indicated that hearing did not play an important role in perceiving sounds transmitted tactually. These tests also indicated
that subjects perceived the tactually transmitted sounds at a level above chance when strange speakers were used.

Figure 4 indicates the proportion in per cent of correct identifications and confusions of tactually perceived vowels by a group of eleven of Gault's observers. The vowel /a/ was presented 591 trials, column one, and identified as /a/ 39.7 per cent of the time; as /OI/ 8.7 per cent of the time, etc. Gault trained the observers in this experiment for a period of five weeks and one day. He also reported that using the tactile method not only helped correct vocal pitch but also aided in identifying correctly the number of syllables in a word (9).

Gault's teletactor as he named it was composed of a microphone, filters, and vibrators. The filters directed bands of vibrations to the fingertips in the following order: up to 250 cps to the thumb, 250-500 cps to the index finger, 500-1000 cps to the middle finger, 1000-2000 cps to the third finger, and vibrations above 2000 cps were transmitted to the little finger. This was also the order of finger sensitivity that Gault had discovered (10). The teletactor was installed in a class for the deaf, taught by Alice Powers in 1932. Cloud reported, "Through the use of this device the children gained a smoother speech pattern than that of corresponding deaf children their age (22)." This was accomplished by the children receiving the speech of their teacher through their fingertips which they placed on the vibrators of the teletactor.

Gault, however, was not the first person in the United States to demonstrate that sound vibrations transmitted to the fingertips
Fig. 1. Proportion, in per cent, of correct identifications and confusions of tactually perceived vowels by eleven observers (after Gault).
could be utilized by the deaf in learning speech. In 1925 Goldstein had presented a group of eight deaf children with whom he had been working to a special meeting of the College of Physicians and Surgeons of Philadelphia. These children had been taught tone perception and vocal tone expression with the use of tactile sensations. He also reported the excellent results obtained with one deaf girl by having her place her hand on the large end of a megaphone which had been covered with a parchment-like paper and then speaking into the other end of the megaphone. The girl was able to interpret the sound vibrations which she felt as meaningful speech (14).

**Frequency Range to Which the Sense of Touch Responds**

As a result of Gault's efforts to teach the deaf to utilize sound vibrations transmitted through the fingertips, Knudsen attempted to determine the lower and upper limits of the frequency range to which the sense of touch could respond (22). Normal hearing persons detected sound vibrations throughout a range of 15 to 1600 cps at the fingertips. He also reported that subjects were able to distinguish differences in amplitude of approximately ten per cent for feeble sounds and five per cent for moderately loud sounds. His results, shown in Figure 5, did not agree with those of other researchers as to the frequency range to which the sense of touch could respond.
<table>
<thead>
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<th>Researcher</th>
<th>Date</th>
<th>Frequency Range</th>
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<tr>
<td>von Wittich</td>
<td>1869</td>
<td>1552 cps (upper limit)</td>
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<td>Thiel, C.</td>
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<td>Goodfellow, L.</td>
<td>1933</td>
<td>64-8192 cps</td>
</tr>
<tr>
<td>Gilmer, B.</td>
<td>1935</td>
<td>2600 cps (upper limit)</td>
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</table>

Fig. 5. Results of various researchers' attempts to establish the frequency range and upper and lower limits to which vibratory responses can be elicited (after Knudsen).
Fig. 6. Results of Knudsen, Hugony, Setzepfand, and Gilmer showing the nature of the frequency function using a vibrator with a relatively large contact surface, approximately 6 mm. diam. (after Geldard).
The above results were obtained from rather small populations: Knudsen reported on four subjects, Hugony on "several," Gilmer on five, and Setzeppand on twelve. They did not mention the effect of age on their results but Pearson investigated this in 1928. The vibratory sensibility of seventy-two subjects ranging in age from ten to ninety years who showed no signs of organic disease of the nervous system were tested by Pearson. He found a slight decrease in vibratory sensibility over the lower extremities and this decrease became more pronounced after the age of fifty. Pearson's results also indicated that adolescents perceived vibrations better than any other age group (28).

Studies Concerning Other Aspects of Vibratory Sensitivity

During this period of time, 1926-1928, while Gault and Goldstein were studying and teaching deaf children, Knudsen was studying the vibratory sensibility of normal subjects, and Pearson was studying the effects of age upon vibratory sensibility, Tilney was making an extensive study of "... Helen Keller's sensory equipment to estimate as accurately as possible the value of the several senses contributing to her sensorium by which she gained an impression of her total environment (143)."

Miss Keller's senses of vision and audition were completely inoperable while her senses of taste, smell, and touch remained useful. Tilney reported that she was not able to use her sense of
taste to any appreciable degree in communicating with her environment but that she did use the sense of smell to a large extent. The sense that Miss Keller made the most extensive use of was touch. Tilney also reported that Laura Bridgman, another sensorily deprived person examined by him, was even more limited in her sensory avenues than Miss Keller, having only the sense of touch. Tilney concluded that "the fundamental organization of those senses that remained intact in Laura Bridgman and Helen Keller has no advantage over those of the normal adult (\textsuperscript{43})." Acute powers in the interpretation of vibratory stimuli were developed by both Miss Keller and Miss Bridgman but there was no indication that their vibration receptive ability was any better than that of normal individuals.

Laidlaw and Hamilton used the Henney Pallesthesiometer in 1937 to investigate the vibratory sensibility of sixty normal subjects. The pallesthesiometer had originally been built for Frederick Tilney's study of Helen Keller. Results of the Laidlaw and Hamilton study indicated that the palmar surfaces of the fingertips were the most sensitive of the seventy-six points on the body which they tested. The next most sensitive areas were the tips of the toes and the face. Points over the soft tissues of the arms and legs were less sensitive than points over the upper portions of the trunk. The amount of adipose tissue present at any one point seemed to be responsible for variations in thresholds which the experimenters found. Obese individuals were less sensitive than thin ones to the vibratory stimuli. This would seem to support the earlier theories that
perception of vibrations is due to stimulation of both exteroceptors and proprioceptors (28).

In 1938 Cohen and Lindley used an electrically controlled pallesthesiometer, which permitted variation of amplitude of vibration at a constant frequency of 60 cps, to study the effects of pressure and contactor size on vibratory thresholds. Their results indicated that upon continual stimulation at various intensities for given periods of time vibratory thresholds were modified, independently of size of the stimulating surface, variations of pressure, and within limits, duration of the preceding stimulation. They also reported that larger areas of stimulated surfaces revealed lower thresholds over soft tissue, whereas the reverse was true for points over bony tissue (4).

During the 1910's most research dealing with vibrations was concerned with developing a personal communication system utilizing sound vibrations perceived through various parts of the body. This work is best illustrated by the work of Geldard. He reported that persons with sufficient training could interpret his "vibrotese" language at a rate of thirty-five lettered words per minute which is faster than the trained person can receive morse code (53). Geldard's students continued to experiment with sensitivity of human skin to mechanical vibrations, cutaneous communication systems utilizing mechanical vibrations, and training in these systems during the 1950's (40, 41, 18).
Pickett and Pickett reported in 1963 the results of a study using themselves as subjects in which they tested their vowel and consonant discriminating ability (30). Training themselves beforehand, they tried to discriminate between vowels transmitted to the fingertips by a tactual vocoder. The same procedure was used in the consonant discrimination test. A standard phrase was used to carry the test sound. The vowel /a/ was used in the consonant tests and the consonant /p/ was used in the vowel tests. Their results indicated that a moderate amount of speech information could be transmitted in this manner with a limited level of performance for some of the speech features. The above results indicating that only a moderate amount of speech information can be transmitted through the skin does not detract from the fact that the skin is a channel through which various parameters of speech have been learned by certain individuals.

The review of related research has not located any references indicating that sound vibrations transmitted to parts of the body other than the ear, i.e. fingertips, can be detected and utilized by educable mentally retarded children or normal children. This review has revealed, however, that the cutaneous sense modality referred to as vibratory has been utilized in communication systems by persons that were deaf, deaf and blind, and normal.

In 1953 Heck pointed out the need for education of the impaired child (17). That this need is being partially met is evidenced by the growth of educational programs for practically every type of
handicapped child. In 1961 Schlanger pointed out that mentally retarded children can be trained to use their sense of hearing more effectively (38). Lassers and Low have demonstrated that mentally retarded children can benefit from speech therapy (25). Gault, Goldstein, Geldard, and Pickett have demonstrated the possibility of using sound vibrations transmitted to the fingertips with various types of handicapped individuals and normal subjects in teaching certain aspects of speech (10, 14, 12, 30).

The feasibility of this study is pointed out by Geldard when he wrote, "A skilled receiver can get meanings just as promptly and accurately by feeling dots and dashes as by listening to them. We so habitually think of communication as a function to be mediated by eyes and ears that the existence of other potential channels tends to escape us (13)."
CHAPTER III
METHODS AND PROCEDURES

The review of related research indicated that the skin can be used in a communication system utilizing sound vibrations transmitted to sense organs other than the ear. In addition, the research noted that the fingertips are very sensitive to sound vibrations transmitted to them with a suitable vibrator. Since the fingertips are readily accessible they were chosen as the site of stimulation. The ability of educable mentally retarded children as well as normal children to respond to vibratory stimuli at the fingertips needs investigation. The use of vibratory stimuli as an adjunctive aid in the teaching of certain parameters of speech could be considered only if satisfactory responses were noted.

Preliminary Investigation

During preliminary investigation it was found that subjects received considerable auditory information from the vibrator due to the high amplitudes of vibration necessary for vibratory stimulation. It was also discovered that the amount of pressure that subjects applied to the vibrating surface modified their responses.

A pilot study involving five university students was conducted to determine (a) the level of masking noise needed to mask the audible
signal from the vibrator, and (b) the amount of pressure to be exerted on the vibrating surface by the subjects to produce the most consistent responses.1

Thresholds2 were obtained under the following three conditions. Condition (a) involved the use of white noise presented to the subjects binaurally through earphones (Permaflux, Model ADH1A) at a level sufficient to mask the audible signal from the vibrator (Sonotone, Model 6AS); (b) involved an absence of noise; and (c) involved obtaining thresholds of vibratory sensitivity for each finger at three different levels of pressure, i.e., 200 grams, 300 grams, and 400 grams under each of the other conditions listed above.

Two 500 D.C. Microampere Meters (Triplet, Model 1420 P1) were calibrated with a Hunter Spring Company Pressure-Force Gauge (Model, L-1000). The calibration was carried out in the following manner: the experimenter applied the point of the pressure-force gauge to the contact surface of the vibrator and two assistants adjusted the microampere meters to read identically at each of three test pressures, i.e., 200 grams, 300 grams, and 400 grams.

Results of the pilot study indicated that 300 grams of pressure (force per unit area or force divided by area) exerted on the contact

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1Consistent here means that the subject responded positively when the signal was present at the fingertip two of the three times for each of three trials.

2Threshold here means threshold of detectability or when the subject reported that he felt the vibration.
surface of the vibrator by the subject with his fingertip yielded the most consistent responses. A pressure of 200 grams was not sufficient for the subjects to perceive vibratory stimuli at all frequencies, while a pressure of 400 grams caused the subjects to report a pulse sensation in the fingertip. Therefore, 300 grams was the selected pressure. Results also indicated that white noise at a sound level of 80 dB was sufficient to mask any audible signal from the vibrator.

Selection of Subjects

Forty subjects, separated into two groups of twenty each, participated in this study. The experimental group, educable mentally retarded, contained ten male and ten female subjects. These children were classified as educable mentally retarded by the public school where they were enrolled in a special education program for slow learners. The program was located in Finland and Brookpark Junior High Schools, Southwestern City Schools, Grove City, Ohio. The children in this group ranged in chronological age from 12.6 to 15.5 years, the mean age being 14.1. The mental age of this group ranged from 6.6 to 10.11 years, with a mean of 8.9. The mean intelligence quotient of the experimental group was 70.1, with a range of 56 to 79. All intelligence quotients were taken from an individual test (Stanford Binet, Form L-M and/or Wechsler Intelligence Scale for Children) which had been administered to each child within
the past two years by the school psychologist. There was no attempt to match rigidly the educable mentally retarded group with the group having normal intelligence except for chronological age, sex, an equal number of males and females, and the ability to perceive vibratory stimuli through the fingertips.

The control group contained ten male and ten female subjects who, because of their academic placement in the public schools, were assumed to have normal intelligence. The experimenter had known each child in this group for approximately ten months prior to their participation in the study. All subjects were volunteers. Each child's family was contacted and the purpose of the study was explained to them. This age group was chosen because previous research had indicated that adolescents were the most sensitive age group to vibratory stimuli (28) and because of the experimenter's interest in children of this age.

**Pre-test Screening Procedures**

The pre-test screening as well as actual testing of the control group for vibratory sensitivity was carried out in the Phonetics Laboratory, Department of Speech at The Ohio State University.

The screening procedure involved explaining the test, purpose of the study, and each piece of equipment. Each subject's ability to perceive vibratory stimuli through his fingertips was determined. Twenty-one potential subjects were screened for the control group.
and twenty volunteered for the experiment. To determine the subject's ability to perceive vibratory stimuli through the fingertips, each subject placed a finger on the contact surface of the vibrator which was mounted on a rectilinear potentiometer installed in a padded box having three sides. A constant pressure of 300 grams was exerted on the vibrator by the subject and monitored by both the experimenter and subject. The subject reported orally when he first detected vibration at which time the experimenter attenuated the stimuli 10 dB. The stimuli were then increased in steps of 1 db until the subject again reported detection. This ascending technique was used for one finger of each hand at each of the test frequencies.

For the educable mentally retarded group the only difference in the pre-test situation was that the test was explained to them as a group in their classroom and then again in the testing room. For this group twenty-two potential subjects were screened and twenty volunteered to participate in the study. The testing room for the experimental group was located in Finland Junior High School, Grove City, Ohio. The room was in an area of the school which was relatively isolated from the main stream of traffic through the hallways. The room was quiet and there were no interruptions to distract the subjects during a testing session.
Re-statement of Hypotheses

As previously noted, the potential importance of this study lies in the fact that it was an attempt to investigate the vibratory sensitivity thresholds of educable mentally retarded children and compare them with thresholds obtained with a control group of normal children.

Four hypotheses were advanced which were tested in this study:

1. There is no difference in the vibratory sensitivity thresholds as measured at the fingertips between (a) educable mentally retarded children, and (b) children having normal intelligence.

2. There is no difference among the vibratory sensitivities, as measured at the fingertips, to the five frequencies, 250 cps, 500 cps, 750 cps, 1000 cps, and 1250 cps, as perceived by (a) educable mentally retarded children, and (b) children having normal intelligence.

3. There is no difference in the vibratory sensitivity thresholds of the fingers of the left hand and the fingers of the right hand of (a) educable mentally retarded children, and (b) children having normal intelligence.

4. There is no difference in the vibratory sensitivity of the five individual fingers of the left and right hands of (a) educable mentally retarded children, and (b) children having normal intelligence as tested on the five experimental frequencies.
Testing Procedure

To test the above hypotheses the following procedure was used. When the subject arrived at the testing room he was asked if he remembered the explanation that had already been given to him about what he was going to be doing. Regardless of his answer, he was given a practice period of approximately five minutes to re-familiarize him with the procedure. This training session was the same as the screening procedure except for one additional element. The subject was shown a pair of earphones and told that he would be wearing them during the test to keep him from hearing the sound from the Vibrator. After the subject had demonstrated that he could feel the vibration again, he was given the earphones to put on. While wearing the earphones, through which he was receiving a masking noise at a level of 80 dB, he was told to report orally when he felt the vibration via his fingertips.

When the experimenter was satisfied that the subject understood what he was supposed to do, the test was begun. While the subject exerted a pressure of 300 grams, monitored by the experimenter and subject, on the vibrator with his fingertip the experimenter increased the vibratory stimulus until the subject reported that he could feel it. At this time the experimenter attenuated the signal 10 dB. The stimulus was then increased in steps of 1 dB until the subject again reported that he detected it. This technique was used
at each of the test frequencies for all fingers of each subject. Three separate measures were taken at all frequencies for each finger.

Three measures for each finger at all frequencies were obtained in the following manner: the subject was asked to place a fingertip on the vibrator in a random order and three measures were taken; the corresponding finger of the opposite hand was then placed on the vibrator and three measures taken. The average of the three measures for each finger was considered the threshold of vibratory sensitivity. During the entire procedure, the pressure that the subject was exerting upon the contact surface of the vibrator was being monitored by the experimenter as well as the subject with the two microampere meters. One of the meters faced the experimenter and the other the subject (Figure 1). All responses were recorded on a separate answer sheet which is included in the appendix.

**Instrumentation**

The above testing procedures were carried out with the following equipment. An audio frequency generator (Hewlett Packard, Model 202 C) connected to a power amplifier (Bogen, Model PV10) provided the stimuli at a sufficient power to operate the vibrator. An attenuator (Hewlett Packard, Model 450) connected between the output of the power amplifier and the primary of an impedance matching transformer controlled the amplitude of vibration.
Fig. 7. Instruments Used in This Study.
The output of the transformer was wired through a resistance network that provided a constant impedance to a switch used to interrupt the tone when checking the subjects' responses as well as to turn the signal on and off. An electro-mechanical vibrator (Sonotone, Model 6A) connected to the switch provided the stimuli for the subjects (Figure 7). The monitoring meters (Triplet Microampere Meters, Model 420 P1) were connected in series with a one-and-a-half volt flashlight battery and a rectilinear potentiometer (Bourns, Model 109). The vibrator, potentiometer, and battery were mounted in a padded box having three sides (Figure 7). A schematic representation of the equipment is presented in Figure 8.

Prior to each testing session the voltage across the attenuator was set at fifty volts for 1000 cps using an audio frequency generator (Hewlett-Packard, Model 202C) and a voltmeter (Hewlett-Packard, Model 400C). The output of the vibrator had been verified by an electronic frequency counter (Beckman/Berkely, Model 7350) in the Phonetic Laboratory at The Ohio State University. The test frequencies 250, 500, 750, 1000, and 1250 cps were chosen due to the limitations of the instruments available for the experiment.

All responses were recorded in microns of displacement relative to the attenuator setting, Table 2, at which each subject indicated he perceived the stimulus. As indicated earlier, the vibratory sensitivity thresholds were the average of three measures at each test frequency for all fingers of the forty subjects.
D.C.
Microampere Meters

Subject

Fig. 8. Schematic Representation of Testing Apparatus Used in This Study.
**Table 1**
Voltage and micron equivalents at each attenuator setting used in this study

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<thead>
<tr>
<th>Attenuator Setting</th>
<th>250 cps Voltage Across Terminals of Bone Oscillator</th>
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<th>Microns</th>
<th>500 cps Voltage Across Terminals of Bone Oscillator</th>
<th>Microns</th>
<th>1000 cps Voltage Across Terminals of Bone Oscillator</th>
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<th>1500 cps Voltage Across Terminals of Bone Oscillator</th>
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<tr>
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<td>6.21</td>
<td>.007</td>
<td>1.95</td>
<td>.055</td>
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<td>.100</td>
<td>1.57</td>
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<td>87</td>
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<td>.007</td>
<td>1.95</td>
<td>.058</td>
<td>4.85</td>
<td>.092</td>
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<td>86</td>
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<tr>
<td>82</td>
<td>.014</td>
<td>2.81</td>
<td>.004</td>
<td>.95</td>
<td>.010</td>
<td>1.40</td>
<td>.030</td>
<td>.95</td>
<td>.041</td>
<td>.68</td>
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</tbody>
</table>
All data gathered in this manner were tabulated and a four factor analysis of variance was used to determine the amount of variance which could be attributed to each of the four factors. The design used was an extension of Lindquist's Type VI (26).
CHAPTER IV
RESULTS AND DISCUSSION

The purpose of this study was to investigate the vibratory sense channel of educable mentally retarded children by means of the fingertips. Comparisons with normal children were to be made. To accomplish this twenty educable mentally retarded children and twenty children having normal intelligence comprised the groups used in this experiment. Four null hypotheses were formulated and tested. The results obtained and discussion concerning these hypotheses are presented in this chapter.

Hypotheses I—There is no difference in the vibratory sensitivity thresholds as measured at the fingertips between (a) educable mentally retarded children, and (b) children having normal intelligence.

The scores used in comparing the vibratory sensitivity thresholds of the two groups are reported in microns of displacement. They were the averages of three observations made at each of the experimental frequencies for the ten individual fingers of all subjects. For example, three observations were made at 250 cps, 500 cps, 750 cps, 1000 cps, and 1250 cps for the thumbs, index fingers, middle fingers, third fingers, and the little fingers of each subject in both groups. These observations were averaged to produce a mean threshold across
fingers for each subject at each of the experimental frequencies. The mean threshold scores for each frequency of all subjects having normal intelligence (G1) were then summated and averaged to produce a mean threshold for the group at each experimental frequency. This procedure was repeated for the educable mentally retarded group (G2). These thresholds were then compared at each frequency. This technique enabled the experimenter to ascertain if there were significant differences in the mean vibratory sensitivity thresholds of the two groups across frequencies and fingers.

When the data in Table 2 were examined it was noted that the F ratio of .05 for groups (G) indicated that there was no significant difference between the two groups. That is to say, the two groups responded to relatively similar thresholds of vibratory stimuli. Although not significant the data revealed that mentally retarded children were more sensitive to three of the five test frequencies than normal children. The lower thresholds for educable mentally retarded children as compared to the normal children were as follows: 500 cps, 11.37 microns (μ) to 11.59 microns for the normals; 1000 cps, 11.06 microns to 11.18 microns for the normals as noted in Table 3. These findings were not in agreement with assumptions of various special educators with whom the experimenter had discussed the experiment. Their assumptions had been that the retarded would respond to higher thresholds than normals.
<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>G (Groups)</td>
<td>12.82</td>
<td>1</td>
<td>12.3</td>
<td>.05</td>
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<td>Error</td>
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<td>38</td>
<td>240.66</td>
<td></td>
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<tr>
<td>Within Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H (Hands)</td>
<td>9.01</td>
<td>1</td>
<td>9.01</td>
<td>1.41</td>
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<tr>
<td>D (Fingers)</td>
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<td>4</td>
<td>27.23</td>
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<tr>
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<td>4</td>
<td>1,930.43</td>
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<td>11.25</td>
<td>4</td>
<td>2.81</td>
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<td>1.11</td>
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<td>4</td>
<td>3.55</td>
<td>.26</td>
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<td>DFG</td>
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<td>16</td>
<td>6.07</td>
<td>.23</td>
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<td>HFG</td>
<td>11.74</td>
<td>4</td>
<td>2.91</td>
<td>.04</td>
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<td>HDRG</td>
<td>88.78</td>
<td>16</td>
<td>5.55</td>
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<tr>
<td>Error H</td>
<td>243.58</td>
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<td>13.62</td>
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</tr>
<tr>
<td>Error DF</td>
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<td>608</td>
<td>26.25</td>
<td></td>
</tr>
<tr>
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<td>608</td>
<td>33.37</td>
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</table>

*Results significant at the 1 per cent level of confidence.
TABLE 3

Mean thresholds* obtained for the two groups of subjects at each of the five experimental frequencies

<table>
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<tr>
<th>Group</th>
<th>250 cps</th>
<th>500 cps</th>
<th>750 cps</th>
<th>1000 cps</th>
<th>1250 cps</th>
</tr>
</thead>
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<td>8.80</td>
<td>14.59</td>
<td>9.17</td>
<td>7.29</td>
<td>11.18</td>
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<td>G2</td>
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<td>11.37</td>
<td>10.29</td>
<td>6.69</td>
<td>11.06</td>
</tr>
</tbody>
</table>

*Means reported in Microns (µµ).
It will also be noted in Figure 9 that the two groups were sensitive to the frequencies in almost identical order. They were the most sensitive to 1000 cps as indicated by the lowest mean thresholds 7.29 μm (G1) and 6.69 μm (G2) and the least sensitive to 500 cps as indicated by the highest mean thresholds 11.59 (G1) and 11.37 μm (G2). Until further information is available concerning the vibratory sensitivity of educable mentally retarded children, these results can only be subject to conjecture. The testing procedure was a new experience for both groups. The normal subjects, however, were unanimous in asking "will it hurt?" or "will I be shocked?" This did not occur with the subjects in the educable mentally retarded group. It is felt that while the normal subjects seemed to accept the explanation that there was no pain connected with the experiment, they were "on guard" and were not as attentive to their task as the educable mentally retarded subjects. That is to say, the normal subjects expected to be tricked and to receive some kind of unpleasant sensation. Their expectations may have acted as a mediating factor in their responses. Presently this seems to be the only explanation for the lower thresholds obtained from the educable mentally retarded subjects to three of the five vibratory stimuli presented.

The significant interaction between the frequencies and the groups indicated that the groups differed in an irregular fashion to the different frequencies. Though the first null hypothesis was not rejected, the significant interaction (FxG, Table 2) revealed that
Fig. 9. Comparison of the two groups of subjects illustrating their mean thresholds* at each frequency. *Means reported in Microns (µm).
the educable mentally retarded subjects were more sensitive at 500, 1000, 1250 cps than the normal subjects; the normals were more sensitive at 250 and 750 cps.

Hypothesis II—There is no difference among the vibratory sensitivities, as measured at the fingertips to the five frequencies 250 cps, 500 cps, 750 cps, 1000 cps, and 1250 cps, as perceived by (a) educable mentally retarded children, and (b) children having normal intelligence.

The mean scores used in determining the sensitivity thresholds at the five experimental frequencies for all subjects were obtained in the same manner as the scores used in testing the first hypothesis. That is three observations were made at each of the experimental frequencies for the ten individual fingers of all subjects. These observations made at each frequency across subjects and fingers were averaged to produce a mean threshold score.

The mean threshold scores in microns for each frequency across all subjects and fingers were then summated and averaged to produce a mean threshold for all subjects at each frequency.

These thresholds at each frequency across subjects were then compared. This technique enabled the experimenter to ascertain if each frequency produced significantly different mean thresholds across subjects.

The results of the analysis of variance, Table 2, indicated that the five experimental frequencies did produce significantly
different mean vibratory sensitivity thresholds across subjects.

An F ratio of 26.6 was obtained. This was significant at the 1 per cent level. It was noted upon examining Table 4 that the mean threshold for all subjects at 1000 cps was 6.99 μν which was the lowest threshold obtained at any of the five frequencies. The remaining frequencies produced mean vibratory sensitivity thresholds in the following order: 9.69 μν at 250 cps, 9.73 μν at 750 cps, 11.12 μν at 1250 cps, and 12.98 μν at 500 cps. These mean threshold scores were used to construct a critical differences table in order to determine where the significant differences were. It was noted by examining the table of critical differences, Table 5, that significant differences were found between 250 and 500 cps, 500 and 750 cps, 500 and 1000 cps, and 750 and 1250 cps. On the basis of these results the second hypothesis was rejected.

The result indicating that subjects were the most sensitive to 1000 cps was not in agreement with those of Geldard who reported, "the optimal frequency of the point of maximum sensitivity is in the range of 250 cps (11)." Verrillo reported similar findings when he investigated the cutaneous threshold for vibration (146). Other researchers have obtained similar results (Figure 6, page 32) but they reported on far fewer subjects than the present study employed. The lowest thresholds in earlier studies were obtained at 250 cps. One cannot compare the results reported in this study
TABLE 4

Mean vibratory sensitivity thresholds* obtained for all subjects at each frequency

<table>
<thead>
<tr>
<th></th>
<th>250 cps</th>
<th>500 cps</th>
<th>750 cps</th>
<th>1000 cps</th>
<th>1250 cps</th>
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<td>9.69</td>
<td>12.98</td>
<td>9.73</td>
<td>6.99</td>
<td>11.12</td>
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</table>

*Means are reported in microns (μm).
### TABLE 5

Critical differences for mean vibratory sensitivity thresholds obtained for all subjects at each frequency

<table>
<thead>
<tr>
<th></th>
<th>500 cps</th>
<th>750 cps</th>
<th>1000 cps</th>
<th>1250 cps</th>
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<td>250 cps</td>
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<td>1.43</td>
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<td>500 cps</td>
<td></td>
<td>3.25*</td>
<td>5.99*</td>
<td>1.86</td>
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<tr>
<td>750 cps</td>
<td></td>
<td></td>
<td>2.74</td>
<td>1.39</td>
</tr>
<tr>
<td>1000 cps</td>
<td></td>
<td></td>
<td></td>
<td>4.13*</td>
</tr>
</tbody>
</table>

*3.12 needed for 1 per cent level of confidence.
with those directed in (Figure 6). This is due, in part, to the fact that the present study encompasses a range of frequencies from 250 to 1250 cps, whereas the results shown in Figure 6 covered a range from 16 to 1024 cps.

One cannot find in the literature on vibratory sensitivity two investigators who used the same size vibrator, stimulated the same area of the skin, or used the same frequencies. The present study did, however, use one parameter that was employed by the majority of the past researchers. This was the site of stimulation which was the volar surface of the fingertip.

There was no simple explanation for the findings reported here or in other sources. We will have to content ourselves with explanations dealing with technique, size of the contactor used, site of stimulation, and populations tested until this and other studies can be replicated.

Hypothesis III—There is no difference in the vibratory thresholds of the fingers of the left hand and the fingers of the right hand of (a) educable mentally retarded children, and (b) children having normal intelligence.

The scores used in determining the mean vibratory sensitivity thresholds for the left and right hands of all subjects were obtained in the same manner as those used in testing the first two hypotheses. The scores were reduced statistically by determining the mean threshold scores for the left and right hands across
subjects and frequencies. This produced a mean vibratory sensitivity threshold for the left hands across subjects and frequencies of 10.03 μ as compared to 10.17 μ for the right hands of all subjects at all frequencies.

The F ratio of 1.41 for hands (H) shown in Table 1 indicated there was no significant difference between the left and right hands. Thus, the third hypothesis was not rejected.

Although left-handed and right-handed subjects were used in the present study, no significant difference was found in the mean vibratory sensitivity thresholds between the left and right hands. These findings are not in keeping with the findings of Gault who reported the right hand to be more sensitive than the left (10).

On the basis of so few subjects one cannot draw any conclusions or make any assumptions. There is, however, an indication that the vibratory sensitivity of left and right-handed persons should be investigated further.

Hypothesis IV—There is no difference in the vibratory sensitivity of the five individual fingers of the left and right hands of (a) educable mentally retarded children, and (b) children having normal intelligence, as tested on the five experimental frequencies.

The scores used in determining the vibratory sensitivity thresholds for each finger across subjects and frequencies were obtained in the same manner as those used in testing the first three
hypotheses. The scores were reduced by determining the mean threshold for each finger across subjects and frequencies. To do this the mean thresholds across frequencies were obtained for each finger of the left hand of all subjects. This procedure was repeated for the right hand of all subjects and the mean thresholds added to those of the corresponding finger of the left hand thereby producing five mean threshold scores for all subjects. By summating the mean scores for each pair of fingers across frequencies and subjects the experimenter was able to compare the mean vibratory sensitivity thresholds of the five pairs of fingers.

The results as shown in Table 2, line D, revealed that significant differences existed between the five fingers in their sensitivity to vibratory stimuli. An obtained F ratio of 3.84 was significant at the 1 per cent level. In order to determine where the differences were a table of critical differences was constructed using the scores presented in (Table 6). As indicated in the critical differences table, Table 6, there were significant differences between the thumb and middle, third, and little fingers; the index finger and middle, and third fingers. On the basis of these results the fourth hypothesis was rejected.

Upon examining these mean thresholds it was noted that the thumb responded to the lowest threshold, 9.78 μm. The highest threshold, 10.36 μm was obtained by the third finger with the remaining fingers obtaining thresholds in the following order: index
TABLE 6

Mean vibratory sensitivity thresholds* obtained for pairs of fingers across subjects and frequencies

<table>
<thead>
<tr>
<th>Thumb</th>
<th>Index Finger</th>
<th>Middle Finger</th>
<th>Third Finger</th>
<th>Little Finger</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.78</td>
<td>9.86</td>
<td>10.28</td>
<td>10.36</td>
<td>10.23</td>
</tr>
</tbody>
</table>

*Means reported in microns (μm).
TABLE 7
Critical differences for mean thresholds obtained for pairs of fingers across frequencies and subjects

<table>
<thead>
<tr>
<th></th>
<th>Index Finger</th>
<th>Middle Finger</th>
<th>Third Finger</th>
<th>Little Finger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thumb</td>
<td>.08</td>
<td>.50*</td>
<td>.50*</td>
<td>.45*</td>
</tr>
<tr>
<td>Index Finger</td>
<td></td>
<td>.42*</td>
<td>.50*</td>
<td>.37</td>
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<tr>
<td>Middle Finger</td>
<td></td>
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<td>.05</td>
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<tr>
<td>Third Finger</td>
<td></td>
<td></td>
<td></td>
<td>.13</td>
</tr>
</tbody>
</table>

* .39 needed for 1 per cent level of confidence.
finger, 9.86 μm; middle finger, 10.28 μm; and the little finger, 10.23 μm. These results support an observation by Wyburn, Pickford, and Hirst that man has learned to make very fine discriminations with his fingers (53). For example, we note this use of thumb and index finger when a person is inspecting a piece of cloth or the finish of a table top by the way he rubs the cloth between these specific fingers or runs his hand over the surface of the table.

Man's ability to make fine discriminations with his fingertips has been utilized by such persons as Helen Keller, studied by Gault and Geldard and most recently by Petar Guberina. Miss Keller used her fingertips almost exclusively in communicating with her environment (21). Gault's apparatus, which was installed in a classroom for the deaf taught by Alice Powers, proved to be beneficial in teaching smoother speech patterns to the children (10). Geldard's "vibrotese" has been demonstrated as having a possible use in situations where the normal channels of communication are already engaged (13). The method by Guberina utilizing vibrations has likewise been demonstrated, albeit on a limited scale in this country, to be useful in teaching speech and language to the deaf.

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1 P. Guberina demonstrated his method of using the vibratory sense as a transmitter of speech and language to the deaf in the Speech Science Laboratory at The Ohio State University during the summer of 1964.
In light of the success that the above-named persons have experienced with the vibratory sense and results of this study, one can conjecture that this sense channel might be useful as an adjunctive aid to vision and audition in teaching speech to the educable mentally retarded as well as normal children.
CHAPTER V
SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the vibratory sense channel of educable mentally retarded children and children having normal intelligence. This was done by determining their ability to perceive vibratory stimuli presented at the fingertips and comparing the scores.

Summary

Measures were obtained of the vibratory sensitivity of the fingers of both hands of two groups of subjects for the frequencies 250, 500, 750, 1000, and 1250 cps. Vibratory sensitivity thresholds were obtained for (a) individual fingers of all subjects across frequencies, and (c) for all frequencies across subjects.

Statistical analysis of the data indicated that there was no significant difference between the vibratory sensitivity threshold of educable mentally retarded children and children having normal intelligence. The educable mentally retarded were, however, more sensitive to three of the experimental frequencies. These frequencies were 500, 1000, and 1250 cps. This difference in vibratory sensitivity at three of the frequencies, although not significant, is an interesting finding worthy of further exploration.
No significant difference was found when the hands of all subjects were compared. There were significant differences, however, when the individual fingers were compared. This was especially true of the thumb and index finger whose vibratory sensitivity thresholds of 9.78 μm and 9.86 μm, respectively, were lower than the highest threshold of 10.36 μm obtained for the third finger. Finally, significant differences were found when the five experimental frequencies were compared. The lowest threshold was obtained at 1000 cps (6.99 μm) and the highest at 500 cps (12.98 μm).

Conclusions

On the basis of this study, several conclusions are presented:

a) Although the overall vibratory sensitivity thresholds of the two groups did not differ significantly, the two groups did react differently to the various experimental frequencies. It was indicated that the educable mentally retarded children had lower mean thresholds at 500, 1000, and 1250 cps while the normal children had lower mean thresholds at 250 and 750 cps.

b) When the hands of all subjects were compared it was found that both left and right hands of the combined groups were equally sensitive to the experimental frequencies.

c) Results obtained from a comparison of individual fingers revealed that all fingers were not equally sensitive to the
vibratory stimuli of different frequencies. This was especially true of the thumb and index finger which were most sensitive to all frequencies.

d) One of the most interesting conclusions that can be drawn from the findings of this study is that the fingertips of both educable mentally retarded children and children having normal intelligence were sensitive enough to detect differences in vibratory stimuli.

It might also be concluded from the findings of this study that the vibratory sense channel might be adapted as an adjunctive aid in teaching certain parameters of speech to educable mentally retarded children.

**Implications for Further Research**

Further research needs to be done to determine if educable mentally retarded children can learn to distinguish the more complex speech sounds transmitted to the fingertips, since they do demonstrate an ability to perceive vibratory stimuli presented at the fingertips. Research comparing the ability of different groups of children having different levels of intelligence, i.e., educable mentally retarded, normal, and those children classed as gifted. This should be done in an attempt to establish the truth of the assumption that is generally held that gifted children's senses are more acute than other children's. Also an attempt should be made to
determine which finger is the most sensitive to which frequency, not only with educable mentally retarded children, but also with children having various types of handicaps.

An investigation concerning the usefulness of the vibratory sense channel in sense training with young children is one that seems to have possibilities in helping children become more aware of their environment.
APPENDIX
## VIBRATORY SENSITIVITY

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REFERENCES


23. Laidlaw, Robert W., M.D. and Hamilton, Mary Alice, B.S. "Thresholds of Vibratory Sensibility as Determined by the Pallesthesiometer; a Study of Sixty Normal Subjects," Bulletin of the Neurological Institute of New York, 6:3 (December, 1937), 494-503.


