A STUDY OF THE RESPIRATORY TECHNIQUE FOR OBTAINING AUDITORY THRESHOLDS

by

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CHAPTER I

INTRODUCTION

Investigators interested in the measurement of auditory sensitivity agree that the development of a test which does not depend upon a conscious, cooperative response by the person being tested would have marked significance in the field of audiology. Such a test would be particularly beneficial in obtaining auditory thresholds of persons who are frightened or confused by the process of responding to a presented auditory stimulus. Facilitation of threshold determinations could be expected in cases of mental retardation, malingering, or psychogenic hearing loss. Equally important would be its use in the diagnosis of language disorders in young children, since with standard audiometry it is often difficult to detect whether this disorder is due to a hearing loss or a neurological problem.

A number of objective methods of measuring auditory sensitivity are being utilized at this time. The two most widely used techniques are electroencephalic and electrodermal audiometry, both of which are reported to have had relative success, but at the same time, certain limitations. In electroencephalic audiometry, subjects often object to the electrode placement on the head and the need for immobility during the test. If sedation is necessary for hyperactive subjects, the matter becomes further complicated, as the testing procedure is lengthened and the responsiveness of the subject is greatly reduced. Likewise in electrodermal audiometry, persons are often reluctant to have electrodes placed on their fingers and forearms. The conditioning process, involving a mild electrical shock, frequently produces undesirable behavioral reactions as well. When referring to electrodermal procedure, Davis states, "Very often it has to be annoyingly uncomfortable and even painful."[1]

In addition to these restrictions dealing with the physical discomfort of the subject, also to be considered with these two techniques is the question of interpretation and the variation in responsivity. Davis mentions the problem in electroencephalic audiometry of distinguishing between the small electrical activity of the brain which is always taking place and the specific electrical activity which is aroused during the perception of auditory stimuli.[2] In electrodermal audiometry the difficulty occurs in interpreting the failures to respond. According to Davis, "Many normal individuals fail completely to establish the desired association between the auditory signal and the electrodermal response."[3] A number of circumstances may account for this. For example, Goldstein

[1]Hallowell Davis and Richard Silverman (eds.), Hearing and Deafness (New York: Holt, Rinehart and Winston, Inc., 1961), p. 232.

[2]Davis, p. 237.

[3]Davis, p. 233.

states, "Very young children are less responsive and conditionable than older children. Very old persons are more variable as a group and are less responsive electrodermally than younger adults."[4] He also notes that women are less responsive electrodermally than men.

A more recent objective method, developed with the hope of overcoming the particular limitations of the aforementioned techniques, has been concerned with the effects of the perception of tonal stimuli upon breathing. It was developed on the assumption that tones presented near a person's threshold of hearing sensitivity would be associated with a reduction of the breathing rate. Only limited research has been conducted in this area, but several studies have shown that the rhythmic act of breathing is disturbed by the introduction of an auditory stimulus.

This technique is reportedly easy to administer and has shown a relatively high correlation with conventional pure tone testing. It has been suggested that this technique is not as frightening to the subjects as electroencephalic and electrodermal audiometry, since it is free of such disturbing factors as electrode placement and electrical shock conditioning.[5]

[4]Robert Goldstein, "Electrophysiologic Audiometry," Modern Developments in Audiology, ed. James Jerger (New York, 1963), p. 172.

[5]Ronald Poole, "A Study of the Effects of Auditory Stimuli on Respiration," Unpublished Master's thesis, University of Kansas, Lawrence, 1965.

Studies involving this respiratory technique for measuring auditory sensitivity have involved both subjects whose hearing was normal as well as subjects whose hearing was not within the range of normalcy. With both groups there has been reported a significant, high, positive correlation between thresholds obtained by conventional pure-tone testing and thresholds obtained by this respiratory technique. However, to date, investigators using this respiratory technique have all employed an experimental procedure in the presentation of the tonal stimuli, presenting in random order tones near or below the subject's threshold of hearing to levels approaching the threshold of discomfort. Aspinall[6] and Winston[7] have suggested that future research might explore this respiratory technique utilizing a method more amenable to clinical use.

A preferred method for clinical determination of pure-tone thresholds by conventional audiometry is an improved version of the Hughson-Westlake technique as described by Carhart and Jerger.[8] The fundamental feature of this method is that

[6]Kenneth Aspinall, "A Comparison Between Auditory Thresholds Obtained by Conventional Audiometry and by Respiration Involving 12-16 Year-old Deaf Subjects," Unpublished Master's thesis, University of Kansas, Lawrence, 1966, p. 32.

[7]Michael Winston, "A Comparison of Auditory Thresholds Obtained by a Conventional Method and a Respiratory Method in a Deaf Population Ranging in Age from 17-21 Years," Unpublished Master's thesis, University of Kansas, Lawrence, 1966, p. 27.

[8]Raymond Carhart and James Jerger, "Preferred Method for Clinical Determination of Pure-Tone Thresholds," _Journal of Speech and Hearing Disorders_, XXIV (November 1959), 330-345.

minimum audibility is measured only by progressively increasing the stimulus intensity. This technique, accepted by the Committee on Conservation of Hearing of the American Academy of Ophthalmology and Otolaryngology, is now popularly accepted by audiologists as the standard procedure for obtaining pure-tone thresholds.

In respect to the respiratory technique of measuring thresholds, Winston and Aspinall have also indicated that the development of instrumentation amenable to clinical methods is another area for future research. Previous investigators have used a mercury-in-rubber strain gauge as a sensor for detecting thoraxic activity associated with respiration. A mercury-in-rubber strain gauge, when purchased ready-made, is expensive. If home-made, the materials are often difficult to obtain, and, in spite of claims to the contrary, it sometimes proves difficult to construct. While this has been an adequate instrument for its intended purpose, another type of strain gauge may prove better adapted to clinical use.

In light of this discussion, then, the following questions were proposed for exploration in the present investigation:

1. Do different levels of tonal stimulation, when presented by the clinical ascending technique, have a differential effect on the length of the respiration cycle as measured by a simple mechanical transducer?

2. Are the respiration cycles which are associated with tonal stimulation near zero sensation level longer than those

respiration cycles associated with tonal stimulation levels that are not near zero sensation level?

3. What is the relationship between the threshold level determined by the respiratory technique and the threshold level determined by behavioral response when both utilize an ascending method of obtaining thresholds?

CHAPTER II

REVIEW OF THE LITERATURE

Literature on the Problem

A review of the literature reveals that considerable emphasis has recently been placed on the use of techniques for indirectly measuring auditory sensitivity. This emphasis on "objectivity" stems from the realization that in behavioral audiometry the overt response of the subject is under his voluntary control and may not be indicative of his actual ability to hear. When referring to the client being tested, Hirsh states, "We assume that he follows our instructions to do something when he hears a tone, but we have no observable way of knowing this except for the temporal relations between the occurrence of the stimulus and that of the response."[9] Thus, electrophysiologic audiometry came into existence.

Electrophysiologic audiometry differs from behavioral audiometry in that the response to acoustic stimulation manifests itself by some measurable change in the observed electrical properties of the person being tested, while in behavioral audiometry the response is some overt bodily reaction. Goldstein comments, "An electrophysiologic response is some relatively abrupt change in the ongoing activity associated with

[9] Ira J. Hirsh, The Measurement of Hearing (New York, 1952), p. 255.

an acoustic stimulus."[10] He further adds that the listener has no control over this type of a response.

To date, various kinds of electrophysiologic responses in audiology have been explored, most of which employ some measure either of autonomic function or of the ongoing electrical activity of the central nervous system. As has been stated, the two most widely used techniques of indirectly measuring auditory sensitivity employ electrodermal responses (EDR) and electroencephalic responses (EER). Although these methods have contributed significantly to the field, they are not without restrictions such as those which have already been mentioned.

A more recent area of interest in indirect audiology utilizes the effects of tonal stimulation upon the normal pattern of respiration. In contrast to electrodermal and electroencephalic audiometry, literature dealing specifically with this technique is not plentious. Goldstein comments that, "Respiratory changes, a prominent feature in regular polygraph work, have not been adapted in a consistent way for audiometry."[11] Also Rousey, et. al. state that, "Little experimentation relating changes in respiration to auditory stimuli has been reported."[12]

[10]Goldstein, p. 167.

[11]Goldstein, p. 168.

[12]Clyde Rousey, Charles Snyder and Carol Rousey, "Changes in Respiration as a Function of Auditory Stimuli," The Journal of Auditory Research, IV (April 1964) 107.

However, the literature reveals that increased interest is being shown in this area.

Observations and assumptions have been made to support the possibility of experimentation in this area of audiology. When referring to attention, Woodworth contended that there is a clear correlation between momentary attention and partial or complete inhibition of breathing. "Sudden stimuli will make the subject "catch his breath." If he is listening to a faint sound, arrested breathing eliminates disturbing respiratory sounds."[13] Poole made the observation that in free-field testing situations, mothers holding a child on their laps commented that, "the child "held his breath" during the presentation of low intensity sound stimuli."[14] After making personal laboratory observations, Rousey speculated that tones near a person's threshold of hearing would be accompanied by a tendency toward the slowing of breathing.[15]

As a test of this hypothesis, Rousey et. al. set about to observe the changes which occur in the respiratory process of ten subjects, ages fourteen to seventeen years, while they listened to a series of pure tones. To the writer's knowledge, this was the first study of this kind to be conducted, although

[13]Robert S. Woodworth, Experimental Psychology (New York, 1938), p. 260.

[14]Poole, p. 6.

[15]Rousey, p. 107.

Rosenau had earlier studied the effects of auditory stimuli on respiration rate in a group of children during sleep periods, and found consistent responses to pure tone stimuli.[16] In this pilot study Rousey et. al. reported that five of their ten subjects showed the greatest slowing in breathing during presentations of pure tones within plus or minus ten decibels of thresholds obtained by the conventional method. Two of the subjects were within plus or minus twenty decibels of the threshold which was used as the criterion, while the remaining subjects showed rather wide deviations. In summary, the authors state, "The results did suggest that there was such a phenomenon as a differential respiratory response (consisting of slowing of breathing) which occurs to pure tones presented at threshold level."[17]

Poole, pursuing this same hypothesis, tested thirty-six college students and reported findings that support Rousey's previous experimental and clinical observations.[18] He found that a highly significant difference in the length of the respiratory cycles occurred when tone-on values were compared with tone-off values over all levels of intensity. His findings also indicated that slowing of the respiration cycle is greater for low intensity tonal stimulation than for tonal stimulation

[16]H. Rosenau, "Sleep Hearing Test: A Method of Testing Hearing In Infants," Z. Laryng. Rhinol. Otol., XXXXI (1962), 194-208.

[17]Rousey et. al., p. 114.

[18]Poole, pp. 35-36.

of high intensity. In reference to this finding, Poole suggests that this would seem to imply that an ascending method of threshold searching would be preferred in the clinical application of this respiratory technique.[19] Further analysis of his data revealed that respiration thresholds agree well with voluntary thresholds determined by the conventional method; and that there is good agreement between test-retest respiration thresholds.

In an attempt to make certain broader generalizations, Teel, Aspinall, and Winston conducted research employing this respiratory technique with a population whose hearing was not within the range of normalcy. Their subjects were all enrolled at the Kansas School for the Deaf at Olathe, Kansas. The subjects in Teel's investigation were thirty-four children from age seven to eleven;[20] Aspinall's thirty subjects were in the twelve to sixteen year-old age group;[21] while Winston's thirty subjects ranged in age from seventeen to twenty-one years.[22] With the exception of the differences in the ages of their subjects, these three researchers basically investigated

[19]Poole, p. 36.

[20]Jerry Teel, "Respiratory Audiometric Thresholds for Children ages Seven to Eleven," Unpublished Master's thesis, University of Kansas, Lawrence, 1966, p. 12.

[21]Aspinall, p. 12.

[22]Winston, p. 10.

the same question. Their primary purpose was to determine whether auditory thresholds could be predicted by a respiratory method. When comparing respiratory thresholds with thresholds obtained by conventional methods, values within plus or minus 15 decibels of each other were considered as being in agreement. This is comparable to the acceptable deviation of earlier research on indirect audiometry utilizing EDR and EEG responses. Teel found a ninety-two per cent agreement between the two methods. Aspinall reported that the respiratory test was effective in predicting threshold to criterion in ninety-one per cent of the thresholds, while Winston found one hundred per cent agreement between these two methods of obtaining thresholds.

Literature on the Method. For the purpose of clarification, mention should be made of the varying procedures and methods used in the respiratory studies which have been cited, for as Goldstein contends, audiometry is a procedure, not a response. "In order for audiometry to be fully objective the procedures of the tester, as well as the responses of the patient, must be objective."[23]

Rosenau observed the effects of auditory stimuli on the respiration cycle of a group of children during sleep periods. Their respiration cycles were recorded by means of a belt-pnuemograph connected to a drum-kymograph. The stimulus, presented by a loudspeaker above the child's head, was given

[23]Goldstein, p. 178.

immediately prior to inspiration. A response to this stimulus was recognized by an alteration in the inspiratory pattern, by what was referred to as "step-forming," which gives either a step ladder or plateau appearance to the respiratory cycle.

Rousey and Poole both used subjects whose hearing was within the range of normalcy as measured by the standard clinical procedure suggested by Carhart and Jerger. This voluntary pure-tone threshold was obtained prior to the respiratory test and was later used as a basis for comparison. As has been mentioned, Rousey's sample consisted of ten subjects, while Poole used thirty-six.

Both Rousey and Poole utilized a mercury-in-rubber strain gauge attached to a recorder, which registered the subject's respiration cycles.

In determining the effects of tonal stimulation upon respiration, both studies presented auditory stimuli at one frequency only. Rousey administered tones at 1000 cps., while Poole used the test frequency of 2000 cps. To each subject Rousey presented, in random order, a total of 275 possible stimuli, 25 of which were simulated presentations, and 250 of which were tonal presentations ranging in 5 decibel steps from 100 decibels through -20 decibels. In contrast, Poole used sixty stimulus events, thirty of which were simulated presentations and thirty of which were actual tonal presentations ranging from 50 decibels through -15. These were also presented in random order and immediately prior to inspiration.

In both of these respiration studies the tone duration was controlled manually, and thus the stimuli varied. Rousey attempted to have each stimuli last one second, while Poole administered a temporal duration of approximately three seconds.

In their examination of the respiratory traces on the graph paper, both Rousey and Poole used the length of the respiration cycle as the basis for determining differences. Poole stated that the criteria used for selecting the cycle to be measured was to start the initial point of measurement at the nearest peak or valley to the onset of the tone, using the following peak or valley as the final point of measurement. Thus, a straight line measurement, utilizing the millimeter scale of a plastic ruler, was taken of each complete breathing cycle that was to be measured. Poole used the median score of the series of presentations at a stimulus level as a measure of the length of the respiratory cycle.

Rousey used two methods for the computation of the changes in respiration. Method I employed a difference score and Method II a percent of change score. In both methods a median score was obtained, with the highest median representing the greatest slowing of breathing and thus considered to be threshold. The authors state that Method I seems to allow estimation of thresholds which are most similar to thresholds obtained by the standard clinical procedure. These were the results which were previously cited in the present paper.

In their study of subjects with a sensorineural hearing loss, Teel, Aspinall, and Winston also used a mercury-in-rubber strain gauge connected to a recording instrument. However, they used the test frequencies of 250 and 500 cps. These frequencies were selected because the majority of the subjects had no measurable hearing beyond 500 cps. The tonal stimuli were presented randomly in five decibel steps, ranging from 0 to 80 decibels at 250 cps. and from 0 to 100 decibels at 500 cps. Each five decibel step was presented five times, and in addition, five simulated presentations were included for each frequency. Each subject was tested in both ears, one ear being stimulated by the 250 cps. tone and the other ear by the 500 cps. tone. The frequency to be presented to each ear was alternated with each subject.

The ascending technique described by Carhart and Jerger was employed by the above investigators to determine the pure-tone thresholds of each subject. Each ear of the subject was tested by conventional audiometry after the respiration test had been completed.

In respect to tone duration, the presentation of the stimuli was controlled manually by the individual researcher. Teel made no mention of the tone duration, but Aspinall reported the duration of the stimuli as approximately one second, while Winston states a temporal duration of approximately two seconds.

The measurement of the respiration cycles was obtained in the same manner by Teel, Aspinall and Winston. The criterion used for selecting the cycle to be measured was to start the initial point of measurement at the nearest peak or valley to the onset of the tone. A 'notch' occurring in the following expiration or inspiration phase of the respiratory cycle was taken as the final point of measurement. Thus, these two points allowed a straight line measurement to be taken of the duration of each breathing cycle to be measured. The five measurements were summed for each of the attenuator levels. Since the largest sum represented the greatest lengthening of the respiratory cycle, this figure was also taken to represent the subject's auditory threshold as determined by the respiratory method.

It has already been mentioned that Rousey, Poole, Teel, Aspinall, and Winston all used a mercury-in-rubber resistance strain gauge for measuring respiratory movements. Ackner reports this to be a simple and yet effective method of recording respiration. He explains it as follows:

> In this method the linear changes of a very small-bore rubber tube are derived from the changes in electrical resistance. Mercury-filled tubes form the variable resistance in two limbs of a conventional bridge circuit, and changes in balance are amplified and suitably recorded.[24]

This mercury-in-rubber strain gauge was attached to the carrier amplifier of a recorder and registered the subject's respiration cycle and variations in rate of the subject's respiratory cycle.

Although this mercury-in-rubber strain gauge has proven to be an effective means of measuring respiratory movements, other

[24]Brian Ackner, "A Simple Method of Recording Respiration," Journal of Psychosomatic Research, I (1956), 144.

types of transducers may have certain advantages. The small-bore rubber tubing, recommended by Ackner, is not available in the United States. In the pilot work by the present investigator considerable difficulty was experienced with the problem of filling the rubber tubing with mercury while making sure no foreign material or air bubble was introduced into the tubing. It should also be noted that the mercury-in-rubber strain gauge calls attention to itself, for it is necessary to fasten it completely around the subject's body. This placement may direct attention to respiration and disrupt the normal periodicity of the subject's breathing.

CHAPTER III

PROCEDURE

Subjects

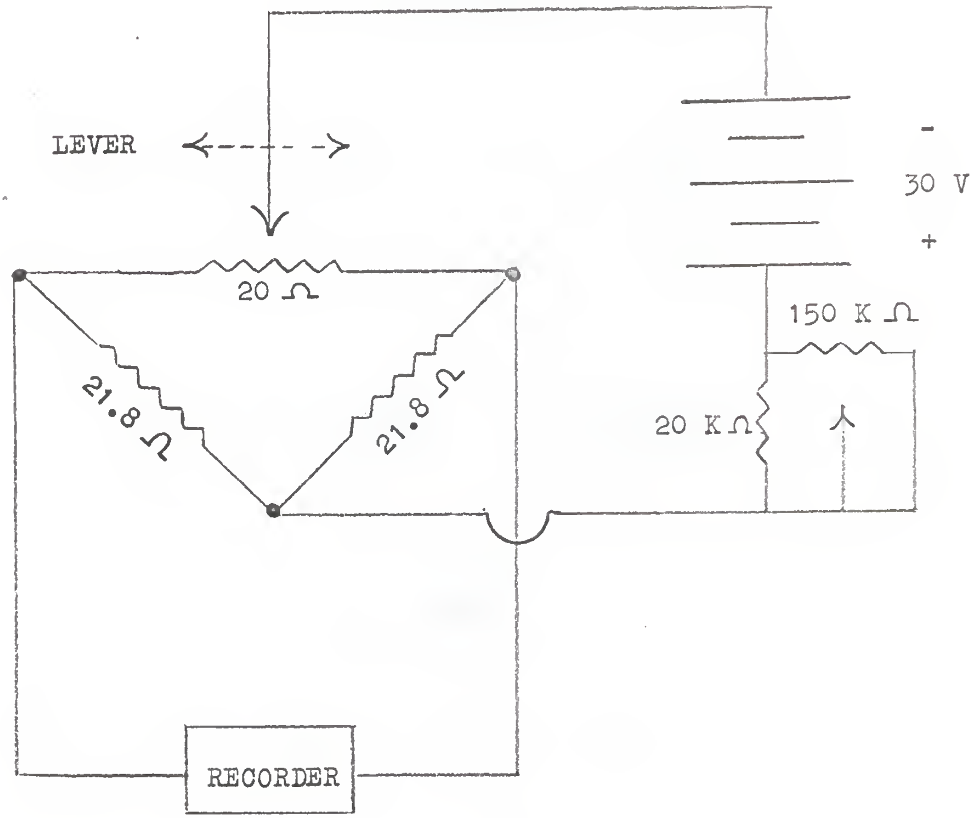
Thirty subjects were used for this study, the group consisting of males and females between the ages of 16 and 20 years whose hearing levels were between 10 dB and 55 dB (re: I.S.O. 1964 reference level for normal hearing) at 4000 cps. Thus, the hearing levels of the subjects ranged from clinically normal to moderate hearing loss and were somewhat representative of those encountered in daily clinical practice. Each subject was tested by standard audiometry using the ascending method for obtaining thresholds as suggested by Carhart and Jerger. Only one ear of each subject which met the above criteria was selected. Consequently, the results of thirty ears are presented.

Instrumentation and Test Chamber

The tone stimulus was generated by a Maico audiometer, Model MA-8 equipped with TDH-39 receivers mounted in David Clark P/N-2014 earcushions. This audiometer was factory calibrated to I.S.O. 1964 standards prior to the study.

A mechanical strain gauge transducer was devised which consisted of a bridge circuit employing as one leg a variable resistor, as illustrated in Figure 1. The output of this transducer was fed through a jack panel in the wall separating the test and control rooms. The output was then further directed

Figure 1. Strain gauge circuit.



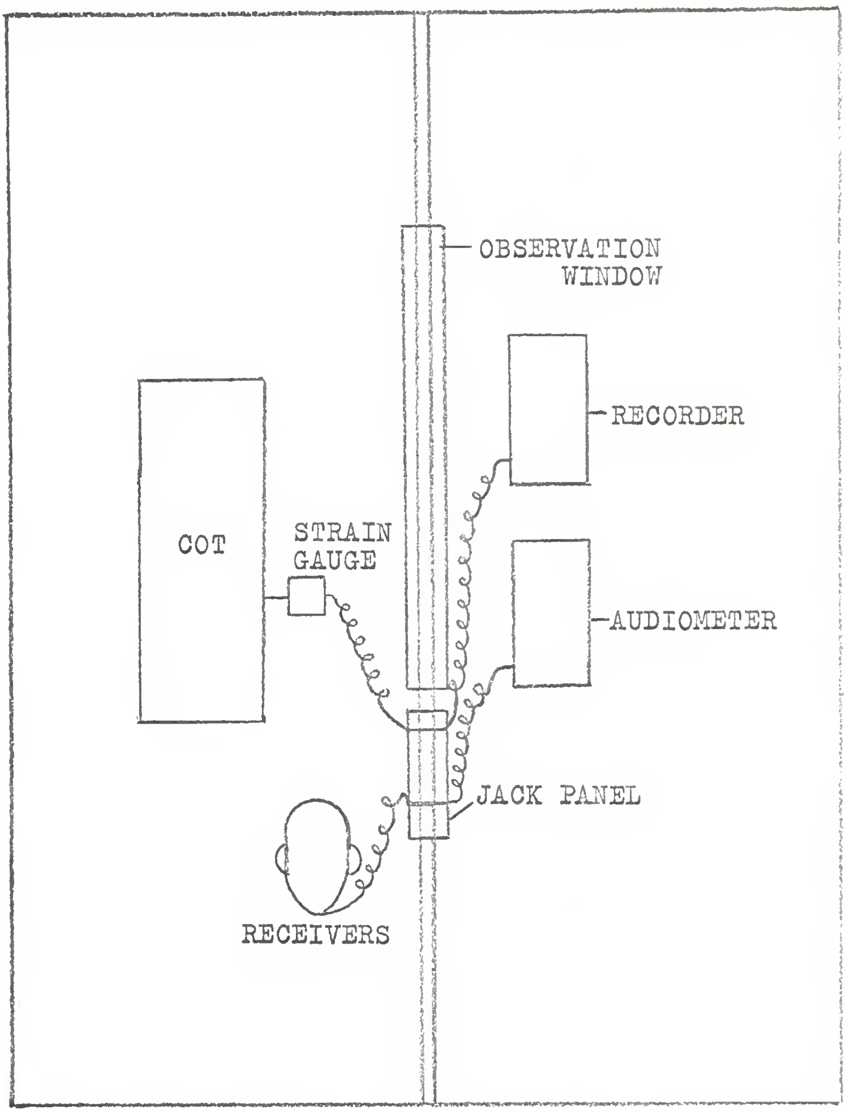
to a Nesco, Model JY-110, graphic level recorder. The entire bridge circuit was mounted on one side of an aluminum cot. A thread attached to the variable leg of the bridge could then be passed over the thorax of a subject lying on the cot and secured to the other side. Movements of the thorax thus effected changes in the variable leg of the bridge, which in turn effected movements in the writing pen of the recorder. Adjustment of the resistance to the power supply of the bridge permitted manipulation of the amplitude of the recorded cycles of respiration to levels suitable for analysis.

All tests were conducted in the same sound-treated room, in which the ambient noise levels were 44-54 dB SPL and 28-30 dB SPL on the C Scale and A Scale respectively. The examiner was situated in an adjacent room which contained the audiometer and the recorder. As shown in Figure 2, an observation window between the two rooms allowed the examiner to easily view the subject.

<u>Test Events</u>

Tones at the test frequency, 4000 cps., were presented at six different attenuator levels. The initial level was a preparatory tone and not a test event given 40 dB above the subject's threshold level. It was presented to each subject only once immediately prior to the presentation of the twenty-five test tones. This clearly audible tone was given to alert the subject and help him identify the stimulus he was to listen for at lower intensity levels. The remaining tones were given in ascending

Figure 2. Block diagram of respiratory audiometric instrumentation.



order in five decibel steps from ten decibels below his threshold of hearing to ten decibels above his threshold. This procedure was repeated five times, allowing each subject to receive a total of twenty-five test tone presentations.

The order of presentation of the test events was the same for all subjects. However, the attenuator levels presented differed depending upon the subject's threshold for hearing as determined by the standard testing procedure already mentioned. Excluding the preparatory tone, the attenuator levels presented were numbered Level I to Level V, corresponding with the subject's threshold of hearing as follows:

Test Level	Sensation Level	
Level I	-10 dB	(10 dB below subject's threshold)
Level II	-5 dB	(5 dB below subject's threshold)
Level III	0 dB	(subject's threshold)
Level IV	+5 dB	(5 dB above subject's threshold)
Level V	+10 dB	(10 dB above subject's threshold)

Administration of the Test

After the subject was brought into the test chamber and his name and age recorded, he was given the following instructions:

> "During this test you are to lie quietly on the cot with your eyes closed and listen carefully to the tones which you will hear from time to time. At first you are to say "yes" whenever you hear a tone, but later it will not be necessary for you to respond verbally."

The earphones were placed on the subject and he was asked to recline on the cot. The string attached to the strain gauge was secured over the subject at approximately the level of the xiphoid process. After thus situating the subject, the examiner obtained his pure-tone threshold by conventional audiometry. The subject responded by saying "yes" each time the tone was heard. This threshold was obtained five times, with the average of the response levels considered to be his threshold by this method of testing.

The subject was retained in the reclining position during the testing by conventional audiometry and as much longer as necessary until a regular breathing pattern had been established. He was then told that he should no longer respond verbally to the tones, but that he should still listen carefully. The graphic level recorder was then switched from "standby" to "record" and the paper drive motor switched on. The test events were then administered according to the order previously described. Tonal duration, controlled manually, was approximately two seconds. Tones were presented only during times of breathing regularity, and an attempt was made to present the tonal stimulus as nearly as possible to the beginning of inspiration. Before each stimulus was given, an attempt was made to have at least two respiratory cycles which showed no evidence of body movement or disturbance. Simultaneously with stimulus presentation, a mark was made on the recording paper to show the examiner exactly where the tone had been presented relative to the display of respiration. As previously indicated, each trial consisted of five tones ranging in five decibel steps from ten decibels below the subject's threshold to ten decibels above his threshold, the tones being presented in ascending order. This procedure was repeated five times for each subject.

Scoring of the Test

The length of each respiration cycle which occurred during a stimulus presentation was measured with a plastic ruler using the millimeter scale. The criterion used for selecting the cycle to be measured was to start the initial point of measurement at the nearest peak or valley to the onset of the tone. The proper cycle was easily selected since an identifying mark had been placed on the graph paper at the onset of the tone. The final point of measurement was the following peak or valley, depending upon the location of the onset of the tone. Thus, a complete breathing cycle was measured for each tone, from peak to peak or from valley to valley. The preparatory tone was not measured.

For each subject there were thus five breathing cycles measured for each of the five attenuator levels. The numerical values were summed for each level, and since the largest sum represented the greatest lengthening of the breathing cycle, this level was designated as the subject's auditory threshold as determined by the respiratory method.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this investigation was basically to determine whether or not respiration was altered by the perception of tonal stimulation when the stimuli were presented in an ascending order near zero sensation level. More specifically, the following questions were posed:

1. Do different levels of tonal stimulation have differential effects on the length of the respiration cycle when employing an ascending technique of tonal stimulation?

2. Are the respiration cycles which are associated with tonal stimulation near zero sensation level longer than those respiration cycles which are associated with tonal stimulation away from zero sensation level?

3. What is the relationship between the threshold level determined by the respiratory technique and the threshold level determined by the behavioral response when both utilize an ascending method of obtaining thresholds?

With reference to the first question, the Friedman Two-Way Analysis of Variance by Ranks was used to test the null hypothesis that different levels of tonal stimulation (± 10 dB, ± 5 dB, and 0 sensation level) have no differential effect on length of respiration cycles. The sum of the values of the five trials at each sensation level was used to compute the ranking. The obtained Ch Square value of 11.88 is significant beyond the

.05 level of confidence, indicating that different levels of tonal stimulation do have an effect on the length of the respiration cycle.

The Normal Approximation to the Binomial Test was employed to test the null hypothesis that there is no difference in the distribution of the longest respiration cycles associated with near zero sensation level stimuli and those associated with away from zero sensation level stimuli. Tonal presentations at plus and minus ten decibels were arbitrarily designated as tones away from zero sensation level, with the tonal presentations at sensation level and plus or minus five decibels being considered near zero sensation level. The mean score was used for each subject to determine the decibel level at which the greatest slowing in the breathing cycle occurred. In nine events the longest respiration cycle was associated with tonal stimuli away from zero sensation level; in twenty-one events the longest respiration cycle was associated with tonal stimuli near zero sensation level. The obtained z score of 2.07 was found to have an exact probability of .0192 and would support the rejection of the null hypothesis beyond the .02 level of confidence, and accept the inference that the association of the longest respiration cycle with tonal stimuli near zero sensation level could not have occurred by chance alone.

Further analysis of the data concerned the degree of agreement between pure-tone thresholds and respiratory thresholds.

The Spearman Rank Correlation Coefficient Test was used to test the null hypothesis that there is no significant relationship in the threshold level determined by the longest respiration cycle and the threshold level determined by behavioral response when both utilize an ascending method of obtaining thresholds. The results of this test yield a correlation of .91, significant beyond the .01 level of confidence, and form the basis for the rejection of the aforementioned null hypothesis. Consequently, inspection of the scores on this test strongly suggests that the two methods of obtaining auditory thresholds are comparable.

Discussion of Results

The results of this study confirm the findings obtained by previous investigators who have supported the hypothesis that upon tonal stimulation near threshold the respiration cycle is measurably lengthened. Although the reasons for the occurrence of this change in respiration rate are not fully understood, some speculation has been made. According to Rousey et. al., one theoretical model which may be used to explain the changes in respiration is the orienting reflex. They state:

> The orienting reflex may be thought of as variation in the sensory, motor, and integrative systems of the body in response to external change or stimulation. As such, the reflex occurs so long as each succeeding stimulus changes. The orienting reflex is extinguished when an identical stimulus is repeated.

However, it is felt that stimuli close to an individual's threshold of hearing are not capable of setting up a neuronal model necessary to extinguish the orienting response. The authors, therefore, go on to suggest that:

> Repeated sound stimulation above threshold resulted in extinguishing the orienting reflex (measured in this case by disturbance in respiration), whereas auditory stimulation close to threshold never resulted in the extinguishing of the orienting reflex because no neuronal model of the stimulus was present.[25]

Another explanation for this noticeable change in respiration when auditorily stimulated by tones near threshold would be Woodworth's contention that there is a correlation between momentary attention and partial or complete inhibition of breathing.[26] That is, in an attempt to reduce bodily noises and thus enhance hearing sensitivity, the subject may, either consciously or unconsciously, momentarily hold his breath. Furthermore, it has been suggested by Winston that this arrested breathing pattern may also be an attempt to reduce psychological noises interfering with the perception of auditory stimuli.[27]

As a means of further exploring this arrested breathing pattern associated with tones near threshold, in the present study the amplitude (or breadth) or each breathing cycle was

[25]Rousey, p. 112.

[26]Woodworth, p. 260.

[27]Winston, p. 24.

measured as well as the length. Although no statistical analysis was done on the data so gathered, it was observed by this investigator that the breathing was generally more shallow at threshold level.

The results of this study not only confirm the findings obtained by previous researchers interested in this area, but they also indicate that the clinical technique of presenting tonal stimuli in ascending order may be effectively utilized. Also, the use of the different strain gauge described previously facilitated the procedure and appeared to yield equally good results. Although the actual differences in the length of the respiration cycles were at times small, they were statistically significant. Thus, the results suggest that this method of obtaining auditory thresholds could well be adapted to clinical use.

However, to obtain sufficient clinical utility by this method for practical application, it would be necessary to improve upon the method of measuring the respiration cycles. The major concern here is that it is necessary to carefully measure the recorded respiration cycles. It is not possible to measure the length of each breathing cycle as the moving graph paper comes from the recorder. This must be done upon completion of the testing process, thus increasing the length of the evaluation period. The notch in the respiration wave form described by Aspinall, Teel, and Winston would perhaps allow determination of near threshold stimulation levels within a very short period of time following tonal stimulation, but unfortunately this notch was not observed to occur by the present investigator.

Another way of increasing the clinical utility of this respiratory technique may be through the placement of the client in a sitting position. Other methods of measuring auditory sensitivity require that the client be seated in a chair. The upright position when employing the respiratory technique would have the advantage of requiring less space in the typically limited confines of the test chamber. Whether or not this is feasible with the present instrumentation is not known, but would seem to be an area worthy of investigation.

The results of this study, as well as previous studies, confirm the value of the respiratory method as an objective means of auditory assessment. Furthermore, the advantages of this method over other indirect methods should be considered. With the respiratory technique there is no need for elaborate preparation of the subject. That is, electrode placement is not necessary, a conditioning process is not required, and sedation is not needed. Moreover, the respiratory technique is easy to administer and does not require elaborate or expensive instrumentation.

However, in order for this respiratory method of measuring hearing to become a useful clinical tool, additional areas of research should be pursued. Suggested areas for further research are:

1. Further improvement in the instrumentation, testing procedures, and scoring procedures to make this method an accurate and effective clinical tool.

2. Investigation of the effects of bone conduction and speech stimuli upon respiration.

3. Examination of the effectiveness of this method with subjects having a known functional hearing loss.

4. Exploration of the psychological and physiological bases for the reduction of breathing associated with tonal stimulation near threshold.

CHAPTER V

SUMMARY AND CONCLUSIONS

The need for "objectivity in audiometry has long been acknowledged by investigators interested in measuring auditory sensitivity. Recognition of this need has generated interest in the development of various indirect methods of measuring the auditory thresholds of those patients who cannot (e.g., the mentally retarded) or will not (e.g., malingerers) give adequate responses during behavioral audiometry. Accurate assessment of the auditory thresholds of these patients is needed for a variety of reasons, among which are differential diagnostic purposes, assessment for a hearing aid or for surgery, prediction of the proper educational approach for children, and vocational guidance.

It has been pointed out that the current indirect methods of assessing auditory sensitivity, electroencephalic audiometry and electrodermal audiometry, are not without drawbacks in all situations. Seeking to improve upon these techniques, investigators have been studying the effects of tonal stimulation on respiration. Reported findings of several studies in this area indicate that the breathing cycle is lengthened at the point where the threshold of hearing is reached and that this corresponds with the threshold of hearing obtained by conventional clinical procedure.

To further investigate this phenomenon, an endeavor was made in the present study to determine whether or not respiration was altered by the perception of tonal stimuli presented in an ascending order near zero sensation level. It was thus an attempt toward refinement of this respiratory technique utilizing a method more amenable to clinical procedures.

The subjects involved in this investigation were from sixteen to twenty years of age. At the test frequency, 4000 cps., each subject's threshold was determined by conventional audiometry and by the respiratory technique.

The findings of this study indicated first that different levels of tonal stimulation have differential effects on the length of the respiration cycles when tonal stimulation is presented in an ascending order. The Chi Square values obtained were significant beyond the .05 level. Secondly, treatment of the data revealed that the probability that the longest respiration cycles would be associated with tonal stimulation near zero sensation level by chance alone less than two percent of the time. Another area inspected was the relationship between the threshold level determined by the respiratory technique and the threshold level determined by conventional audiometry. Statistical treatment of the data indicated a correlation of .91, significant beyond the .01 level of confidence.

Thus, in spite of the basic methodological change of presenting auditory stimuli in an ascending order, the results of this investigation support the experimental and clinical observations of previous researchers (i.e., Rousey et. al., Poole, Aspinall, Teel, and Winston). The advantages of the respiratory technique over other types of objective audiometry have been stated. Although further refinement of instrumentation and methodology is still necessary, it is concluded that the respiratory technique for obtaining auditory thresholds has the potentiality of becoming an invaluable tool in the field of audiometry.

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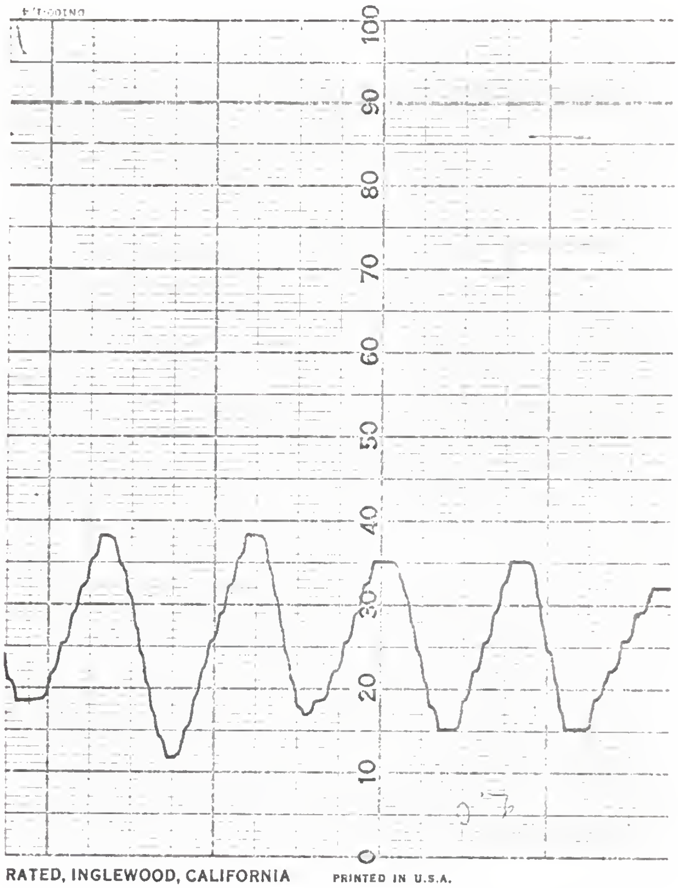
APPENDIXES

APPENDIX A

SAMPLE OF GRAPH PAPER
SHOWING RESPIRATORY TRACE

Figure 3. Sample of graph paper showing respiratory trace.



APPENDIX B

LENGTH OF RESPIRATION CYCLES

Table 1. Sum of the length in millimeters of the respiration cycles of the subjects by levels of tonal stimulation.

Subjects	-10	-5	0	+5	+10
1.	12.1	13.2	13.3	12.0	13.1
2.	11.3	11.2	12.4	11.9	11.1
3.	13.9	19.1	13.0	13.3	13.3
4.	10.6	10.0	9.4	10.3	11.0
5.	11.1	12.6	11.6	10.2	10.5
6.	10.1	11.3	11.6	10.3	11.9
7.	11.5	12.0	11.5	11.3	10.7
8.	12.0	11.1	10.4	10.4	10.3
9.	12.2	12.8	11.1	11.2	12.4
10.	18.0	16.6	20.1	16.3	16.7
11.	8.5	8.5	9.1	9.0	8.0
12.	14.6	14.2	13.7	14.4	14.8
13.	14.7	15.4	15.7	15.4	14.8
14.	10.2	9.4	9.9	9.4	10.9
15.	12.5	10.1	10.9	16.2	10.6
16.	9.5	9.1	10.0	9.8	9.3
17.	11.5	12.2	12.4	11.8	11.9
18.	8.8	8.9	10.0	8.9	9.4
19.	9.7	9.8	10.2	9.9	10.1
20.	14.4	12.7	15.5	13.8	14.0
21.	12.1	13.5	12.6	12.3	12.0
22.	14.7	13.9	14.8	13.3	14.3
23.	8.5	9.3	16.9	15.4	16.7
24.	13.2	10.7	11.0	10.4	10.4
25.	13.0	12.9	13.9	12.9	12.5
26.	11.1	11.0	11.3	11.2	10.4
27.	16.8	15.6	18.6	19.5	18.9
28.	13.7	11.7	12.7	11.1	12.0
29.	11.2	11.5	12.0	11.4	12.5
30.	11.2	10.6	10.3	10.1	10.4

APPENDIX C

DISTRIBUTION OF LONGEST RESPIRATION CYCLE BY STIMULUS LEVEL

Table 2. Distribution of the longest respiration cycle by stimulus level, using the mean score.

Subjects	± 5 dB or 0	± 10 dB
1.	X	
2.	X	
3.	X	
4.		X
5.	X	
6.		X
7.	X	
8.		X
9.	X	
10.	X	
11.	X	
12.		X
13.	X	
14.		X
15.	X	
16.	X	
17.	X	
18.	X	
19.	X	
20.	X	
21.	X	
22.	X	
23.	X	
24.		X
25.	X	
26.	X	
27.	X	
28.		X
29.		X
30.		X

APPENDIX D

THRESHOLD LEVELS BY THE TWO TECHNIQUES

Table 3. Threshold levels of subjects by respiratory and conventional audiometric techniques.

Subjects	Respiratory Threshold	Conventional Threshold
1.	40	40
2.	35	35
3.	50	55
4.	65	55
5.	10	15
6.	55	45
7.	15	20
8.	20	30
9.	10	15
10.	35	35
11.	50	50
12.	25	15
13.	30	30
14.	30	20
15.	25	20
16.	35	35
17.	15	15
18.	20	20
19.	45	45
20.	35	35
21.	15	20
22.	20	20
23.	45	45
24.	15	25
25.	20	20
26.	20	20
27.	30	25
28.	45	55
29.	60	50
30.	35	25

A STUDY OF THE RESPIRATORY TECHNIQUE FOR OBTAINING AUDITORY THRESHOLDS

by

ELAINE D. GIESCHEN

B.A., Midland Lutheran College, 1958

AN ABSTRACT OF A MASTER'S THESIS

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1967

The purpose of the present study was to determine whether or not respiration was altered by the perception of tonal stimuli presented in an ascending order near zero sensation level. It was thus an attempt toward refinement of this respiratory technique utilizing a method more amenable to clinical procedures.

In this study thirty subjects were used between the ages of 16 and 20 years whose hearing level was +10 dB or greater. At the test frequency, 4000 cps., each subject's threshold was determined by conventional audiometry, and then by the respiratory technique utilizing a mechanical strain gauge attached to a recorder. The subject, reclining on a cot in a sound-treated room, was presented in 5 dB steps, tonal stimuli in an ascending order from 10 dB below his threshold to 10 dB above his threshold. This procedure was repeated five times. Following the testing, the length of each respiration cycle associated with tonal stimulation was measured.

The findings of this study indicated first that different levels of tonal stimulation have differential effects on the length of the respiration cycle when tonal stimulation is presented in an ascending order. The Chi Square values obtained were significant beyond the .05 level. Secondly, treatment of the data revealed that the respiration cycles associated with tonal stimulation near zero sensation level were longer than those respiration cycles away from zero sensation level. Results of the Binomial Test indicated a probability of less than .02 chance occurrence of the latter result. Another area inspected was the relationship between the threshold level determined by the respiratory technique and the threshold level determined by conventional audiometry. Statistical treatment of the data indicated a correlation of .91, significant beyond the .01 level.

Thus, the results of this investigation support the experimental and clinical observations of previous researchers and confirm the value of the respiratory method as an objective means of auditory assessment. With this method are advantages over other objective techniques since complicated equipment and testing procedures are not required. Although further refinement of instrumentation and methodology is still necessary, it is concluded that the respiratory technique for obtaining auditory thresholds has the potentiality of becoming an invaluable tool in the field of objective audiometry.

Investigators interested in the measurement of auditory sensitivity agree that the development of a test which does not depend upon a conscious, cooperative response by the person being tested would have marked significance in the field of audiology. The need for such a test has generated interest in the development of various indirect methods of measuring the auditory thresholds of those clients who cannot (e.g., the mentally retarded) or will not (e.g., malingerers) give adequate responses during behaviroal audiometry. Accurate assessment of the auditory thresholds of these clients is needed for a variety of reasons, among which are differential diagnostic purposes, assessment for a hearing aid or for surgery, prediction of the proper educational approach for children, and vocational guidance.

The two most widely used objective methods of measuring auditory sensitivity at this time are electroencephalic and electrodermal audiometry, both of which are reported to have had relative success, but at the same time, certain limitations. Seeking to improve upon these techniques, investigators have recently been studying the effects of tonal stimulation on respiration. Reported findings of several studies in this area indicate that the breathing cycle is lengthened at the point where the threshold of hearing is reached and that this corresponds within limits to the threshold of hearing obtained by conventional clinical procedure. To date researchers have employed an experimental procedure in the presentation of the tonal stimuli, presenting in random order tones near or below the subject's threshold of hearing to tones approaching the threshold of discomfort.