AN INVESTIGATION OF INTRA- AND INTER-TEST RELATIONSHIPS BETWEEN SELECTED AUDITORY MEASURES ON NORMAL HEARING MENTALLY RETARDED ADULTS

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CHAPTER I

INTRODUCTION

A review of the literature on testing the hearing of mentally retarded adults (MRA) does not reveal sufficient research basis to verify the reliability of the measures. Considerable discrepancy exists in the reported incidence of hearing impairment among mentally retarded populations varying from eight to fifty-six per cent. Inter- and intra-test relationships need to be explored before the auditory and before adequate medical and non-medical habilitation can be provided for retarded adults with hearing impairment.

Statement of the Problem

The reported higher incidence of hearing impairment among mentally retarded groups may result from any number of possible influencing factors:

(1) Inability to comprehend directions or to respond adequately to unusual stimuli which may result in suprathreshold rather than threshold results.

(2) Lack of validity of the audiometric technique utilized.

(3) Higher incidence of central auditory pathologies and sensori-neural pathologies present in mentally retarded populations.

(4) Higher incidence of genetic and other congenital anomalies resulting in sensori-neural and/or conductive hearing impairments.

(5) Inadequate development of self-care health habits or skills producing a higher incidence of conductive impairments related to upper respiratory infections. (This factor may be offset by superior medical and otological attention many individuals receive in an institutional setting.)

A critical evaluation of the current methods which are used in the audiologic evaluation of mentally retarded adults would seem indicated, based upon some of the possible explanations for the differences between the indications of medically significant hearing problems in mentally retarded and non-mentally retardation populations (the generally accepted incidence in the general population is from four to five per cent).

A generally accepted premise in testing non-mentally retarded subjects is that the procedure used to measure auditory acuity (including stimulus, instructional procedure, method of response and rapport established with the subject) may in part determine the results obtained. (Hirsh, 1952) These variables inherent in the methodologies used would seem compounded when testing mentally retarded individuals.

Limitations of the Study

The study is limited to an evaluation of five audiometric methods used in testing the auditory function of a population parameter of adult mentally retarded patients at the Winfield State Hospital and Training Center (WSH&TC), Winfield, Kansas. Both inter- and intra-test results are reported and interpreted.

Purpose of the Study

This study has two main purposes: The first is to compare the intra-method reliability of various speech and pure-tone audiometric techniques when utilized with mentally retarded adults. The second is to compare the mean thresholds obtained using various speech and pure-tone audiometric techniques with mentally retarded adults. The specific questions posed are:

(1) When testing institutionalized mentally retarded adults, what are the intra-test (test-retest) reliabilities for: standard pure-tone (hand raising), Bekesy pure-tone stimuli (stapedius reflex relative threshold measurement), speech reception test (say the word), speech reception test (point to the picture)?

(2) Does a statistically significant difference exist between the auditory thresholds obtained from different trials of various pure-tone tests (standard, Bekesy, and Acoustic Impedance) and speech tests (say the word and point to the picture) when they are utilized with institutionalized mentally retarded adults?

(3) Do statistically significant differences exist between various pure-tone thresholds (standard pure-tone, Bekesy pure-tone, Acoustic Impedance measurement pure-tone) and the two speech reception thresholds obtained from institutionalized mentally retarded adults?

(4) Does a statistically significant difference exist between the auditory thresholds obtained from institutionalized mentally retarded adults when various pure-tone tests (standard, Bekesy, and Acoustic Impedance) and speech tests (say the word and point to the picture) are used?

The following terms are defined on a functional basis:

Acoustic Impedance Measurement - measurement of the relative change in resistance of the middle ear mechanism (used frequently in connection with changes of resistance resulting from the muscle contraction following elicitation of the acoustic reflex).

Bekesy Audiometry - an audiometric technique which utilizes subject control of stimulus intensity.

Conventional Pure-Tone Audiometry (Hand Raising) - an audiometric method in which the subject responds to the presentation of a pure-tone auditory stimulus by raising one hand.

Decibel (dB) - a unit of sound intensity measurement.

Hertz (±2) - a measurement of sound frequency in terms of cycles per second.

Speech Reception Test - an auditory test utilizing speech stimuli to determine a subject's hearing threshold for speech.

Spondee Words - two syllable words of equal syllabic stress frequently used in the administration of speech reception tests.

CHAPTER II

REVIEW OF THE LITERATURE

Technical Background

As early as 1951, Birch and Matthews reported an audiometric survey of a mentally retarded population. Mentally retarded children were reported to have a significantly higher incidence (55.5%) of hearing impairment than found in non-mentally retarded children. Since 1951, several additional studies which reported the incidence of hearing loss in MR populations (Bradley, Evans, and Worthington, 1955; Foale and Patterson, 1954; Gaines, 1961; Johnson and Farrell, 1954; Kodman, Powers, Phillip, and Weller, 1958; LaCrosse and Bidlake, 1964; Pantelakos, 1963; Rigrodski, Prunty, and Glovsky, 1961; Rittmanic, 1959; Schlanger, 1953; Schlanger, 1957; Schlanger, 1961; Schlanger and Christenson, 1964; Schlanger and Gottselben, 1956; Siegenthaler and Krzywicki, 1959; Webb, Kinde, Weber and Beedel, 1964; Lloyd and Melrose, 1966; Barber, 1967).

The result of these studies suggested an incidence of hearing loss (excluding "untestable" individuals) ranging from eight to forty-nine per cent. One or several variables may have interacted to yield such a variation in percentages. These variables may include:

(1) Reliability and/or validity of the audiometric testing techniques.

(2) Testing environment.

(3) Level of measured intelligence (MI or IQ).

(4) Criteria used for determining significant hearing loss.

(5) Chronological age of the subject.

The studies, however, tend to reinforce the conclusions of Birch and Matthews that the incidence of hearing loss is higher in mentally retarded individuals than in non-mentally retarded children. Most of the studies tend to deal with mentally retarded children with emphasis on a high number of "untestable" children in the populations reported.

Testing the Hearing of Mentally Retarded Children and Adults

Many of the reports cited previously relating to the hearing testing of mentally retarded populations were based on results using higher level retardates. The results were dependent upon the individual's ability to adequately respond to speech audiometry and/or pure tone audiometric techniques. Responses in speech audiometry required the individual to repeat the stimulus word or point to the object or picture representing the stimulus word. Pure-tone audiometric techniques required one from several possible responses including raising the hand, pointing to the ear in which the sound was heard, pushing a button which lighted lights, and various play activities (such as putting toys or blocks in a container or putting rings on a peg, etc.).

The introduction of an indirect relative auditory threshold measurement based upon a reflex level of function would seem to provide valuable audiometric test data for this MR population. Jepsen, 1953, 1955; Ewertsen, 1958; Klockhoff, 1961; Moller, 1958, 1960; Terkeldsen, 1959, 1960, 1961; and Zwislocki, 1961; have indicated the diagnostic

significance of the increased middle ear impedance resulting from the stimulation of the acoustic reflex. General agreement exists in studies which describe the acoustic reflex activity as being initiated by pure-tones at intensities of from 70 to 90dB above auditory threshold at the frequencies 500, 1000, and 2000 Hz.

Only a few reports have appeared in the literature (including unpublished theses and occasional papers) which have as their primary focus a study of the reliability and validity of various audiometric procedures used with retarded individuals (Aronson, Hind, and Irwin, 1957; Atkinson, 1960; Bradley, et al, 1955; Fulton, 1962; Gaines, 1961; Moss, Moss, and Tizard, 1961; Perry, 1956; Schlanger, 1961; Schlanger, 1962; Schlanger and Christensen, 1964; Webb, et al, 1964).

A review of the literature yielded several points of interest and of application to this study as follows: First, few of the students were concerned with the incidence of and procedures having direct utility in testing mentally retarded adults. Second, various audiometric procedures have yielded varying results in testing mentally retarded populations. Third, within the limits of the studies citing high variability in incidence, there was a general agreement that a higher incidence of hearing loss was present among mentally retarded individuals than was found among non-mentally retarded individuals. Fourth, a need exists for intra- and inter-test reliability data on mentally retarded individuals utilizing selected auditory test procedures. The procedure of obtaining a relative pure-tone auditory threshold through an involuntary response pattern provides additional data which may reflect a reliable threshold measure and correspond

to results obtained using previously reported techniques. The use of this procedure with mentally retarded populations has not been reported in the literature, although Lamb and Peterson (1967) suggest the possible application of this procedure in assessing hearing function of mentally retarded individuals.

A limited number of studies have been reported in the literature (including occasional papers and unpublished theses) which have been primarily focused on a comparison of correlating various audiometric procedures used in testing mentally retarded individuals (Atkinson, 1960; Barber, 1967; Bradley, et al, 1955; Fulton, 1962, 1966; Gaines, 1961; Irwin, Hind, and Aronson, 1957; Kodman, Fein, and Mixon, 1959; MacPherson, 1960; Moss, Moss, and Tizard, 1961; Perry, 1956; Schlanger, 1961, 1962; Schlanger and Christenson, 1964; Webb, et al, 1964; Wolfe and MacPherson, 1963).

Atkinson (1960, pp. 2, 15, 16) described a procedure in pure-tone audiometry which involved an avoidance response in the "eye puff test" in which the subject could avoid a puff of air in his eye by closing his eye as soon as he heard the tone. He also described a four-choice forced choice test which involved the subject pressing a switch by the light where the tone is heard in a one from four light pattern. Statistical significance of the relationships between the various tests was not reported. However, the data presented seemed to indicate that the eye puff, four-choice forced choice, and standard tests were in general agreement, while the reported Bekesy test results indicated poorer thresholds than the other three tests. (The Bekesy type audiometric test represents a technique in which the subject controls

auditory stimulus intensity.) Of the four measures, the standard hand raising technique was the most effective in applicability in testing most of the mentally retarded children.

Barber (1967) reports significantly reliable pure-tone test results utilizing test-retest methods in testing a population paramater of mentally retarded children from Dixon (Illinois) State School. Although the study is primarily concerned with placement of the bone conduction oscillator placement, the test-retest results indicated significant reliability in the administration of pure-tone audiometric tests with nine through thirteen-year-old mentally retarded boys. (Essentially the same instructions and hand raising responses are used in both conventional air conduction and bone conduction pure-tone testing.)

Bradley, et al, (1955) reported test-retest variation data; however, their findings cannot be considered significant as either inter- or intra-method comparisons because of the inter-method and intra-method cross contamination. This contamination resulted from the almost identical instructions used for both the ear-choice and standard method and from the systematic administration of the standard method first to the subjects. This test sequence provided the possibility of the standard procedure serving as a "practice session" for the ear-choice technique.

Perry (1956) compared the obtained threshold of 51 mentally retarded children ranging in age from eight to four years to fourteen to five years, with a mean CA of eleven to five years and ranging in IQ from thirty to seventy with a mean IQ of 51.7 using what she described as a conventional and a modified technique. The conventional

method was a standard hand raising technique. The modified technique used a hand raising response also, but it added the visual stimulation of a toy object as an attention holding device. Toy objects were paired with test signals of 500, 1000, 2000 and 4000 Hz, respectively. In summary, the difference between the two methods varied with frequency and the difference between the two methods failed to be significant at 4000 Hz. Perry did, however, demonstrate a difference between the two methods described, but did not present any inter-method correlational information.

Gaines (1961) described a comparison of a conventional audiometric with a technique utilizing an instrumental conditioning audiometric technique called the "Train test," which was used as both a screening test and as a threshold test. These tests were administered to 92 institutionalized retarded children between the ages of eight and eighteen and ranging in IQ from 50 to 80. This study found differences between the two methods investigated, but data concerning intra-test reliability were not presented.

The results of studies reported by Atkinson (1960), Perry (1956), along with the findings of Gaines (1961) tend to indicate that, in testing a given mentally retarded child, different audiometric techniques produce different thresholds.

Several of the test comparison studies (Irwin, et al, 1957; Kodman, et al, 1959; MacPherson, 1960; Moss, et al, 1961; Schlanger, 1961; Fulton, 1962; Webb, et al, 1964) used galvanic skin response (GSR) audiometry. The data presented in these studies indicated that GSR audiometry was no more effective than the more conventional audiometry with mentally retarded children.

Four of the studies cited (Barber, 1967; Bradley, et al, 1955; Fulton, 1962; and Schlanger, 1961) reported reliability data, but only one of the above cited studies (Fulton, 1962) presented clearly intra-method data. (Lloyd and Melrose, 1966, presented clear inter-method and intra-method data with institutionalized mentally retarded children.) McPherson (1960) presented some test-retest (pre-test and post-test) data, but he did not report test-retest reliability because his investigation was not designed as an intra-test reliability test. Lloyd and Melrose (1966) cite findings which indicate play techniques in pure-tone audiometry represented the most stable pure-tone method. Moderately high correlations were obtained between the four pure-tone and two speech audiometric techniques reported in testing mentally retarded children.

Summary of Literature

The investigations described above suggested that some audiometric techniques were frequently more successful than others in attempting to obtain audiometric data on mentally retarded children. It may be also noted that some techniques were successful with some retardates but not with others. The use of acoustic impedance measurements to obtain relative threshold measurements has been suggested as having application with retardates. However, no investigations utilizing this technique in combination with other techniques have been reported. In view of the differences in the results of the cited studies concerning the applicability of various methods of administering pure-tone and speech audiometric tests and also in view of the fact that most of the reported studies utilized mentally retarded children, it seemed

that there was a need to investigate the relationship between obtained thresholds of various pure-tone and speech techniques with mentally retarded adults. It was also felt that the inclusion of acoustic impedance measurements and Bekesy pure-tone measurements in the pure-tone audiometric techniques were justified to further investigate the appropriateness of these techniques with mentally retarded adults.

The review of the literature revealed several points of significance. First, no reported utilization of acoustic impedance measurements which yield relative pure-tone thresholds was reported in testing mentally retarded populations. Second, the investigations reported generally utilized populations made up of mentally retarded children rather than mentall retarded adults. Third, there were a limited number of investigations which reported inter- and intra-method reliability data on auditory measurement techniques used with retardates. Fourth, within the limits of the varying results reported in the incidence of hearing loss among mentally retarded children, there seems to be a higher incidence of hearing loss among mentally retarded children, there seems to be a higher incidence of hearing loss among mentally retarded children than among non-mentally retarded children. Fifth, there is a need for inter- and intra-audiometric test technique reliability data gathered from mentally retarded adults.

CHAPTER III

METHODS AND PROCEDURES

Instrumentation and Materials

All tests were administered in an acoustically treated auditory testing room (IAC Model 402) within the WSH&TC Speech and Hearing Department.

The pure-tone stimuli (500, 1000, and 2000 Hz) were produced and controlled by a Tracor Rudmose (Model ARJ 5) audiometer. All pure-tone stimuli were presented as pulse-tone stimuli at two pulses per second in both conventional and Bekesy pure-tone testing to provide for stimulus similarity (calibrated to ISO-1964 reference level). The attenuation rate of the Bekesy pure-tone test stimuli was 2.5dB per second. The speech stimuli were presented live voice by an experienced audiologist who habitually used the General American Dialect using an Electro-voice (Model 650) microphone and Grason-Stadler (Model 162) Speech audiometer. The stimulus words were presented with a peak response of all stimulus words within $\pm$ 1.5dB of the VU meter of the Grason-Stadler Speech Audiometer. The speech stimuli presented for the verbal response test consisted of four lists of familiar spondaic words used in the Collaborative Study of Cerebral Palsy, Mental Retardation, and other Neurological and Sensory Disorders of Infancy and Childhood Speech, Language and Hearing Examination (National Institutes

of Health, U. S. Public Health Service, [CCDP] which is administered to children at about age three years [CA]). (See Appendix I) The words were presented with an interval of at least five seconds between words. The speech stimuli presented for the picture pointing or non-verbal response consisted of four lists of familiar spondaic words. The pictures were presented in a spread of six pictures. The words and pictures were also from the CCDP Hearing Examination. The words were presented with an interval of at least seven seconds between words. Pictures were used which could be identified by most three-year-old non-mentally retarded children. A Madsen Acoustic Impedance Meter (Model ZO 61) was for the acoustic impedance measurements (calibrated to the ISO 1964 reference level).

The audiologist remained in the test room while giving the instructions to the subjects and while demonstrating the appropriate response. The testing was conducted with the audiologist in the adjacent room but with constant contact with the subject through the window and the two-way communication system which connects the rooms, for all tests except the acoustic impedance test. During the administration of this test, the audiologist was in the test room with the subject.

At the beginning of and during the period covered by the study the audiometers were periodically calibrated acoustically with an artificial ear (Bruel and Kjaer: artificial ear--Model 4152 with a DB 0162, 6cc coupler) and sound pressure level meter (Bruel and Kjaer: Sound Pressure Level Meter Model 2203 with a condenser microphone--Model 4132, 1-inch/pressure).

Selection of the Subjects

Forty mentally retarded adults (MRA) from WSH&TC between the chronological ages of 21 and 36 years with measured intelligence levels (MI) of -2 or -3 were to be selected for this investigation. (MI level -2 includes WAIS IQ's of from 55-69 while MI level -3 includes WAIS IQ's of 40-54.) The forty adults were selected from the MI levels -2 and -3 of the normal hearing adults.

For the purpose of this study the term "normal hearing adults", is defined as adults passing a bilateral 20dB (ISO 1964) air conduction screening test for the octave frequencies 250 Hz through 4000 Hz, having no otoscopically observable ear pathology, and having no history of a hearing impairment.

Administration of Tests

Auditory thresholds for conventional pure-tone and both speech procedures were obtained by using a combined descending and ascending technique utilized by Carhart, 1946; and by Jerger, Carhart, Tillman and Peterson, 1959, using 5dB steps. Since the Grason-Stadler speech audiometer (Model 162) has attenuators graduated in 2dB steps, the speech thresholds were determined by using alternating 4dB and 6dB steps; but for the purpose of this investigation, the speech thresholds will be considered as though they were determined by 5dB steps. For speech audiometry attenuator settings of 36, 30, 26, 20, 16, 10, 6, 9, -4, and -10dB were considered as 35, 30, 25, 20, 15, 10, 5, 0, -5, and -10dB, respectively.

Thresholds are defined as the lowest intensity at which the subject responded appropriately to 50 per cent of the stimuli presented. A minimum of three responses to six presentations was necessary to meet the established criterion. The Bekesy pure-tone method utilized a "method of adjustment" technique in obtaining auditory threshold measurement in which the subject adjusted the attenuator and stimulus intensity.

Each subject was seen for two testing sessions and was given each of the following threshold tests during each session in the order in which the methods are listed. Prior to each testing session, each adult received an otoscopic screening examination of both ears as a check against hearing fluctuations related to temporary conductive hearing impairments due to accumulated Cerumen or foreign objects in the external ear canal. Lloyd and Melrose (1966) indicated no significant difference between various sequences of test administration.

The order of test presentation was as follows:

A. Pure-tone air conduction, (conventional hand raising), pulse tone 2 pulses per second, frequencies tested 500, 1000, 2000 Hz.

B. Pure-tone air conductional Bekesy, pulse tone 2 pulses per second, 2.5dB per second attenuation rate frequencies tested 500, 1000, 2000 Hz.

C. Speech Reception Test (verbal response) say the word.

D. Speech Reception Test (non-verbal response) point to the picture.

E. Acoustic Impedance Measurement (relative threshold).

The administration of the second sequence of tests followed the first sequence at intervals of no less than two weeks or greater than four weeks.

The procedure involved in the administration of conventional pure-tone air conduction tests with the subjects were as follows:

1. Instructions were presented to the subject by the examiner in the test room. The instructions involved asking the subject to raise his hand when he heard the beeping sound. Verbal instructions were frequently reinforced by auditory cues and by gestural reinforcement.

2. Pure-tone stimuli were presented in primarily a descending order starting at a hearing level of approximately 30dB (re: 1964 ISO reference level).

3. A threshold criterion of the least intensity level at which three responses to a sequence of five stimulus tone presentations was obtained, established the level of hearing for any frequency.

4. The intensity of test tones was diminished in steps of ten and five dB until the subject responses met the criterion for auditory threshold at each test frequency (criterion: three positive responses to five stimulus tone presentations).

The procedures involved in the administration of the Bekesy pure-tone test to the subjects were as follows:

1. Instructions were presented to the subject by the examiner in the test room. The instructions involved asking the subject to press the button when he heard the beeping sound and take his thumb off the button as soon as the beeping sound went away. Verbal instructions were frequently followed by a demonstration and trial session.

No time limit was allotted. However, seldom more than three trials were utilized.

2. Pure-tone stimuli were presented at discrete frequency intervals of 500, 1000, and 2000 Hz, with intensity ranging from -10dB to 90dB (re: 1964 ISO reference level) until the button was depressed by the subject. The subject controlled stimulus intensity which increased tracings of stimulus intensity variations for each of the three test frequencies were automatically recorded graphically. These tracings were evaluated for threshold determination by averaging the mid-points of the excursions.

The procedures utilized in the administration of both the verbal response and the non-verbal response speech reception tests were the same with the exception of the mode of response. The general procedures were as follows:

1. The subject was requested to say the word he heard. The subject was informed that the words would become softer and softer and that he was to say the words as long as he thought he heard the word. The threshold criterion for hearing level (reference level: normal speech reception threshold) was the least intensity level at which three of five words were repeated correctly.

2. The subject was requested to point to the picture on the page of six pictures when he heard the name for the picture and to turn the page as requested. The threshold criterion for hearing level was the lowest intensity level at which three of five of the names of pictures were correctly identified.

The procedures in the administration of the acoustic impedance meter test to the subjects were as follows:

1. The subject was informed he would hear some sounds in one ear and that he was only to listen to the sounds.

2. The earphone through which the stimulus tone was presented was placed on the ear under test while the acoustic probe was inserted in the Contra-lateral ear canal.

3. The seal of the cavity produced by the insertion of the probe into the outter ear canal was tested by air pressure and a stable vacuum/pressure gauge reading.

4. The meter was then adjusted for maximum sensitivity and for a null reading.

5. The pure-tone stimuli were presented to the ear under test in one to two second duration presentations. The criterion for relative acoustic impedance threshold was the least intensity level which produced a meter deflection of 20 points or more on the meter scale from the null position.

All tests were conducted following adequate orientation and sufficient informal conversation to establish rapport with the subject, without varying from a standard presentation of instructions to each subject.

Treatment of Data

The hearing sensitivity level thresholds of a subject for each trial obtained through the use of each procedure were recorded on an individual data sheet as found in Appendix I. The data for subjects were subsequently subjected to analyses of variance and correlational treatments. Most of the statistical analyses were done on a Monroe Epic (Model 2000) Calculator.

The null hypothesis may be stated as follows: "No significant difference exists between the pre-test nor post-test obtained auditory thresholds and no significant difference exists between the auditory thresholds obtained by the various audiometric procedures." ($H_0 : \mu_1 = \mu_2$) The hypothesis will be tested at the .01 level of confidence.

The alternate hypothesis may be stated as follows: "A significant difference exists between the pre-test and post-test obtained auditory thresholds and no significant difference exists between the auditory thresholds obtained by the various audiometric procedures." ($H_1 : \mu_1 \neq \mu_2$)

CHAPTER IV

RESULTS

The study was developed to compare first intra-method reliability of various speech and pure-tone audiometric techniques and secondly, mean thresholds obtained using two speech and pure-tone audiometric techniques. This chapter is divided into two sections, first section considering pure-tone and speech test, intra-test reliability and the second section considering inter-test relationships.

Intra-method Considerations

The following two questions were cited relating to intra-method or test-retest comparisons:

(1) When testing institutionalized mentally retarded adults, what are the intra-test (test-retest) reliabilities for: standard pure-tone (hand raising), Bekesy pure-tone, Acoustic Impedance Measurement in response to pure-tone stimuli (stapedius reflex relative threshold measurement), speech reception test (say the word), and speech reception test (point to the picture)?

(2) Does a statistically significant difference exist between the auditory thresholds obtained from different trials of various pure-tone tests (standard, Bekesy, and Acoustic Impedance) and speech tests (say the word and point to the picture) when they are utilized with institutionalized mentally retarded adults?

Three frequencies were tested in each of the three pure-tone test sequences (500, 1000, and 2000 Hz) and a pure-tone average (PTA) was obtained from the three frequencies tested for each trial. Four measures were obtained for each pure-tone method during each trial. One speech threshold measure was obtained from the 40 subjects for each of the two speech methods for each of the two trials. (See Appendix III)

Table I presents the test-retest Pearson product-Moment coefficient reliabilities of each of the pure-tone techniques for each of the three frequencies tested. Table I also presents the test-retest reliabilities for the two speech techniques.

Inspection of the reliability coefficients in Table I suggests the highest test-retest reliability (.782) was calculated for Method 1, at the 1000 Hz frequency. The lowest reliability (.634) was calculated for the Method 4a. The means and standard deviations for both trials are presented in Table II.

An examination of the means and standard deviations for the three frequency averages Hz of the pure-tone method and the speech measures yields the following observations:

(1) The test-retest means fall within a $\pm$ 2.5dB range which is within the generally accepted test-retest range in clinical andrology.

(2) The standard deviations for each of the test distributions for Trials I and II fall within a $\pm$ 7.25dB range.

Table III presents the critical difference between the two trials for the various pure-tone audiometric procedures at each frequency. The difference in dB between trials of these measures, along with the

TABLE I

TEST-RETEST RELIABILITIES (TRIAL I VS TRIAL II)

(N=40)

Decibel Level

		500 Hz	1000 Hz	2000 Hz	SRT
1.	Conventional Pure-Tone Hand Raising	.7531	.7817	.7409	
2.	Pure-Tone Bekesy	.7622	.7249	.7714	
3.	Pure-Tone Impedance Meter	.7511	.6947	.7080	
4a.	Speech - Say the Word				.759
4b.	Speech - Point to the Picture				.634

To be significantly different from a zero correlation at the .01 level of confidence, the r must be larger than .403.

critical differences in dB required for statistical significance ($p = .01$) may be noted in Table III.

It may be observed that the pure-tone measures were generally higher (poorer) on the first trial than the second trial with the exception of the impedance meter (3) measure. The speech method, say the word, was slightly higher (poorer) on the first trial than on the second trial while the point to the picture (4b) method was slightly higher (poorer) on the second trial.

A three-way analysis of variance was performed with variable 1, frequency; variable 2, audiometric method; and variable 3, trials. The summaries of these analyses are presented in Table IV.

TABLE II

MEANS AND STANDARD DEVIATIONS FOR PURE-TONE TECHNIQUES AVERAGE Hz AND SPEECH TECHNIQUES 4a AND 4b

		Trial I		Trial II	
		M	σ	M	σ
1.	Conventional Pure-Tone Hand Raising	1.358	5.254	.500	5.063
2.	Pure-Tone Bekesy	2.345	6.568	2.205	7.137
3.	Pure-Tone Impedance Meter	6.248	6.247	6.872	6.744
4a.	Speech - Say the Word	-1.875	6.198	-2.000	5.967
4b.	Speech - Point to the Picture	-4.925	5.155	-3.550	5.148

The only significant f-tests are for frequency (Hz). The main effects may be described as follows: 1) That the overall trend in the three frequencies differs from chance. 2) That the overall trend of the differences between the three audiometric methods differ from chance. It may be further noted that no significant difference exists between trials. No significant 2 or 3 way interactions exist.

The means obtained for each frequency (Hz) by each of the three pure-tone procedures on Trial I and Trial II are included in Table V. An inspection of Table V indicates quite clearly that no significant difference exists between method and trials on pure-tone Methods 1, 2, or 3 or Trials I or II at any frequency.

In summary, Method 1, the conventional pure-tone hand raising, of the five methods used, seems to be the most constantly reliable measure

TABLE III

TABLE OF CRITICAL DIFFERENCES BETWEEN TRIALS FOR THE VARIOUS PURE-TONE AUDIOMETRIC PROCEDURES

Trial I 500 Hz	Trial I 1000 Hz	Trial I 2000 Hz
1-2 = 2.125	1-2 = .750	1-2 = .875
1-3 = 5.250*	1-3 = 4.000*	1-3 = 6.250*
2-3 = 3.125*	2-3 = 3.250*	2-3 = 5.375*
Trial II 500 Hz	**Trial II 1000 Hz**	**Trial II 2000 Hz**
1-2 = 1.500	1-2 = 1.000	1-2 = 2.250
1-3 = 5.625*	1-3 = 6.375*	1-3 = 6.375*
2-3 = 4.500*	2-3 = 5.375*	2-3 = 4.125*

*$p \leq .01$ (required value 3.02)

of the auditory sensitivity level of a selected group of institutionalized mentally retarded adults. The Speech Method 4b, point to the picture, seems to be the least reliability of the five methods. No significant value was found to exist between Trials I and II for any of the five audiometric methods used in testing institutionalized mentally retarded adult patients.

Inter-Method Considerations

The following two questions were posed relative to inter-method analyses:

(1) Do statistically significant differences exist between various pure-tone thresholds (standard pure-tone, Bekesy pure-tone, Acoustic

TABLE IV

SUMMARY OF THE THREE WAY ANALYSIS OF VARIANCE FOR THE THREE PURE-TONE PROCEDURES, THREE FREQUENCIES AND TWO TRIALS

Source	SS	df	MS	F
Frequency H_z (H)	1,150.20	2	575.10	11.19*
Audiometric Procedure (A)	4,240.80	2	2,120.40	41.24*
Trial (T)	.04	1	.04	.00
H x A	41.50	4	10.38	.20
H x T	33.90	2	16.95	.33
A x T	37.00	2	18.50	.36
H x A x T	73.20	4	18.30	.36
Within	36,090.60	702	51.41	
Total	41,667.20	719		

*$p \leq .01$ (required value 4.005)

Impedance Measurement pure-tone) and the two speech reception thresholds obtained from institutionalized mentally retarded adults?

(2) Does a statistically significant difference exist between the auditory thresholds obtained from institutionalized mentally retarded adults when various pure-tone tests (standard, Bekesy, and Acoustic Impedance) and speech tests (say the word and point to the picture) are used?

An examination of Table III suggests that Method 3, pure-tone acoustic impedance, is consistently different from the other two pure-tone methods. Examination of Table II suggests that hearing sensitivity levels obtained by the two speech procedures, 4a, say the word,

TABLE V

MEANS AND STANDARD DEVIATIONS FOR ORIGINAL DATA MATRIX

Trial I

	500 Hz		1000 Hz		2000 Hz		Average	
	M	σ	M	σ	M	σ	M	σ
1. Conventional Pure-Tone Hand Raising	2.625	6.421	1.000	6.633	-0.375	6.744	1.083	6.714
2. Pure-Tone Bekesy	4.750	6.704	1.750	8.555	0.500	7.399	2.333	7.798
3. Pure-Tone Impedance Meter	7.875	8.207	5.000	6.021	5.875	7.149	6.250	7.282
Average of the Three Methods —	5.083	7.471	2.580	7.359	2.000	7.621	3.222	7.603

Trial II

	500 Hz		1000 Hz		2000 Hz		Average	
	M	σ	M	σ	M	σ	M	σ
1. Conventional Pure-Tone Hand Raising	2.250	6.016	.750	5.761	1.125	5.418	.625	5.401
2. Pure-Tone Bekesy	3.750	7.644	1.750	7.790	1.125	7.785	2.208	7.821
3. Pure-Tone Impedance Meter	8.250	7.700	7.125	7.322	5.250	7.241	6.875	7.529
Average of the Three Methods —	4.750	7.606	3.208	7.550	1.750	7.378	3.229	7.607

and 4b, point to the picture, yielded consistently lower (better) threshold measures than the pure-tone methods.

In examining the summary of the three-way analysis of variance in Table IV, two of the main effects relating to the inter-method

TABLE VI

SUMMARY OF THE ANALYSIS OF VARIANCE PERFORMED FOR COMBINATIONS OF EACH PURE-TONE AND SPEECH THRESHOLD MEASURES FOR TWO TRIALS

Source	df	SS	MS	F
Method 1, Conventional Pure-Tone Hand Raising and Method 4a, Speech – Say the Word				
Audio Test (A)	1	328.62	328.62	10.07*
Audio Trial (T)	1	9.66	9.66	.30
Audio A x T	1	5.36	5.36	.16
Within (error)	156	5,089.71	32.63	
TOTAL	159	5,433.35		
Method 1, Conventional Pure-Tone Hand Raising and Method 4b, Speech – Point to the Picture				
Audio Test (A)	1	1,067.6056	1,067.6056	39.1689*
Audio Trial (T)	1	2.6781	2.6781	.0982
Audio A x T	1	49.8405	49.8405	1.8285
Within (error)	156	4,252.0128	27.2564	
TOTAL	159	5,372.1370		
Method 2, Pure-Tone Bekesy and Method 4a, Speech – Say the Word				
Audio Test (A)	1	709.8063	709.8063	16.4698*
Audio Trial (T)	1	0.7023	0.7023	.0162
Audio A x T	1	.0022	.0022	.0000
Within (error)	156	6,723.6530	43.0972	
TOTAL	159	7,434.1638		
Method 2, Pure-Tone Bekesy and Method 4b, Point to the Picture				
Audio Test (A)	1	1,696.5063	1,696.5063	44.9639*
Audio Trial (T)	1	15.2523	15.2523	0.4042
Audio A x T	1	22.9522	22.9522	0.6083
Within (error)	156	5,885.9530	37.7304	
TOTAL	159	7,620.6638		

*$p \leq .01$

TABLE VI (Continued)

Source	df	SS	MS	F
Method 3, Pure-Tone Impedance Meter and Method 4a, Speech - Say the Word				
Audio Test (A)	1	2,888.3030	2,888.3030	71.0571*
Audio Trial (T)	1	2.5000	2.5000	0.0615
Audio A x T	1	5.6250	5.6250	
Within (error)	156	6,341.0345		
TOTAL	159	9,237.4598		
Method 3, Pure-Tone Impedance Meter and Method 4b, Speech - Point to the Picture				
Audio Test (A)	1	4,663.4403	4,663.4403	71.2366*
Audio Trial (T)	1	40.0000	40.0000	0.6110
Audio A x T	1	5.6250	5.6250	0.0859
Within (error)	156	10,212.3998		
TOTAL	159	14,921.4651		
Method 4a, Speech - Say the Word and Method 4b, Speech - Point to the Picture				
Audio Test (A)	1	211.6000	211.6000	6.4654
Audio Trial (T)	1	15.6250	15.6250	0.4774
Audio A x T	1	22.5000	22.5000	0.6874
Within (error)	156	5,105.55	32.7278	
TOTAL	159	5,332.7750		

*$p \leq .01$

analysis, the first indication suggests that the overall trend in the three frequencies differs from chance. The second effect suggests that the overall trend of the difference between the three audiometric methods differs from chance. No significant 2 or 3 way interactions are noted when all combinations of differences between means for methods for the three frequency levels and the two trials are considered.

The trend noted in Table VI suggests that the pure-tone acoustic impedance Method 3 is consistently different from the other two pure-tone and the two speech methods. It may also be noted that no significant difference exists between the two speech methods, say the word, 4a, and point to the picture, 4b. The two speech methods are observed to differ consistently from the pure-tone methods.

In summary, it may be noted that these findings are consistent with the findings of Schlanger (1961) who found that Speech Reception Threshold test results were better (lower) than Pure-Tone averages. These findings are not consistent with the findings of Lloyd and Melrose (1966). The observed findings, that no significant difference exists between the two speech reception test methods, do not agree with the findings of Lloyd and Melrose (1966), who reported a significant difference between the two speech methods, but do agree with the findings of Lloyd and Ried (1967) who reported no significant difference between the two speech procedures with mentally retarded children.

CHAPTER V

INTERPRETATION OF RESULTS

Summary

This investigation evaluated the intra-test and intra-test relationship of three pure-tone and two speech audiometry techniques employed in testing the hearing sensitivity levels of forty normal hearing, mentally retarded adults. Forty mentally retarded adults (MRA) from WSH&TC between the chronological ages of 21 and 36 years with measured intelligence levels (MI) of -2 or -3 were to be selected for this investigation. (MI level -2 includes WAIS IQ's of from 55-69 while MI level -3 includes WAIS IQ's of 40-54.) The forty adults were selected from the MI levels -2 and -3 of the normal hearing adults.

Hearing sensitivity levels (pure-tone thresholds) for frequencies 500 Hz, 1000 Hz, 2000 Hz, and pure-tone averages were obtained by three methods: 1) Pure-tone conventional, hand raising; 2) Pure-tone, Bekesy; 3) Pure-tone, Acoustic Impedance Meter. Speech reception thresholds were determined by two methods: 4a, Say the Word and 4b, Point to the Picture. The methods were administered in the same sequence during each testing session. The first and second test sequences (Trial I and II) were separated by an interval of at least two weeks. A total of five audiometric methods made up each of the two trials. Data obtained were subjected to appropriate correlations and analysis of variance statistical analyses. Intra- and inter-method procedures were also compared

using the ± 5dB basis for comparison, which is a generally accepted test-retest and inter-test agreement in clinical audiology (Witting and Hughson, 1940 and Hirsh, 1952).

Conclusions

The following conclusions seemed appropriate within the limits of the population sampled and the audiometric methods described:

1. The three pure-tone and the two speech audiometric methods proved to be reliable as clinical methods of testing the hearing sensitivity levels of mentally retarded adults considering the ± 5dB clinically acceptable test-retest differences.

2. The conventional (hand raising) method seemed to be the most reliable of the three pure-tone and two speech methods.

3. The speech method, say the word, appeared to be the most reliable of the two speech methods.

4. The relative thresholds obtained from the acoustic impedance methods differed consistently from the other pure-tone methods. The use of a conversion increment of 85 decibels rather than 80 decibels as reported in the literature, for representative samples of normal populations, would appear to yield results which correspond closely to the other two pure-tone methods.

5. There appeared to be no significant difference between the means obtained from the first two pure-tone methods (conventional and Bekesy).

6. The high degree of reliability found for the initial test of all of the methods would tend to suggest that routine use of clinical retest sequences, in testing comparable MI levels II and III mentally

retarded adults (see Appendix II) should be reconsidered since the retest results tend to agree with initial test results for all five methods.

7. The frequency 1000 Hz, was found to have the highest test-retest reliability for the conventional (hand raising) method, the frequency 2000 Hz, was found to have the highest test-retest reliability for the Bekesy method while the frequency 500 Hz, was found to have the highest test-retest reliability for the acoustic impedance method.

8. The conventional (hand raising) method yielded the lowest (best) thresholds of the pure-tone measures while the speech method (point to the picture) yielded consistently lower (better) thresholds than the other speech (say the word) method or than any of the pure-tone methods.

9. No significant differences existed between the results of the two speech measures.

10. The three pure-tone methods and the two speech methods yielded results which were in agreement, when the clinical criterion (+ or -5dB) is applied and when the impedance conversion increment is adjusted to 85 decibels from 80 decibels.

11. Acoustic impedance measurements provide additional useful clinical information in evaluating the auditory function of mentally retarded adults.

Suggestions for Future Research

Several implications are inherent in this investigation for further research in the area of methods and techniques used in the

audiologic evaluation of mentally retarded adults. A significant subsequent study would involve the development of conversion norms for the acoustic impedance population measurement with parameters of mentally retarded children and adults. It would also seem reasonable that such norms may also be developed, using the same instrumentation, with population parameters of individuals within the normal range of intelligence and representing various chronological age groupings. Such a study could provide data concerning whether or not the conversion increment in acoustic impedance measurements is affected by chronological age, and this factor should be considered in using a conversion increment. Another area of possible research would include the use of the methods described in this investigation in the assessment of hearing function of population parameters of hearing impaired retarded adults and children with hearing impairments related to various etiologies.

The clinical corroboration of the results of this study along with possible replications with various other clinical populations would also seem indicated as an area of future research.

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APPENDIX I

WORD TEST

Spondaic Word Test (Verbal), Word Lists I through VIII for Speech Reception Tests 4a, Say the Word, and 4b, Point to the Picture from the Speech, Language and Hearing Test section of the Collaborative Study of Cerebral Palsy, Mental Retardation, and other Neurological and Sensory Disorders of Infancy and Childhood, 1964. (NINDB, NIH, USPHS)

List I	List II	List III
cowboy	doorbell	mailman
baseball	flashlight	seesaw
hot dog	goldfish	ice cream
	lipstick	lipstick
	football	haircut
	sidewalk	toothbrush
	toothpaste	outside
	oatmeal	sailboat
	cupcake	airplace
	bathtub	birthday

List IV	List V	List VI
popcorn	cowboy	bathtub
icebox	baseball	ice cream
pancake	hot dog	seesaw
porkchop		redbird
ashtray		hairbrush
ice cream		ice cream
birthday		redbird
hairbrush		hairbrush
airport		seesaw
		bathtub

List VII	List VIII
mailman	popgun
bluebird	goldfish
toothbrush	necktie
sailboat	flashlight
mailman	teaspoon
toothbrush	goldfish
bluebird	popgun
	flashlight
	necktie

APPENDIX II

LEVELS OF MEASURED INTELLIGENCE

Conversion of I.Q. Scores According to Standard Deviation Values

Level	Range of Level in S.D. Units	W-B I & II WISC & WAIS	Stanford Binet Forms L & M	Arthur Adaptation of Leiter	Arthur Point Scale Form I	Draw a Person Test
-1	-1.01 to -2.00	84-70	83-68	83-68	83-67	77-61
-2	-2.01 to -3.00	69-55	67-52	67-52	66-50	60-48
-3	-3.01 to -4.00	54-40	51-36	51-36	49-33	47-36
-4	-4.01 to -5.00		35-20	35-20	32-16	35-25
-5	-5.0		20	20	16	

Consideration of the conditions under which testing occurred, special handicaps in the testing situation, projective test evidence concerning intellectual efficiency or personality factors that might have introduced artifact into the measurement results, and similar clinical judgment are also used in assigning these levels. In cases with the results of two or more tests indicating different levels, the strongest (i.e., the more comprehensive, the more valid, the more reliable) test is to receive more weight in assigning the level. This information is based on reports by Heber (1961), pp. 57-60.

APPENDIX III

DATA SHEET

AUDITORY STUDY: INTER-TEST CORRELATION DATA SHEET

Case Number _____
Age _____ Sex _____
NR _____ RT _____
Trial _____ Date _____

Number and Type of Test	Hearing Level in dB (Re: ISO 1964) Frequencies 500Hz		1000Hz		2000Hz		Freq. Ave. (500, 1000 & 2000Hz) & SRT, Re: Normal SRT	
1. Pure-Tone A/C Conventional Hand Raising (Pulse-2pps.)	R	L	R	L	R	L	R	L
2. Pure-Tone A/C-Bekesy (Pulse-2pps, 5dB per sec. Attenuation Rate)	R	L	R	L	R	L	R	L
3. Impedance Meter-Relative Thresholds (Correction Factor _____dB, Subtracted from Direct Readings to obtain Relative Threshold)	R	L	R	L	R	L	R	L
4. Speech Reception Threshold; a. Say the Word	R	L	R	L	R	L	R	L
b. Point to the Picture								
NOTATIONS:								

APPENDIX IV

SUBJECT RESPONSES

INTER-TEST CORRELATION DATA SHEET—TRIAL I

Subject	500 Hz	1000 Hz	2000 Hz
1. Conventional Pure-Tone Hand Raising			
1-	5	10	0
2-	5	0	0
3-	15	20	20
4-	15	20	10
5-	15	20	20
6-	15	10	15
7-	10	5	0
8-	20	15	10
9-	0	15	15
10-	10	10	5
11-	20	20	20
12-	25	20	15
13-	10	10	10
14-	10	10	10
15-	10	10	10
16-	20	20	20
17-	10	5	0
18-	5	0	0
19-	15	0	0
20-	15	15	5
21-	20	5	5
22-	15	20	20
23-	25	15	20
24-	10	10	15
25-	30	20	15
26-	15	10	10
27-	10	0	15
28-	15	20	20
29-	5	10	5
30-	15	5	0
31-	15	15	10
32-	15	10	5
33-	10	20	5
34-	15	5	5
35-	0	0	10
36-	5	5	10
37-	5	10	0
38-	10	5	10
39-	10	10	10
40-	10	10	10

NOTE: A constant of 10 was added to each value to eliminate negative values.

INTER-TEST CORRELATION DATA SHEET--TRIAL I

Subject	500 Hz	1000 Hz	2000 Hz
2. Pure-Tone Bekesy			
1-	15	0	0
2-	20	15	10
3-	15	20	30
4-	15	20	10
5-	20	25	30
6-	15	10	10
7-	20	15	15
8-	20	20	10
9-	30	10	15
10-	15	10	15
11-	20	40	20
12-	30	20	15
13-	10	10	10
14-	10	10	10
15-	10	10	10
16-	20	15	10
17-	10	5	5
18-	5	0	0
19-	15	5	10
20-	10	5	5
21-	15	0	5
22-	30	30	30
23-	20	15	15
24-	10	10	0
25-	30	25	20
26-	20	15	10
27-	15	0	15
28-	10	5	10
29-	10	5	5
30-	10	5	5
31-	10	15	5
32-	10	5	5
33-	10	20	5
34-	15	10	5
35-	5	5	10
36-	10	5	5
37-	5	10	0
38-	10	5	10
39-	10	10	10
40-	10	10	10

NOTE: A constant of 10 was added to each value to eliminate negative values.

INTER-TEST CORRELATION DATA SHEET--TRIAL I

Subject	500 Hz	1000 Hz	2000 Hz
3. Pure-Tone Impedance Meter			
1-	30	10	20
2-	20	15	15
3-	25	15	15
4-	25	25	25
5-	40	20	30
6-	10	10	15
7-	15	20	10
8-	20	20	25
9-	10	20	25
10-	25	20	20
11-	30	20	30
12-	30	30	25
13-	10	10	10
14-	10	10	10
15-	10	10	10
16-	25	30	25
17-	5	10	0
18-	20	20	15
19-	10	0	0
20-	20	10	10
21-	20	20	15
22-	15	20	20
23-	25	10	20
24-	25	20	20
25-	30	15	15
26-	20	15	20
27-	5	15	20
28-	10	10	5
29-	15	10	10
30-	15	15	15
31-	20	15	10
32-	15	10	20
33-	10	10	10
34-	20	15	20
35-	5	15	10
36-	20	15	20
37-	25	20	20
38-	10	10	10
39-	10	10	10
40-	10	10	10

NOTE: A constant of 10 was added to each value to eliminate negative values.

Trial I	Trial II
Say the Word	Say the Word
10	6
0	0
12	10
10	10
10	16
10	10
0	18
4	2
4	0
10	10
16	14
16	18
14	14
17	10
14	14
10	6
0	0
0	2
6	12
10	10
10	10
12	0
18	18
0	0
18	18
18	16
2	4
10	8
4	4
4	4
4	6
2	2
2	4
4	4
2	2
0	2
4	4
2	2
16	16
20	14

NOTE: A constant of 10 was added to each value to eliminate negative values.

Trial I	Trial II
Point to the Picture	Point to the Picture
0	0
0	0
0	8
0	10
0	6
0	0
0	18
0	0
0	0
4	4
10	10
10	16
10	10
10	10
14	12
10	4
0	0
0	4
10	12
8	10
14	12
0	0
16	18
0	0
4	14
4	10
2	2
10	8
4	6
4	4
8	4
4	4
2	4
5	6
0	2
2	2
4	4
4	4
14	10
16	10

NOTE: A constant of 10 was added to each value to eliminate negative values.

INTER-TEST CORRELATION DATA SHEET--TRIAL II

Subject	500 Hz	1000 Hz	2000 Hz
1. Conventional Pure-Tone Hand Raising			
1-	10	10	0
2-	10	10	5
3-	10	10	10
4-	30	30	20
5-	20	20	10
6-	15	10	10
7-	15	10	10
8-	20	10	10
9-	0	10	15
10-	10	10	5
11-	15	20	10
12-	20	20	15
13-	10	10	10
14-	10	10	10
15-	10	10	10
16-	10	10	5
17-	10	5	0
18-	0	0	0
19-	15	0	0
20-	15	15	5
21-	20	10	5
22-	20	15	15
23-	20	15	20
24-	10	10	15
25-	20	20	15
26-	10	10	10
27-	10	5	15
28-	15	15	20
29-	5	10	5
30-	15	10	5
31-	10	10	5
32-	15	10	5
33-	10	15	5
34-	10	5	5
35-	0	0	10
36-	10	5	10
37-	5	5	0
38-	10	10	10
39-	10	10	10
40-	10	10	10

NOTE: A constant of 10 was added to each value to eliminate negative values.

INTER-TEST CORRELATION DATA SHEET--TRIAL II

Subject	500 Hz	1000 Hz	2000 Hz
2. Pure-Tone Bekesy			
1-	15	10	10
2-	10	10	5
3-	10	10	10
4-	30	30	20
5-	15	10	30
6-	15	10	15
7-	20	20	15
8-	20	20	10
9-	20	15	15
10-	20	10	10
11-	20	20	20
12-	25	25	15
13-	10	10	10
14-	10	10	10
15-	10	10	10
16-	10	10	5
17-	5	5	0
18-	5	0	0
19-	15	5	10
20-	10	15	5
21-	20	5	5
22-	40	40	40
23-	25	20	25
24-	15	10	10
25-	20	20	20
26-	20	15	10
27-	10	5	15
28-	10	5	10
29-	5	10	5
30-	10	5	5
31-	10	15	10
32-	10	10	5
33-	10	10	5
34-	10	10	5
35-	0	0	10
36-	5	5	10
37-	5	5	0
38-	10	5	10
39-	10	10	10
40-	10	10	10

NOTE: A constant of 10 was added to each value to eliminate negative values.

INTER-TEST CORRELATION DATA SHEET—TRIAL II

Subject	500 Hz	1000 Hz	2000 Hz
3. Pure-Tone Impedance Meter			
1-	20	25	20
2-	20	20	25
3-	25	20	20
4-	35	30	35
5-	30	35	10
6-	20	20	25
7-	20	20	10
8-	30	20	20
9-	20	20	20
10-	20	20	20
11-	25	30	20
12-	30	30	25
13-	10	10	10
14-	10	10	10
15-	10	10	10
16-	20	20	20
17-	5	10	0
18-	20	20	15
19-	10	0	0
20-	20	15	5
21-	20	20	15
22-	25	20	20
23-	10	20	10
24-	25	20	15
25-	30	25	25
26-	25	20	20
27-	10	10	15
28-	10	10	5
29-	10	10	10
30-	20	10	10
31-	20	15	10
32-	15	10	20
33-	10	10	10
34-	20	20	20
35-	0	5	10
36-	20	15	20
37-	20	20	20
38-	20	20	15
39-	10	10	10
40-	10	10	10

NOTE: A constant of 10 was added to each value to eliminate negative values.

VITA

Clarence Ellery Young

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